Beyond Economic Growth: The Role of Innovation in Shaping Social Impact

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Inhalt

I. Introduction.....1

II. Article 1: The social impact of universities: assessing the effects of the three university missions on social engagement.....23

III. Article 2: From technical to social innovation – The changing role of principal investigators within entrepreneurial ecosystems 55

IV. Article 3: Radical innovation and objective well-being: Really such a harmonious relationship?.....81

V. Article 4: Bridging the Gap: A Scalable Approach to Measuring Regional Social Innovation Capacities 141

VI. Conclusion 179

Please note:
References are provided at the end of each chapter and research paper, respectively.
Equations, tables, and figures are numbered within each chapter and research paper, respectively.

Zusammenfassung

Das übergeordnete Ziel der Wirtschaftswissenschaften ist es, das soziale Wohlergehen zu verstehen und zu verbessern (Ali & Cantner, 2020; Hartmann & Pyka, 2013). Dennoch konzentriert sich die vorherrschende Diskussion in der Ökonomie noch immer auf Produktion, Konsum und Geld (Komlos, 2023). Als Treiber der regionalen und nationalen Wettbewerbsfähigkeit und damit des Wirtschaftswachstums, steht technologische Innovation oft im Zentrum dieser Überlegungen (z.B. Aghion et al., 2014; Galor & Tsiddon, 1997; Wong et al., 2005). Wachstum und Innovation werden jedoch zunehmend auch mit negativen Auswirkungen in Verbindung gebracht. Beispielsweise stehen beide Konzepte in Zusammenhang mit wachsender Ungleichheit (Aghion et al., 2019; Baymul & Sen, 2020; Kuznets, 1985). Darüber hinaus kann die Implementierung neuer Technologien negative Auswirkungen auf Umwelt, Gesellschaft, Wirtschaft und politische Entscheidungen hervorrufen (Biggi & Giuliani, 2022; Dilaver, 2014; Klingelhöfer, 2017). Entsprechend richtet sich der prägende Fokus der bestehenden Literatur auf die positiven Aspekte des technologischen Wandels und führt zu einer Vernachlässigung dessen sozialer und ökologischer Nachteile (Coad et al., 2022).

Das Bewusstsein für die Notwendigkeit inklusiver, sozialer und ökologischer Themen wächst jedoch in allen Teilen der Gesellschaft (Kuhlmann & Rip, 2014). Dies führte zu einem Paradigmenwechsel, der den Fokus von reinem wirtschaftlichen Wachstum und technologischer Innovation auf umfassendere Überlegungen verlagert sowie Fragen bezüglich sozialer und gesellschaftlicher Auswirkungen aufwirft (z.B. Giuliani, 2018; Kuhlmann & Rip, 2014; Schot & Steinmueller, 2018; Wettstein et al., 2019). Dies zeigt sich unter anderem an der rapide steigenden Anzahl von wissenschaftlichen Publikationen zu entsprechenden Themen (Cavanaugh & Breau, 2018; Donnelly & Yu, 2017; Velasco-Muñoz

et al., 2018). Zudem entstanden in der wissenschaftlichen Literatur neue Strömungen, die sich mit Phänomenen wie der ‚dunklen Seite' der Innovation (Coad et al., 2022) oder ‚Degrowth' (Kallis et al., 2018) befassen. Darüber hinaus gibt es einen steigenden Trend zu Überlegungen, soziales Wohlergehen und Lebensqualität in den Mittelpunkt zu rücken (z.B. Ali & Cantner, 2020; Komlos, 2023). Diese Betrachtungen führen beinahe zwangsläufig zum Konzept der sozialen Innovation. Soziale Innovation zielt ausdrücklich darauf ab, die Lebensqualität zu verbessern (Edwards-Schachter et al., 2012; Pol & Ville, 2009). Sie wird als geeignetes Mittel angesehen, um Allokationsprobleme und Ungleichgewichte in sozialen Strukturen zu bewältigen (Nicholls et al., 2015) und birgt daher erhebliches Potenzial für soziale und politische Transformationen (Galego et al., 2022).

Diese umfassenden Überlegungen verdeutlichen, dass es dringend notwendig ist, über reines wirtschaftliches Wachstum hinauszudenken. Die Rolle der Innovation sollte dahingehend überarbeitet werden. Statt der Fokussierung auf wirtschaftliches Wachstum sollte die Lebensqualität der Menschen im Mittelpunkt stehen (Phelps, 2013). In diesem Zusammenhang müssen bestehende Konzepte und Prozesse überprüft und soziale Überlegungen in den Innovationsprozess einbezogen werden.

Diese Dissertation adressiert eben jene Notwendigkeit, indem sie verschiedene Aspekte des Paradigmenwechsels von rein wirtschaftlichen hin zu inklusiveren und sozialen Ansätzen erforscht. In diesem Zusammenhang untersucht Kapitel 2 die Rolle der Universitäten. Diese beeinflussen die Gestaltung von Innovationsprozessen durch ihre drei Missionen – Lehre, Forschung und Transfer – entscheidend (Cinar, 2019). Während die Rolle der Universitäten bei technologischer Innovation und regionaler wirtschaftlicher Entwicklung unbestritten und durch zahlreiche Studien belegt ist (Fritsch & Slavtchev, 2007; Lehmann & Menter, 2016), zeigt sie erhebliches, ungenutztes Potenzial hinsichtlich ihres

sozialen Einflusses (Anderson et al., 2018; Cinar & Benneworth, 2021). Kapitel 2 dieser Dissertation leistet einen Beitrag zu dieser Literatur, indem empirisch untersucht wird, ob und wie Universitäten das soziale Engagement von ansässigen Unternehmen beeinflussen. Die Ergebnisse zeigen einen statistisch signifikanten, positiven Effekt der Universitäten auf das soziale Engagement von privaten Unternehmen. Dieser wird hauptsächlich durch die Auswirkungen der Lehre geprägt. Folglich sollte die politische Unterstützung für Universitäten über Forschungsexzellenz hinausgehen und, um die soziale Wirkung der Universitäten zu verstärken, auch die Qualität der Lehrtätigkeit gezielter fördern.

Nach der Betrachtung der organisationalen Ebene des akademischen Sektors, fokussiert sich Kapitel 3 auf die Mikro-Ebene – konkret auf Principal Investigators, also Leiter großer Forschungsgruppen. Als zentrale Akteure in Entrepreneurial Ecosystems wirken sie als Vermittler und Koordinatoren zwischen den verschiedenen Parteien innerhalb dieser Ökosysteme, wodurch sie deren Struktur und Dynamik beeinflussen (Cunningham et al., 2019). Principal Investigators weisen somit erhebliches Potenzial auf, den Paradigmenwechsel von technologischer zu sozialer Innovation zu gestalten. Dennoch existiert kaum Literatur, die die Bereiche der Principal Investigators und sozialen Innovationen miteinander verknüpft. Daher untersucht das dritte Kapitel dieser Dissertation die Rolle der Principal Investigators bei der Gestaltung des Transformationsprozesses von wirtschaftlich fokussierter zu sozialer Innovation. Dabei wird ein Quadruple-Helix-Modell angewendet, das den akademischen Sektor, die Regierung, die Industrie und den zivilen Sektor abbildet. Auf Basis der Erkenntnisse von Mulgan (2006) wird dabei angenommen, dass der beschriebene Paradigmenwechsel seinen Ursprung im zivilen Sektor hat. Er wird folglich als externer Schock für den akademischen Sektor – und somit Principal Investigators – betrachtet. In ihrer Rolle als transformative Akteure tragen Principal Investigators jedoch proaktiv

zu diesem Veränderungsprozess bei, indem sie sich darauf einstellen und anschließend ihre angepassten Ideen und Ziele verfolgen. Da sie im Zentrum der Quadruple-Helix stehen, sind sie mit allen anderen Akteuren im Austausch und können somit Einfluss auf diese ausüben (Cunningham et al., 2018). Um ihre eigene Vision zu verwirklichen, die sie dem Paradigmenwechsel entsprechend angepasst haben, beschleunigen Principal Investigators den Transformationsprozess in allen Teilen der Quadruple-Helix proaktiv, um die Realisierung der eigenen Ziele voranzutreiben.

Kapitel 3 leistet einen Beitrag zur Literatur über soziale Innovation und Entrepreneurial Ecosystems, indem es diese dynamischen Bereiche miteinander in Verbindung setzt und somit neue Erkenntnisse fördert. Das Kapitel kann zudem als Ausgangspunkt für empirische Untersuchungen zu diesem Thema dienen.

Neben dem sozialen Einfluss wesentlicher Akteure des Innovationsprozesses ist der soziale Einfluss technologischer Innovationen, der in der Literatur weitgehend vernachlässigt wird (Devaraj et al., 2021), ein zweiter Aspekt, der im Zuge des Paradigmenwechsel genauer untersucht werden sollte. Während die positiven Aspekte von technologischer Innovation auf ökonomisches Wachstum und seine Implikationen fokussiert sind, ist die Literatur über die nachteiligen Effekte sehr heterogen und fragmentiert. Daher ist es schwierig, den sozialen Einfluss in seiner Gesamtheit einzuschätzen (Biggi & Giuliani, 2022). Kapitel 4 adressiert diese Lücke in der Literatur, indem es den Einfluss von radikalen Innovationen auf objektives Wohlbefinden ermittelt. Objektives Wohlbefinden dient dabei als Maß für Lebensqualität, was ein etablierter Ansatz im regionalen oder gesellschaftsbezogenen Kontext ist (Gasper, 2010). Da radikale Innovationen durch die Einführung neuer, disruptiver technologischer Methoden gekennzeichnet sind, die zu grundlegenden Veränderungen führen können (Arthur, 2007; Hesse & Fornahl, 2020; Verhoeven et al., 2016),

haben sie weitreichende Implikationen für Märkte sowie technologischen und sozialen Wandel (Knuepling et al., 2022). Somit sind sie von besonderem Interesse bei der Analyse des sozialen Einflusses technologischer Innovationen.

Während die Ergebnisse die bekannte positive – wenn auch indirekte – Verbindung zwischen Innovation und Wohlbefinden über wirtschaftliches Wachstum bestätigen, zeigen sie auch, dass der direkte Effekt von radikaler Innovation auf objektives Wohlbefinden statistisch signifikant und negativ ist. Daher trägt dieses Ergebnis zur Literatur über die „dunkle Seite" der Innovation bei und betont die Bedeutung, die Konsequenzen von Innovationen über das wirtschaftliche Wachstum hinaus zu betrachten. Zudem trägt dieses Kapitel zur Forschung über regionale Entwicklung bei, indem es regionale Unterschiede und Muster bzgl. radikaler Innovation und objektivem Wohlbefinden berücksichtigt. Außerdem liefern die Ergebnisse von Kapitel 4 weitere Erkenntnisse, indem sie die komplexe Beziehung zwischen radikaler Innovation und objektivem Wohlbefinden in direkte und indirekte Effekte aufschlüsseln.

Ein Teil der Innovationsliteratur, der sich bereits mit der Verbesserung der Lebensqualität beschäftigt, ist das Feld der sozialen Innovation (Edwards-Schachter et al., 2012). Die Messung sozialer Innovationen ist jedoch aufgrund ihrer komplexen und vielfältigen Charakteristika anspruchsvoll, was die Identifizierung und Evaluierung ihrer Effekte erschwert. In der Literatur über die Messung sozialer Innovationen besteht weitgehende Einigkeit darüber, dass es durch die vielschichtige und komplexe Natur sozialer Innovationen unwahrscheinlich ist, dass eine einzelne Variable als Proxy dienen kann, wie z.B. Patente für technologische Innovationen. Kapitel 5 dieser Dissertation adressiert diesen Bedarf an einem Messansatz, indem es einen Index auf der Grundlage des Konzepts der sozialen Innovationskapazitäten erstellt: den *Social Innovation Capacities Index* (SICI). Soziale

Innovationkapazitäten beschreiben die Fähigkeit, soziale Innovationen nachhaltig zu produzieren und umzusetzen. Bezüglich des technologischen Innovationsprozesses hat sich ein analoger Ansatz als wirksame Methode zur Messung von Innovationen erwiesen (Furman et al., 2002; Oura et al., 2016; Porter & Stern, 2001).

Diese Dissertation erweitert die bestehende Literatur damit um einen neuen Messansatz für soziale Innovationen. Dieser Index könnte ein Fortschritt auf dem Weg zu einem robusten Maß sein, das auf verschiedene Kontexte anwendbar ist. Durch die Konstruktion eines einfach anwendbaren Maßes macht diese Arbeit soziale Innovationen besser sichtbar und bietet somit Anreize für politische Entscheidungsträger und lokale Akteure, sich im Prozess zur Erschaffung sozialer Innovationen zu engagieren. Zudem könnte die empirische Bewertung bestehender theoretischer Konzepte zu detaillierten Erkenntnissen führen und sowohl die qualitative als auch die konzeptionelle Dimension der sozialen Innovationsforschung stärken.

Insgesamt leistet diese Dissertation einen Beitrag zur Literatur über die nicht-ökonomischen Konsequenzen von Innovationen. Sie verdeutlicht die Notwendigkeit eines Umdenkens in der Innovationsforschung und -politik (siehe Giuliani, 2018). Sie zeigt weiterhin das erhebliche ungenutzte Potenzial des akademischen Sektors bezüglich des Paradigmenwechsels von rein ökonomischen zu sozialen Zielen (Anderson et al., 2018; Cinar & Benneworth, 2021). Folglich könnte der alleinige Fokus der politischen Entscheidungsträger auf Technologietransfer (Cunningham & Menter, 2021) kontraproduktiv hinsichtlich der sozialen Auswirkungen von Universitäten sein. Daher sollte die Transfermission von Universitäten erweitert werden, um mehr soziale Aspekte einzubeziehen. Weiterhin ergeben sich aus dieser Dissertation die Implikationen, dass die negativen sozialen Auswirkungen technologischer Innovationen zumindest kurzfristig die Vorteile des erzielten

technologischen Fortschritts überwiegen können. Durch diese Untersuchung wird dem dringenden Aufruf nach einem Innovationskonzept, das die Lebensqualität anstelle der Akkumulation von Vermögen in den Vordergrund rückt, nachgekommen (Phelps, 2013).

Darüber hinaus trägt die Schaffung eines robusten und skalierbaren Maßes für soziale Innovationen dazu bei, die begrenzte empirische Evidenz in der sozialen Innovationsliteratur zu überwinden (Cunha & Benneworth, 2020). Dies birgt das Potenzial, unterschiedliche Stränge der sozialen Innovationsliteratur zu verbinden, da sie die sozialen Innovationskapazitäten disziplinübergreifend vergleichbar macht (Pel et al., 2020). Zudem könnte die empirische Überprüfung bestehender theoretischer Konzepte zu weiteren Erkenntnissen führen. Eine solche Bewertung könnte die „kreative Zerstörung“ innerhalb dieser Konzepte beschleunigen (Mihci, 2020, p. 356), wodurch die in der sozialen Innovationsforschung vorherrschenden Unstimmigkeiten und Mehrdeutigkeiten verringert würden. Daher birgt diese Arbeit das Potential, das Forschungsfeld signifikant voranzubringen (siehe Cajaiba-Santana, 2014).

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I. Introduction

The ultimate goal of economics is to understand and improve social welfare (Ali & Cantner, 2020; Hartmann & Pyka, 2013). Nevertheless, the dominant discussion in economics is still centered on production and consumption (Komlos, 2023). Therefore, economic growth has been one of the main goals of politics for the last decades (Hasan and Tucci, 2010). As a prominent driver of technological progress, regional and national competitiveness, and, ultimately, economic growth, technological innovation is often at the core of these considerations (e.g., Aghion et al., 2014; Galor & Tsiddon, 1997; Wong et al., 2005). However, growth and innovation are also increasingly associated with adverse side effects. For example, both are associated with increasing inequality (Aghion et al., 2019; Baymul & Sen, 2020; Kuznets, 1985). Moreover, implementing new technologies can cause adverse effects (Biggi & Giuliani, 2022). These detrimental consequences relate to job satisfaction and turnover intention (Ragu-Nathan et al., 2008; Turel et al., 2011), work-life conflicts (Golden, 2006; Turel et al., 2011), and burn-out (Maslach et al., 2001), among others. Further, innovation can lead to unsustainable transition, i.e., negative impacts on biophysical, social, economic, and institutional factors (Biggi & Giuliani, 2022). These include environmental degradation (Wigboldus et al., 2016), increased waste, pollution, and energy consumption, induced even by new products and policies that intended to reduce it (Gillingham et al., 2016; Røpke et al., 2010), and harmful social and economic decisions (Dilaver, 2014; Klingelhöfer, 2017). Accordingly, the prevalent focus of the existing literature on the 'bright side' of technological change overlooks its social and environmental downsides (see Coad et al., 2022).

However, awareness of the need for inclusive, societal, and environmental issues increases in all parts of society, i.e., academia, policies, the civil sector, and private industry, as described for each societal part below.

In academia, the moving the focus from pure economic growth and technological innovation towards more inclusive considerations and approaches is increasingly raising questions about social impact, inclusiveness, and societal outcomes (e.g., Giuliani, 2018; Kuhlmann & Rip, 2014; Schot & Steinmueller, 2018; Wettstein et al., 2019). This manifests, inter alia, in a rapidly growing number of publications related to such topics (see Cavanaugh & Breau, 2018; Donnelly & Yu, 2017; Schiederig et al., 2012; Velasco-Muñoz et al., 2018). Further, new strands of the scientific literature emerged, dealing with related phenomena, such as 'the dark side of innovation' (Coad et al., 2022) or 'research on degrowth' (Kallis et al., 2018). Moreover, there is an increasing trend in demanding a transition to center considerations around social welfare and quality of life, i.e., the well-being of individuals within an economy (e.g., Ali & Cantner, 2020; Komlos, 2023). Following this demand, the concept of social innovation inevitably enters the playing field. Social innovation can be seen as a complemental concept to technological innovation that emphasizes innovations' potential to address social needs (Pol & Ville, 2009). It, therefore, answers the calls for more inclusive considerations (Giuliani, 2018; Schot & Steinmueller, 2018). The concept of social innovation explicitly aims to improve the quality of life (Edwards-Schachter et al., 2012). It is, further, perceived as the silver bullet to cope with problems related to allocating social welfare, hence addressing fundamental societal needs (Nicholls et al., 2015). Consequently, many scholars agree that social innovation has considerable potential for inclusive governance as well as social and political transformations (Galego et al., 2022).

However, the paradigm shift from purely economic to more social goals does not solely affect the academic sector. Policymakers also recognize the capability of social innovation and generally follow similar trends (Galego et al., 2022). Programs of transnational organizations, such as the Agenda 2030 (United Nations, 2015) or a "Sustainable

Europe 2030" (European Commission, 2019), put pressure on national authorities to pursue inclusive and sustainable goals. In fact, promoting people's well-being is seen as the primary goal of all EU social and economic policies (Domínguez-Torreiro, 2016; Eurostat, 2015). Several governments have already followed these calls and decided to transition to a 'Wellbeing Economy'[1]. By doing so, the respective governments proactively promised to put human and planetary needs at the center of their activities and implemented concrete well-being policies. A central consideration of this initiative is the transition away from GDP as a central measure of development to account for more inclusive goals.

The civil sector is also becoming more aware of significant and urgent societal issues, such as climate change and social injustice (e.g., Lee et al., 2015; Newman et al., 2018). This awareness is reflected in various movements in past years, such as 'Fridays for Future' and mass protests in several Latin American countries (Ordorika, 2022), which call for social change and prompt politicians to act. Moreover, this awareness and motivation to address the prevalent grievances have led to changes in consumer behavior, as people demand more environmentally friendly and ethical products (e.g., Carlile et al., 2018; Steinemann et al., 2017). This shift in consumption patterns reflects a call for more inclusive strategies and social innovation from the civil sector.

Finally, the industry sector also pursues more inclusive and sustainable goals. It may be more pulled toward this direction since private firms aim to satisfy the customers' needs to stay competitive (Chong & Chen, 2010). The shifted consumption towards ethical products (Carlile et al., 2018; Steinemann et al., 2017) may, consequently, cause more sustainable production. Further, the private sector is significantly influenced by laws, regulations, and political incentives (Rodrigue et al., 2013). Therefore, the described policy

[1] See https://weall.org/wego

trend may lead to sufficient rewards for fair, inclusive, and environmentally friendly production, facilitating the shift towards more social considerations among private companies. Despite being more pulled toward social considerations, the private sector significantly adds to this transition through its exceptional ability to create new solutions and capacities (Zulkhibri, 2018). Moreover, companies that proactively pursue inclusive business models are increasingly found to gain a competitive advantage (Desai, 2014; Linder & Williander, 2017), providing growing intrinsic motivations for the private sector to engage in social topics.

Considering this comprehensive evidence, it can be concluded that there is an urgent call to think beyond economic growth from all parts of society. The role of innovation may, consequently, also be reconsidered to improve people's quality of life instead of solely fueling pure economic growth (Phelps, 2013). For this purpose, several research gaps need to be addressed. It is essential to scrutinize existing concepts of the innovation literature and implement social considerations. Regarding, for example, the academic sector, universities are well-known actors in the process of technological innovation (Cunningham et al., 2019a; Fritsch & Slavtchev, 2007) and contribute to regional competitiveness (Audretsch et al., 2012; Audretsch et al., 2016). However, their social impact is largely under-explored. Current research on this topic is shaped by conceptual and theoretical work lacking empirical evidence on academia's contribution to social value creation that goes beyond the accumulation of knowledge (Cunha & Benneworth, 2020).

The private sector is well-known for commercializing knowledge, i.e., transforming knowledge into innovations (Acs et al., 2013; Audretsch & Lehmann, 2005). However, the social and environmental consequences of these innovations are largely overlooked by existing research (Dosi, 2013). Consequently, it is often only implicitly assumed that technological innovations contribute to improving people's lives by

stimulating economic development. Research exploring the direct link between innovation and the quality of life is currently limited (Dolan & Metcalfe, 2012; Lenzi & Perucca, 2020). It is, therefore, a significant research gap that must be addressed to enhance our understanding of the determinants of people's quality of life and innovations' role in shaping social welfare.

To address the described need for more inclusive approaches, policies are increasingly interested in social innovation (Fougère et al., 2017; Pel et al., 2020). However, it is conspicuous that the absence of convincing measurement metrics of social innovation is a significant barrier to the literature (Cunha & Benneworth, 2020; Terstriep et al., 2021). This leads to "much description and much theorisation, but relatively little theoretically informed empirical research" (Cunha & Benneworth, 2020, p. 61). Subsequently, the lack of data and empirical testing significantly impedes the provision of targeted and effective policy support for social innovation (Krlev et al., 2020). Therefore, the call for reliable and meaningful indicators and measurement approaches is one of the most urgent topics in the field (Mihci, 2020).

This dissertation considers these pressing research gaps regarding academia, policies, and the industry sector. The contributions of this dissertation to each of these gaps are described in the following.

1. Social Impact and Responsibility in Academia

On an organizational level, universities are the backbone of the academic sector and "have always played a significant role in the development of society" (Moscardini et al., 2022, p. 812). They are pivotal in shaping innovation processes, mainly through their teaching, research, and transfer missions (Cinar, 2019). The teaching mission of universities equips individuals with cognitive abilities, fostering a culture of complex problem-solving and

creative thought (Harrison et al., 2007). Universities' research affects the quality of their teaching and, thus, reinforces the outcomes of the teaching mission (Cadez et al., 2017). Moreover, university research forms the foundation of basic and applied research, often leading to the genesis of groundbreaking discoveries (Tight, 2016). These academic efforts create knowledge that, when transferred to the industry, can catalyze innovation and economic growth (Cunningham et al., 2019a). The third mission of universities, i.e., the transfer to society, is mainly focused on technological innovation (Benneworth & Jongbloed, 2010) and plays, thus, a significant role in the (technological) innovation process. When universities engage with industry partners, collaborative efforts frequently result in the commercialization of academic findings, with university-industry partnerships serving as a conduit for innovation (Cunningham et al., 2019a). Their role in fostering entrepreneurship further highlights the importance of universities in innovation. By providing support structures like incubators and accelerator programs, universities facilitate the transfer of research findings into successful innovations, actively driving the entrepreneurial landscape (Benneworth & Fitjar, 2019; Klofsten et al., 2019). In conclusion, universities are not only actors in knowledge generation but are also instrumental in disseminating and applying this knowledge in ways that drive innovation. Universities are, therefore, key actors in innovation processes that shape our society (Miller et al., 2014).

However, whereas the contribution of universities to technological innovation and economic growth is emphasized in numerous studies (see Fritsch & Slavtchev, 2007; Lehmann & Menter, 2016), the social impact of universities remains vague. As a result of the paradigm shift described above, there is a growing expectation from policymakers and university stakeholders for universities to make broader contributions to society. Cinar (2019, p. 217) observes that universities face increasing pressure to "address major societal challenges within their regions". In response, numerous universities have

initiated social innovation programs to create social impacts (Milley et al., 2020). These activities concentrate on addressing issues related to the distribution of social welfare and disparities in social structures, aiming to meet fundamental societal needs (Benneworth & Cunha, 2015). Due to the importance of geographical proximity, most university initiatives are implemented at the local level (Ahoba-Sam, 2019). Within these regionally-focused social projects, the beneficiaries of universities' social initiatives include a wide range of local stakeholders, from regional communities to nearby businesses. Cockshut et al. (2020) demonstrate that universities play a pivotal role in shaping the social outcomes of private firms and facilitating societal transformation. Hence, universities are instrumental in boosting the social contributions of local actors.

This dissertation contributes to this literature by examining whether and how universities generate a social impact. The findings indicate universities' statistically significant positive effect on the social engagement of co-located private firms, primarily influenced by the university's teaching mission. Given this, policy support for universities should expand beyond research excellence, also emphasizing and rewarding teaching efforts to enhance universities' social impact. Additionally, the findings suggest that universities deeply engaged in collaborations with industry tend to address fewer social issues. This could be due to an emphasis on technology transfer in the third mission, potentially crowding out social topics (see Benneworth & Jongbloed, 2010). Thus, the full potential of universities in addressing social issues through their transfer mission remains largely untapped. Therefore, the current policy emphasis on technology transfer (Cunningham & Menter, 2021) might limit universities' social impact. University managers should be encouraged to widen the scope of the transfer mission to encompass more social elements, promoting broader societal contributions and inclusive growth. This shift may also help university managers balance the increasing expectation to provide societal

returns beyond economic contributions (Cinar, 2019) by equally prioritizing social aspects alongside technological outcomes.

While universities are key actors on the organizational level, principal investigators are perceived as essential actors on the micro level (e.g., Casati & Genet, 2014; Cunningham et al., 2019b; O'Kane, 2018). Researchers in the principal investigator role in major, publicly funded research initiatives are commonly regarded as 'scientific entrepreneurs' (Casati & Genet, 2014). Their responsibilities include crafting new knowledge frameworks, developing innovative models by amalgamating existing and novel knowledge, shaping emerging paradigms, and directing scientific efforts (Casati & Genet, 2014). Additionally, as essential figures in entrepreneurial ecosystems, principal investigators act as boundary spanners and coordinators, bridging various participants within these ecosystems (Cunningham et al., 2019b), thereby influencing their structure and dynamics. Given that entrepreneurship is significantly connected to knowledge commercialization (Audretsch & Keilbach, 2007), principal investigators play a crucial role in innovation and the technology transfer process. Their contributions extend to shaping new scientific trajectories and generating novel knowledge. They are, thus, key agents of technology transfer and, subsequently, innovation processes (Menter, 2016).

Due to their central and influential role in academia, principal investigators are likely to have significant potential for social innovation. However, analogously to universities, literature on the social impact of principal investigators is scarce. This may be rooted in the prevalent focus on technological progress for economic growth, with innovation outcomes driving prosperity (Hasan & Tucci, 2010). However, in light of the ongoing process of reconsidering innovation and, hence, extending researchers' attention to "innovation phenomena beyond the traditional focus on novel technologies and products"

(Pel et al., 2020, p. 1), the view of principal investigators' role in innovation process may be complemented by social considerations. This dissertation addresses this topic by connecting the two emerging fields of principal investigators and social innovation. For this purpose, Chapter III examines the role of principal investigators in shaping this transformation process from purely technology-focused innovation to more inclusive approaches. It demonstrates the significant potential of principal investigators to influence and shape social innovation and builds a thoroughly substantiated theoretical basis for future empirical analyses. This dissertation, therefore, adds to the fields of social innovation and principal investigators, showing their interrelatedness and demonstrating that the connection of these fields may deliver fruitful insights for an innovation concept that considers technological and social dimensions.

The findings of Chapter III suggest that principal investigators, in their role as transformative agents, proactively contribute to this changing process by adapting to it and, subsequently, pursuing their adjusted ideas and goals. Since they are at the core of the quadruple helix, they are related to all other actors and are, thus, able to exert influence on them (Cunningham et al., 2018). Therefore, they are well-positioned to accelerate and shape this transformation over all parts of society. Furthermore, principal investigators quickly adapt to external influences and, subsequently, shape the transformation of innovation processes. They leverage their well-developed networks (Kidwell, 2013) to proactively influence other actors in the quadruple helix. This evidence demonstrates the considerable potential of supporting principal investigators in fulfilling their role as transformative agents. To shape principal investigators' environment for this purpose, policy needs to reevaluate the role of universities. Universities should, therefore, reconsider their missions and roles within society and enhance their social efforts (see Cinar, 2019). This

may also involve modifying the architectural design of universities to become more open and receptive to social ideas and influences (see Dolan et al., 2019).

2. Exploring the Social Implications of Industry Innovation

In the traditional perspective of innovation research, private firms are driven by profit maximization and pursue innovation to gain competitive advantages (Etzkowitz & Leydesdorff, 2000). Thus, they are powerful in transforming knowledge generated by academia into market-ready applications, making the industry an essential part of the innovation process (see Acs et al., 2013; Audretsch & Lehmann, 2005). However, due to the focus on profit and new technologies, the considered implications of innovation are restricted to technical and economic effects. In contrast, the social and environmental consequences are largely overlooked by existing research (Dosi, 2013). Regarding the call to center innovation considerations around people's quality of life (Phelps, 2013), it is conspicuous that this link is often only implicitly assumed. The prevalent narrative is that technological innovations contribute to improving people's lives by stimulating economic development. However, research exploring the direct link between innovation and the quality of life is currently limited (Dolan & Metcalfe, 2012; Lenzi & Perucca, 2020). Examining this link is, therefore, a significant research gap. Partly addressing this gap, there is a growing number of publications on the social consequences of innovation (Coad et al., 2022). However, a shortcoming of this literature is that various research strands developed largely in parallel, each exploring a specific aspect. The literature on innovations' social implications is, therefore, scattered, and each of the respective sub-communities is shaped by distinct intellectual traditions and revolves around different research questions (Biggi & Giuliani, 2022). However, evidence of the overall social impact of technological innovation remains scarce.

This dissertation addresses this research gap with Chapter IV. It, therefore, contributes to the existing literature by providing evidence of innovations' overall impact on people's quality of life. It further applies a differentiated perspective that explicitly considers the regional level and, therefore, adds to previous research focused on the national level (e.g., Qureshi et al., 2020). The focus of Chapter IV is thereby on radical innovation, an innovation type that has rarely been explored in this context (Binder, 2013). Radical innovation is marked by introducing new, disruptive technological methods that can induce a paradigm shift and lead to fundamental changes (Arthur, 2007; Hesse & Fornahl, 2020; Verhoeven et al., 2016). Such innovations are based on exploratory search processes, forming entirely novel combinations of knowledge that have not been previously assembled (Fleming, 2001; March, 1991; Mewes, 2019). These processes, however, entail higher costs and greater risks of failure, both technologically and commercially, compared to incremental innovation (Ayres, 1988; Fleming, 2007), making them less common (Fleming, 2001; Hesse & Fornahl, 2020). Yet, when successful, they can offer substantial competitive advantages (e.g., Castaldi et al., 2015) and foster the creation of new markets and industries while disrupting existing ones (e.g., Henderson & Clark, 1990; Tushman & Anderson, 2018). Consequently, radical innovations can be seen as an important part of the process of creative destruction (Ahuja & Morris Lampert, 2001). They have far-reaching implications considering markets as well as technological and social change (Knuepling et al., 2022). Therefore, they are of particular interest in analyzing the social impact of technological innovations.

For these reasons, Chapter IV of this dissertation focuses on the influence of radical innovations on the quality of life, operationalized by objective well-being. While the findings confirm the well-established positive, albeit indirect, connection between innovation and well-being via economic growth, they simultaneously indicate that the direct

effect of radical innovation on objective well-being is statistically significant and negative. Therefore, this finding adds to the literature on the 'dark side' of innovation and emphasizes the importance of considering innovations' consequences beyond economic growth. Distinguishing radical innovation and emphasizing its immediate effects prompts policymakers, stakeholders, and researchers to embrace a more nuanced perspective. Although radical innovations offer transformative possibilities, their direct impact on people's quality of life and economic growth should be recognized and appropriately targeted.

3. Enabling Policies for (Social) Innovation to Address Societal Challenges

Innovation policy is a crucial factor in national and regional innovation outcomes (e.g., Asheim et al., 2011; Lundvall et al., 2002). To consider pressing societal challenges, such as poverty, climate change, or energy security, innovation policy needs to change in order to address such challenges more effectively (Giuliani, 2018; Schot & Steinmueller, 2018). In this context, the concept of social innovation has gained significant attention from policymakers (Fougère et al., 2017). However, social innovation remains an unclear concept, plagued by uncertainties in scholarly discourse (Mihci, 2020; van der Have & Rubalcaba, 2016). In mapping the outcomes of an extensive, systematic literature review, Edwards-Schachter & Wallace (2017) identified that social innovations are influenced by a number of interconnected research literatures. A further key debate is whether social innovations are entirely distinct from technological innovations (e.g., Howaldt & Schwarz, 2010) or whether there is an overlap between these concepts (e.g., Pol & Ville, 2009). These unresolved issues contribute to the absence of a universally accepted definition of social innovation despite considerable efforts to define it (Edwards-Schachter & Wallace, 2017; Pol & Ville, 2009, among others).

Another significant barrier in the social innovation literature is the absence of convincing measurement metrics (Cunha & Benneworth, 2020; Mihci, 2020; Terstriep et al., 2021). This literature gap reveals significant political relevance since the lack of data and empirical testing significantly impedes the provision of targeted and effective policy support for social innovation (Krlev et al., 2020). However, measuring social innovations is demanding because of their complex and diverse characteristics, which complicates identifying and measuring their effects. Additionally, social innovations aim to effect societal transformation, a process that is inherently difficult to quantify (Cunha et al., 2022). The context-specific nature of social innovations further complicates this task. Often profoundly rooted in regional contexts and motivated by distinct values and objectives like social justice or environmental sustainability, these innovations resist a one-size-fits-all approach in measuring their impact (Terstriep et al., 2020).

Consequently, there is broad agreement in the literature on measuring social innovation that the multifaceted and complex nature of social innovations has to be captured. Thus, it is improbable that a single variable, such as patents for technological innovations, can serve as a proxy. Chapter V of this dissertation addresses the gap of a meaningful measurement approach by creating an index based on the concept of social innovation capacities. Social innovation capacities are highly related to the concept of innovative capacities from the technological innovation literature (e.g., Cantner et al., 2010; Furman et al., 2002; Novillo-Villegas et al., 2022; Porter & Stern, 2001) that describes the ability to persistently create new technologies. Innovative capacities do, thus, not equal the actual level of innovation output but refer to the determinants of the innovation process (Furman et al., 2002). Analogously, social innovation capacities reflect the ability to produce and implement social innovation. The created index is, therefore, the *Social Innovation Capacities Index* (SICI). Thus, this dissertation adds to the literature

by creating a new measuring approach for social innovations. It may serve as progress toward a robust measure applicable to various contexts and act as an enabler for empirical work on social innovation and targeted social innovation policies. It has, therefore, significant potential to move the field forward (see Cajaiba-Santana, 2014).

The remainder of this dissertation is structured as follows. Chapter II aims to investigate the influence of universities on private firms' social engagement. Hypotheses regarding the impact of the three university missions, research, teaching, and transfer on social engagement are developed and empirically tested.

The third chapter takes a micro-level perspective to examine the impact of the ongoing paradigm shift from technological to social innovation on principal investigators. By applying a quadruple helix model to explore the various influences induced by the paradigm shift, it focuses primarily on the principal investigators' role as transformative agents.

The fourth chapter examines the social impact of radical (technological) innovations by applying objective well-being to measure quality of life. A conceptual framework highlighting the mediating role of economic development is developed and empirically tested.

Chapter V addresses the challenge of measuring social innovation by focusing on the inputs for social innovation, i.e., social innovation capacities. Focusing on regional determinants while simultaneously aiming at scalability, an index incorporating multiple dimensions of social innovation capacities is constructed. Further, detailed explanations of the dimensions and calculations of this *Social Innovation Capacities Index* are provided.

A concluding chapter summarizes the theoretical and practical implications offered by each chapter and the collective contributions of the dissertation. Additionally, it outlines the limitations of the current research and suggests potential directions for future investigations.

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II. Article 1: The social impact of universities: assessing the effects of the three university missions on social engagement

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Abstract

Whereas the economic impact of universities is undisputed, the social impact of universities remains vague. The purpose of this paper is to examine whether and how universities influence firms' social engagement. Based on survey data of more than 7,000 German firms, our results reveal that universities positively affect firms' social engagement mainly through teaching activities. Hence, our findings give impetus to a reinforcement of the university mission 'teaching' as a central lever for social change and increased social awareness as well as to a reorientation of the third university mission toward social needs. This paper thereby contributes to our understanding of the changing missions and values of universities and adds to the literature by exploring the underlying mechanisms of the social impact of universities. We conclude the paper with fruitful future avenues of research.

1. Introduction

Universities are perceived as key organizations within innovation systems, as they create and diffuse knowledge and thus contribute to technological innovation (Audretsch et al., 2006). To make these contributions in a conscious and strategical way, the third mission arose (Zomer & Benneworth, 2011). However, recent (societal) challenges question the sole focus on technological innovation and economic growth and call for the consideration of social aspects (Giuliani, 2018). Accordingly, universities are increasingly expected to contribute also beyond the economic agenda. This paradigm shift places new demands on universities, leading to an ongoing change of universities' roles, missions, and values.

Whereas the contribution of universities to economic innovation and regional wealth is undisputed and proven in numerous studies (see Fritsch & Slavtchev, 2007; Lehmann & Menter, 2016), the social impact of universities remains vague. The purpose of this paper is to examine whether universities influence the social engagement of co-located firms and, if so, through which means. Based on survey data of more than 7,000 German firms, we investigate the underlying mechanisms of universities' social impact on regional firms. We thereby consider all three university missions – teaching, research, and transfer – through which universities might affect their socioeconomic environment.

Our results reveal that universities positively affect firms' social engagement mainly through teaching activities. Hence, our findings give impetus to a reinforcement of the university mission 'teaching' as a central lever for social change and increased social awareness as well as to a reorientation of the third university mission toward social needs. Higher-education policies should not only pay attention to research excellence and the commercialization of knowledge but should also aim at supporting universities' social agendas to unfold the universities' full potential in delivering contributions to society.

This paper contributes to our understanding of the changing roles, missions, and values of universities and adds to the literature by exploring the underlying mechanisms of the social impact of universities.

The remainder of this paper is structured as follows. Section 2 presents the literature review and derives hypotheses, Section 3 describes our data and methodological approach, Section 4 outlines our empirical findings, and Section 5 discusses our results and derives implications. A final section concludes the paper.

2. The Social Impact of Universities

The role of universities in regional development has attracted considerable attention within the literature. Despite the uncontested economic impact, policymakers and citizens are increasingly expecting broader societal contributions from universities. Cinar (2019, p. 217) therefore notes that universities are pressurized to "contribute to solving grand societal challenges in the regions in which they are located". For this purpose, many universities have launched social innovation initiatives to also exert a social impact (Milley et al., 2020). Social innovation activities thereby focus on problems associated with social welfare distribution and imbalances in social structures, hence try to address core societal needs (Benneworth & Cunha, 2015). Due to the importance of geographical proximity, the majority of university projects are implemented locally (Ahoba-Sam, 2019). In the context of these locally bounded social endeavors, beneficiaries of universities' social efforts hence comprise a multitude of regional actors, ranging from the regional population to co-located firms. In her study on micro- and small-sized (mSME) creative businesses in North East England, (Cockshut et al., 2020) shows that universities shape the social engagement of mSMEs and act as enablers of societal change. Universities

consequently contribute to enhancing private firms' social activities. We therefore posit that universities positively influence firms' social engagement.

However, considering private firms' motivations for social engagement and their actual social engagement, it is highly relevant to distinguish between monetary and non-monetary dimensions since they might vary significantly (DelVecchio & Wagner, 2011). In supporting prosocial behavior, monetary incentives might even be counterproductive (Ariely et al., 2009). Therefore, we consider both monetary and non-monetary dimensions when examining universities' influence on firms' social engagement.

H1a: Universities increase co-located firms' monetary and non-monetary motivation to engage in social activities.

H1b: Universities increase co-located firms' monetary and non-monetary engagement in social activities.

The influence of universities on firms' social engagement might work through all three university missions – teaching, research, and transfer. The following sections outline in detail the respective mechanisms that enable universities to positively affect their socioeconomic environments.

Teaching

Universities transfer comprehensive knowledge to their students, which supports students' ability to understand the big picture and think outside the box (Harrison et al., 2007). Consequently, university students should be better able to recognize social needs and thus experience improved alertness for societal and environmental issues. Indeed, teaching can raise the awareness of social and ethical problems (Cotton & Alcock, 2013; Lau, 2010), whereas certain teaching practices, such as problem-based learning, stimulate

students' social engagement and collaboration with external partners and help to overcome local challenges (Gregersen, 2017). Therefore, it could be suggested that universities' teaching mission can increase social engagement by educating people to better perceive social needs and thus improve their alertness regarding the necessity for and importance of social engagement. We argue that teaching may contribute to increase the students' social engagement. Since students are the employees, managers, consumers, and stakeholders of tomorrow, teaching not only contributes to increase students' social engagement but also the social engagement of firms.

H2a: Universities' teaching activities increase co-located firms' monetary and non-monetary motivation to engage in social activities.

H2b: Universities' teaching activities increase co-located firms' monetary and non-monetary engagement in social activities.

Research

New knowledge generated by research can reflect the identification of social needs and their relevance, therefore serving as the starting point of social engagement (Mulgan, 2006). Research findings can thereby reveal the benefits of engaging in social activities, such as improved image and reputation (see Weber, 2008). These benefits may subsequently increase firms' awareness that social engagement also pays off in economic terms. Consequently, we suggest that research can raise firms' motivation to engage in social activities. Moreover, research can also guide and shape fields and thus induce increasing attention for social topics (Howaldt et al., 2016). This might help to overcome a lack of awareness and points out the significance of social issues for regional development

efforts (Neumeier, 2017). Highlighting the significance for regional development in particular might increase regional actors' social efforts (Neumeier, 2017), which strengthes the assumption that universities' social impact is mainly regional.

H2c: Universities' research activities increase co-located firms' monetary and non-monetary motivation to engage in social activities.

H2d: Universities' research activities increase co-located firms' monetary and non-monetary engagement in social activities.

Transfer

The third mission of universities is often described as the transfer to society: universities are expected to actively make societal contributions (Zomer & Benneworth, 2011). However, this mission has largely been interpreted as a contribution to economic development. The transfer mission has thus been focused on technology transfer, almost denying the social aspects of innovation and regional development (Benneworth & Jongbloed, 2010). Due to this focus, stakeholders of humanities and social sciences are not sufficiently salient to the universities and experience significant disadvantages, such as lesser attention and funds.

Despite the neglect of social aspects in the context of universities' transfer mission, the interaction with the socioeconomic environment, and particularly industry, reveals great potential for universities to make social impacts since most of the well-established transfer channels are likely to also transmit social ideas, even though they are focused on technology transfer is (Mirvis et al., 2016). Hence, we suggest that the awareness of social needs might even be transmitted from universities to private firms in a technology-focused university–industry collaboration. We thus argue that technology transfer contributes to increase firms' social engagement and that universities that are intensely

engaged in university–industry collaborations are more likely to affect the social engagement of private firms.

H2e: Universities' transfer activities increase co-located firms' monetary and non-monetary motivation to engage in social activities.

H2f: Universities' transfer activities increase co-located firms' monetary and non-monetary engagement in social activities.

3. Data and Methods

3.1 Sample and Empirical Approach

To evaluate the social impact of universities, we needed to take firm specifics (micro level) as well as firm context (macro level) into account. The firm context was thereby reflected by the regions in which the firms are embedded. Considering the significance of the regional context (see Neumeier, 2017), we applied a multilevel approach, which allowed us to include both the micro and macro level. More specifically, we employed a two-level hierarchical model that considered both levels:

$$Y_{ij} = \beta_{0j} + \beta_1 university_{ij} + \beta_2\, firm_{ij} + \varepsilon_{ij} \qquad (1)$$

$$\beta_{0j} = \gamma_{00} + \gamma_{01} region_j + \mu_{0j} \qquad (2)$$

where (1) represented the micro level, reflecting firms and universities, and (2) represented the macro level, including regional characteristics. The firms and universities were thereby nested within regions. We employed two different estimation approaches. The first approach aimed at examining whether universities affect firms' social engagement by applying a dummy variable that reflected whether a region has a university or not. The second approach addressed how universities might affect firms' social engagement by

operationalizing the three university missions of teaching, research, and transfer. Y_{ij} thereby denoted firms' social engagement that is operationalized by four distinct measures, namely, monetary and non-monetary motivation to engage in social activities as well as actual monetary and non-monetary engagement in social activities.

The vector $university_{ij}$ represented our independent variables – the university dummy for the first approach and the operationalization of the three university missions for the second approach. The subscript i referred to the micro level, and the subscript j referred to the corresponding macro level. The firm controls were covered by the vector $firm_{ij}$, containing firm age, size, revenue, and focus. Analogous, the regional controls were reflected by the vector $region_i$, including regional wealth, density, entrepreneurial activity, innovation activity, education level, and age structure (see Appendix 1). The variables ε and μ represented the error terms. We applied random intercept models with robust standard errors to control for regional differences.

The firm characteristics originated from the corporate citizenship (CC) survey compiled by Labigne et al. (2019) which was conducted in Germany in 2018. After all adjustments, the dataset included 7,368 firms and was representative in terms of company size, industry, and geographical breakdown. The overall scope of this survey was to display the social engagement of German companies. To minimize scopes for interpretation, the questions worked with standardized categories and concepts, whereby social engagement was clearly defined as activities of general interest that are beyond the business activities and legal requirements. A set of questions in the survey allowed us to create an index of firms' motivations to engage socially (H1a, H2a, H2c, and H2e). The structure of the survey further allowed us to distinguish between monetary motivation (e.g., benefits through increased revenue) and non-monetary motivation (e.g., increased employer attractiveness). Firms were also asked about their actual social engagement in the past

three years, which we used to create an index1 of firms' engagement in social activities to test H1b, H2b, H2d, and H2f. The structure of the survey again enabled us to distinguish between monetary engagement (e.g., monetary donations) and non-monetary engagement (e.g., developing social or environmental projects). In addition, participating firms provided self-reported information concerning firm specifics, such as the number of employees, revenue, age, regional focus, and industry sector that we used as controls on the firm level.

The CC survey data was complemented by comprehensive administrative data from the German Federal Statistical Office on regional and university characteristics. The regional level was reflected by regional planning areas (Raumordnungsregionen; RORs). Regional and university data were thus aggregated on ROR levels. On the regional level, we controlled for regional wealth, population density, entrepreneurship activities, innovation activities, and the regional age structure and education level. We operationalized the 'teaching mission' by the number of graduates, the 'research mission' by the number of highly cited publications, and the 'transfer mission' by the amount of university third-party funds from private industry, which reflected the intensity of university–industry collaborations. Since social changes need considerable time to unfold (Lettice & Parekh, 2010), a time-lag structure was reasonable. As it remains unclear how long it takes for universities to affect firms' social engagement, we calculated a five-year average (2012–2016) of our independent and control variables. Although our dependent variables, that is, our indices, originated from 2018, they reflected the years 2016–2018 (firms were asked about their actual social engagement in the past three years). We hence included a lagged time span of one to five years in our regression approach. Additionally, this procedure corrected for annual outliers.

For the robustness tests, we used the same research design, including the same operationalization of our variables of interest, but ran linear regressions (OLS) with robust standard errors (see Appendices 6 and 7). In addition, we again employed multilevel linear regressions but changed the operationalization of our main dependent variables representing the three university missions in order to include the entire higher-education sector instead of universities only (see Appendix 8). All robustness checks confirm our results from the multilevel model, hence suggest robust findings.

3.2 Descriptive Statistics

As shown in Table 1, firms' monetary motivation to engage in social activities as well as their actual non-monetary engagement did not significantly differ between regions with and without a university. However, non-monetary motivation and monetary engagement were significantly higher in regions without a university, which might be an indication that university and non-university regions differ significantly in many respects.

All university-related variables, namely, university graduates, university publications, and university–industry interactions, scored a zero in non-university regions. It is, however, conspicuous that all regional control variables also differed significantly between non-university and university regions. These differences are statistically significant, as the two-sample t-tests revealed. Non-university regions are less wealthy, which might lead to increased social needs. Further, as shown by our variable regional density, university regions are more urban than non-university regions which might be relevant regarding firms' social engagement (Bürcher, 2017). Additionally, regions with at least one university show higher entrepreneurial activities and are more innovative, which might also be related to social engagement (Cinar, 2019). Moreover, university regions have, on average, a higher share of young, well-educated inhabitants, which might

Table 1: Descriptive Statistics - continuous variables

Variable	University					No university						
	Obs.	Mean	Std. Dev.	Min	Max	Obs.	Mean	Std. Dev.	Min	Max	Diff.	T
Dependent variables												
Monetary motivation	5,090	0.68	0.71	0	3	1,076	0.67	0.68	0	3	-0.010	(-0.43)
Non-monetary motivation	5,322	1.54	0.79	0	3	1,131	1.62	0.77	0	3	0.080***	(3.11)
Monetary engagement	5,947	1.57	0.69	0	3	1,256	1.67	0.67	0	3	0.102***	(4.77)
Non-monetary engagement	5,916	0.74	0.67	0	3	1,247	0.73	0.63	0	3	-0.002	(-0.11)
Independent variables												
University graduates	5,983	6,252	4,521	0	19,637	1,264	0	0	0	0	-6,252***	(-49.17)
University publications	5,983	62.12	73.53	0.00	278.20	1,264	0	0	0	0	-62.12***	(-30.03)
University-industry interaction	5,983	30,809	30,293	26	129,660	1,264	0	0	0	0	-30,809***	(-36.16)
Regional wealth	5,983	70,558	11,259	48,711	101,302	1,264	62,976	5,964	50,910	73,654	-7,582***	(-23.26)
Regional density	5,983	645	781	59	3,869	1,264	191	190	43	1,025	-453.5***	(-20.52)
Regional entrepreneurial activity	5,863	5.37	6.06	1.31	28.53	1,066	4.67	2.43	1.64	16.39	-0.703***	(-3.73)
Regional innovation activity	5,983	45.86	45.62	1.25	160.98	1,066	7.10	5.50	0.52	20.05	-38.76***	(-27.70)
Regional education level	5,983	0.37	0.07	0.20	0.55	1,264	0.28	0.05	0.19	0.37	-0.089***	(-42.04)
Regional age structure	5,983	0.24	0.02	0.18	0.29	1,264	0.22	0.02	0.17	0.24	-0.023***	(-32.99)
Firm age	5,445	48	41	3	219	1,155	47	38	2	219	-0.998	(-0.76)

Note: This table shows descriptive data on all continuous variables comparing regions with a university and regions without universities.
*T statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01*

ultimately affect firms' social engagement (Holdsworth & Quinn, 2010).

Contrary to the regional characteristics, firm characteristics in our sample were similar in university and non-university regions. Firms located in non-university regions more often have a regional focus than firms from university regions. However, there seemed to be no difference between university and non-university regions when considering firm size. Moreover, there were only small differences in firm revenue between university and non-university regions (see Appendices 3, 4, and 5). Consequently, while firms in university and non-university regions are rather similar, regional aspects vary significantly. Since these differences might have a significant influence on firms' social engagement, our regression approach, which considers the fact that firms are nested in regions, seems to be well-fitting.

4. Results

The results of our first estimation approach using the university dummy as the explanatory variable to answer the question whether universities affect firms' social engagement are shown in Table 2. Our findings reveal that the presence of at least one university in a ROR only had a statistically significant positive effect on firms' monetary motivation to engage in social activities within the corresponding region ($\beta = 5.667$; $p < 0.05$). However, there are no significant effects on firms' non-monetary motivation to engage in social activities nor on their actual monetary and non-monetary engagement in social activities. Therefore, we can only partly confirm H1a and must reject H1b.

Table 3 shows the results of our regressions, including the three university missions, to assess how universities affect firms' social engagement. Our findings reveal that universities' teaching mission had a positive and statistically significant effect on

Table 2: Estimation results

	Model I *Monetary motivation*	**Model II** *Non-monetary motivation*	**Model III** *Monetary engagement*	**Model IV** *Non-monetary engagement*
University dummy	5.667**	2.778	-0.466	3.627
	(2.732)	(2.974)	(2.924)	(2.766)
Firm age	-0.041*	-0.008	0.126***	0.113***
	(0.024)	(0.029)	(0.026)	(0.023)
Firm size	6.969***	17.834***	9.786***	16.861***
	(1.366)	(1.732)	(1.570)	(1.478)
Firm revenue	-2.129**	2.388*	4.889***	3.056**
	(1.000)	(1.281)	(1.230)	(1.203)
Firm focus	14.791***	14.808***	12.388***	4.454**
	(2.308)	(2.362)	(2.189)	(1.762)
Regional wealth	0.0000	0.0003***	0.0002**	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Regional density	-0.002	-0.006	-0.008***	-0.005***
	(0.002)	(0.004)	(0.002)	(0.002)
Regional entrepreneurial activity	0.120	0.461	0.572**	0.811***
	(0.291)	(0.434)	(0.259)	(0.222)
Regional innovation activity	-0.043*	-0.025	-0.031	-0.029
	(0.023)	(0.031)	(0.037)	(0.018)
Regional education level	17.782	-28.096*	-32.356*	-11.746
	(16.368)	(16.758)	(19.218)	(16.045)
Regional age structure	-97.192**	-92.699**	27.198	-24.768
	(42.681)	(46.396)	(45.780)	(43.473)
Industry dummies	Yes	Yes	Yes	Yes
Observations	5,421	5,662	5,884	5,861

Note: This table reports the results of our multilevel linear regression. We rely on a sample of more than 7,000 firms included in the CC-Survey. The dependent variables consist of firms' monetary and non-monetary motivation to engage in social activities (Model I and II) as well as firms' monetary and non-monetary engagement in social activities (Model III and IV).
*Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01.*

three of our four social engagement measures, namely, firms' monetary motivation to engage in social activities ($\beta = 0.167$; $p < 0.01$), firms' non-monetary motivation to engage in social activities ($\beta = 0.174$; $p < 0.01$), and firms' non-monetary engagement in social activities ($\beta = 0.136$; $p < 0.05$). The effect of teaching on monetary engagement

Table 3: Estimation results

	Model V *Monetary motivation*	**Model VI** *Non-monetary motivation*	**Model VII** *Monetary engagement*	**Model VIII** *Non-monetary engagement*
University mission teaching	0.167***	0.174***	0.047	0.136**
	(0.062)	(0.066)	(0.081)	(0.062)
University mission research	-3.149	-5.763	-5.116	-1.470
	(2.972)	(4.100)	(3.139)	(3.094)
University mission transfer	-0.008	-0.008	-0.006	-0.016***
	(0.006)	(0.008)	(0.009)	(0.005)
Firm age	-4.003*	-0.808	12.346***	11.087***
	(2.380)	(2.862)	(2.629)	(2.316)
Firm size	692.563***	1780.882***	984.264***	1684.979***
	(136.860)	(172.180)	(156.138)	(147.135)
Firm revenue	-213.760**	238.900*	491.096***	306.394**
	(99.538)	(127.957)	(123.519)	(120.508)
Firm focus	1484.196***	1482.049***	1232.381***	445.192**
	(231.203)	(235.959)	(217.541)	(175.951)
Regional wealth	0.000	-0.033***	-0.022**	0.008
	(0.009)	(0.011)	(0.010)	(0.009)
Regional density	-0.362	-0.643	-0.885***	-0.777***
	(0.273)	(0.405)	(0.261)	(0.214)
Regional entrepreneurial activity	14.658	59.773	69.618***	87.136***
	(31.030)	(51.313)	(26.543)	(19.863)
Regional innovation activity	-8.219***	-5.108	2.049*	-2.757
	(2.977)	(3.387)	(2.974)	(2.255)
Regional education level	1586.216	-3814.189**	-3575.030***	-998.792
	(1636.919)	(1908.356)	(2016.551)	(1677.070)
Regional age structure	-9137.044**	-10222.620**	1548.340	-1758.267
	(4119.016)	(4295.659)	(4737.727)	(4077.638)
Industry dummies	Yes	Yes	Yes	Yes
Observations	5,421	5,662	5,884	5,861

Note: This table reports the results of our multilevel linear regression. We rely on a sample of more than 7,000 firms included in the CC-Survey. The dependent variables consist of firms' monetary and non-monetary motivation to engage in social activities (Model V and VI) as well as firms' monetary and non-monetary engagement in social activities (Model VII and VIII).
*Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01.*

was also positive, yet not statistically significant. Hence, we can confirm H2a and partly confirm H2b. As all coefficients of the university research mission were not significant,

the research mission seems to have no effect on firms' social engagement. Consequently, we must reject H2c and H2d.

The effect of universities' transfer mission on firms' non-monetary engagement in social activities ($\beta = -0.016$; $p < 0.01$) was statistically significant but negative. Further, the effects of the transfer mission on firms' monetary motivation to engage in social activities, firms' non-monetary motivation to engage in social activities, and firms' monetary engagement in social activities were not statistically significant. Therefore, we also must reject H2e and H2f.Our control variables reveal several significant effects. Firm age, size, and revenue reveal positive and statistically significant effects on almost all indices, which might be a consequence of more resources available for social engagement. Further, all coefficients of firm focus were highly significant and positive, implying that regional-oriented firms engage more frequently in social activities.

On the regional level, wealth seems to have a negative effect, which might be a consequence of lower social needs in wealthy areas, leading to a reduced awareness of social needs. Further, local authorities in wealthy regions may have a higher budget, which lowers the necessity for firms' monetary engagement in social activities. Regional density also shows negative effects, revealing that firms located in rural areas are engaging more frequently in social activities. The effects of regional entrepreneurial activity are positive, implying that a vibrant start-up scene seems to stimulate firms' engagement in social activities, for example, through social entrepreneurship activities (Cinar, 2019). The educational level shows a negative influence on firms' non-monetary motivation to engage in social activities. Further, the regional age structure reveals negative effects, which means the higher the share of 15- to 30-year-old people, the lower the firms' motivation to engage socially. A possible explanation for these findings is that students and

young people engage less frequently in social activities (Holdsworth & Quinn, 2010), whereas older people show higher levels of social engagement (Burr et al., 2002).

5. Discussion

Hitherto, limited empirical research has been devoted to the social impact of universities. This paper enhances this literature, employing a large empirical basis. Our findings reveal the positive effects of universities on firms' social engagement, distinguishing between monetary and non-monetary aspects. These distinctions might receive more attention in future studies as they have proven to be highly relevant (DelVecchio & Wagner, 2011), which is further emphasized by our results.

Our findings show that the influence of universities on firms' social engagement seems to be mainly driven by the university mission 'teaching', which had a positive effect on firms' monetary and non-monetary motivation to engage in social activities. This finding is supported by the existing literature on university education which states that higher education provides a plurality of paradigms and perspectives that empower students to think outside the box s (Harrison et al., 2007). University students benefit from increased cognitive abilities, enabling them to better perceive social needs, develop ideas addressing social needs, and act as future change agents. Students might transfer the increased awareness for social issues to local firms as interns, employees, managers, consumers, or stakeholders. Additionally, the influence of the teaching mission on firms' non-monetary engagement in social activities is positive and significant. This result is supported by van den Wijngaard et al. (2015), who described social engagement as a learning outcome. The influence of the teaching mission might thereby capture two effects. First, as motivation moves people into action (Markus, 2016), the increased motivation directly leads to an increased engagement in social activities. Second, teaching

might increase the perception of new possibilities to engage in social activities (Crosling et al., 2015) and, thus, increase firms' social engagement.

Universities' research mission seems to have no effect on firms' social engagement. This suggests that the teaching mission is more influential than the research mission. Consequently, the promotion of universities should not only be focused on research excellence (see Menter et al., 2018), as teaching seems to have a great potential to foster universities' social impact. However, research findings might be taught to students and therefore influence the university teaching (Tight, 2016). Further, research quality has a positive relationship with teaching quality (Cadez et al., 2017). Hence, the research mission may bear indirect contributions to increasing firms' social engagement that are not captured by our results.

The university transfer mission has a significant negative effect on firms' non-monetary engagement in social activities. This might be a consequence of the strong focus on technology transfer, transmitting too few social aspects to firms (Benneworth & Jongbloed, 2010). Since the coefficient is negative, focusing on technological contents even seems to lead to a crowding out of the awareness for social needs. This finding highlights the importance of the awareness of social needs on the one hand and shows the urgent need for a reorientation of universities' transfer mission on the other. This reinterpretation of the third mission should be seen as part of the overall changing role of universities (see Benneworth & Fitjar, 2019; Cinar, 2019). Our paper hence broadens the focus on the roles, missions, and values of universities by giving impetus to how to manage the tensions arising from increased pressure on universities to deliver contributions to society (Cinar, 2019).

Our findings further reveal that the effects of the university teaching and transfer missions may work in opposite directions. As our first estimation approach included both

effects, the opposing effects of the teaching and transfer mission may cancel each other out and thus partly explain why the results of the first estimation approach were largely not significant. Consequently, universities that are less focused on technology transfer might have a larger social impact. Hence, policies focusing on technology transfer foster the economic impact of universities but might be counterproductive regarding the social impact, leading to some unintended consequences (Cunningham et al., 2019).

6. Conclusion

This study aimed at examining whether and how universities exert a social impact. Our results reveal universities' positive influence on firms' social engagement, which yet seems to be mainly driven by the university mission 'teaching'. Considering this, political support for universities should not only be focused on research excellence but should also strengthen and incentivize teaching efforts to increase universities' social impact. Further, our findings show that universities that are deeply involved in university–industry collaborations seem to transmit fewer social issues. This paradox may be caused by the third mission's focus on technology transfer, which may lead to a crowding out of social topics. Therefore, the potential of universities' transfer mission on social topics is probably largely unused. Consequently, the sole focus of policymakers on technology transfer (Cunningham & Menter, 2021) might be counterproductive regarding universities' social impact. Hence, university managers should broaden the transfer mission to include more social aspects, enabling augmented contributions to society and inclusive growth. This reorientation might also be helpful for university managers to address the tensions caused by increasing expectations to deliver more returns to society beyond the economic agenda (see Cinar, 2019). In paying more attention to social aspects while not neglecting

technological outcomes, university managers might thereby moderate the growing pressure to deliver both economic and social contributions to regional development.

The contribution of this paper is twofold. First, it explores the social impact of universities and the underlying mechanisms that enable universities to stimulate private firms' social engagement, considering all three university missions and distinguishing between monetary and non-monetary dimensions. Second, it contributes to our understanding of the changing roles, missions, and values of universities (see Miller et al., 2014) by revealing the urgent need to increasingly focus on social aspects to realize universities' full potential in delivering contributions to society.

As with all empirical research, our study is subject to some limitations. Our empirical approach does not account for students moving to other, particularly non-university, regions after graduation. However, in Germany, the country of our analysis, a significant share of the students stays within the ROR where they graduated (Krabel & Flöther, 2014). As this might not be the case in other countries, the generalizability of our results might be limited. Further, the transfer mission is operationalized by the amount of third-party funds from private industry which is a proxy for the intensity of university–industry collaborations. Other transfer channels that might have more potential to transfer social aspects are not captured. Therefore, future research should determine the social impact of universities' third mission with a more comprehensive measurement scale.

This paper examines the social impact of universities and thus adds to the literature on the changing roles, missions, and values of universities. However, several aspects, such as the effects of universities' changing agendas on the three university missions, need to be further explored. As universities might not only be shaped by a (policy-driven) social agenda but might actively contribute to it, the question of how universities push social topics should be investigated. As university managers might be willing to

implement the changing focus on an institutional level, similar to how transfer technology offices were introduced to push commercialization activities, institutional arrangements that support universities' social impact should be determined. Moreover, the incentives for universities to exert social impacts should be analyzed in detail to motivate actors to act. An appropriate measure for the returns on social engagement is thereby key to emphasizing the benefits of a social focus.

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Appendix

Appendix 1: Variables and operationalization

Type	Variable	Measurement	Data source	Literature source (extract)
Dependent Variable	Monetary motivation	Index that reflects answers containing monetary categories on the question: "What is the added value of social engagement for your firm itself?" The index takes the value 0/ 1/ 2/ 3 if there is no/ small/ medium/ significant added value.	CC-Survey	Ariely et al. (2009)
	Non-monetary motivation	Index that reflects answers containing non-monetary categories on the question: "What is the added value of social engagement for your firm itself?" The index takes the value 0/ 1/ 2/ 3 if there is no/ small/ medium/ significant added value.	CC-Survey	Ariely et al. (2009)oor
	Monetary engagement	Index that reflects answers containing monetary categories on the question: "How did your firm engage in social activities in the past three years?" The index takes the value 0/ 1.5/ 3 if there is no/ infrequent/ regular engagement.	CC-Survey	Moore et al. (2012)
	Non-monetary engagement	Index that reflects answers containing non-monetary categories on the question: "How did your firm engage in social activities in the past three years?" The index takes the value 0/ 1.5/ 3 if there is no/ infrequent/ regular engagement.	CC-Survey	de Wit et al. (2019)
Independent Variable	University dummy	Dummy variable that takes the value 1 if there is at least one university in the respective ROR and 0 otherwise	German Federal Statistical Office	Anderson et al. (2018)
	University mission teaching	Number of university graduates	German Federal Statistical Office	Lau (2010)
	University mission research	Number of highly cited university publications	Web of Science	Bornmann (2013)
	University mission transfer	Amount of third-party funds from the private sector	German Federal Statistical Office	Talebzadehhosseini et al. (2021) , Mirvis et al. (2016)

Control Variable	Firm age	Age of the firm	CC-Survey	Coad et al. (2016), Shefer & Frenkel (2005)
	Firm size	Categorical variable that reflects the number of the firm's employees	CC-Survey	Shefer & Frenkel (2005)
	Firm revenue	Categorical variable that reflects the firm's revenue	CC-Survey	Shefer & Frenkel (2005)
	Firm focus	Dummy variable that takes the value 1 if the respective firm's focus is on regional markets and 0 otherwise	CC-Survey	Cooke et al. (1997)
	Industry dummy	Dummy variable that takes the value 1 if the firm belongs to the respective industry sector and 0 if not. There is a dummy for each of the following industries: transport, traffic & logistics; mechanical engineering; agriculture & forestry; art, entertainment & relaxation; vehicle construction & suppliers; information & communication technology; trade; housing sector; health & social services; hospitality and retail; finance & insurance; education; food; energy & water; electrical engineering; services; chemistry & pharmacy; mining; construction.	CC-Survey	Shefer & Frenkel (2005)
	Regional wealth	Gross Domestic Product (GDP) per employee	German Federal Statistical Office	Gössling & Rutten (2007)
	Regional density	Population density	German Federal Statistical Office	Gössling & Rutten (2007)
	Regional entrepren. activity	Start-ups in the private sector per employee (in 10,000)	Start-up Compendium (*Gründungsatlas*)	Audretsch & Keilbach (2004)
	Regional innovation activity	Patents per employee (in 10,000)	OECD REGPAT	Hagedoorn & Cloodt (2003)
	Regional education level	Share of high school graduates among all school leavers	German Federal Statistical Office	Baumol (2005)
	Regional age structure	Share of 15- to 30-year-olds among the population	German Federal Statistical Office	Parsons (2015)

Appendix 2: Creation of the indices

Item	Response options	Utilized for measure	Response options
What is the added value of engagement in social activities for your firm itself?	Develop new business ideas (e.g. impulses for new products, services)	Monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Increase revenue/ profit (e.g. by winning new customers, business partners)	Monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Meet investors requirements (e.g. by meeting standards, requirements)	Monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Increase employer attractiveness (e.g. more applicants, more interesting applicants)	Non-monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Increase regional attractiveness (e.g. upward revaluation of regional environment)	Non-monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Improve staff retention (e.g. by increased variety, fun, creation of meaning)	Non-monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Increase employees' skills (e.g. by new context)	Non-monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
	Increase reputation/ strengthen brand (e.g. increased visibility, positive media reporting)	Non-monetary motivation	Correct/ Rather correct/ Rather not correct/ Not correct
How did your firm engage in social activities in the past three years?	Free services (e.g. pro bono work)	Monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Employee release (e.g. for voluntary work during working time)	Monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Transfer of use (e.g. rooms, vehicles, machines, software)	Monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Material donations (e.g. clothes, office furniture, equipment, food)	Monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Monetary donations (e.g. to non-profit organizations, societies)	Monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Sustainable investments (e.g. ethical investment)	Non-monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Firm related foundation (e.g. to support education)	Non-monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Own projects (e.g. social or environmental projects)	Non-monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Fly the flag for good purposes (e.g. political or public intervention)	Non-monetary engagement	Yes, regularly/ Yes, in some cases/ No
	Help with a tangible cause (e.g. flood, refugee crisis)	Non-monetary engagement	Yes, regularly/ Yes, in some cases/ No

Note: This table reports the questions utilized to create the four outcome indices. All questions and response options were translated from the CC-Survey (Labigne et al., 2019). All answers were codified into categorical variables which are normalized to a minimum value of zero and a maximum value of three. Zero reflects the lowest social engagement score regarding the respective item and, contrary, three reflects the highest possible score. We then calculated the average of each variable over all firms in a region. The indices subsequently represent the means of the averages of all variables belonging to the corresponding index.

Appendix 3: Descriptive statistics – Firm focus

	University			No university				
Firm focus		Regional focus	National/ international focus	Total	Regional focus	National/ international focus	Total	Diff.	T
	Freq.	2,016	3,507	5,523	486	677	1,163	0.0529***	(3.39)
	Percent	36.50	63.50	100	41.79	58.21	100		

Note: This table shows descriptive data on the firm focus comparing regions with a university and regions without universities. Firm focus is a dummy variable that takes the value 1 for a regional focus and the value 0 for a national/ international focus.
*T statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01*

Appendix 4: Descriptive statistics – Firm size

	University		No University		Total	
Firm size	Freq.	Percent	Freq.	Percent	Freq.	Percent
1-9 employees	570	9.54	101	8.00	671	9.27
10-49 employees	2,524	42.25	544	43.07	3,068	42.39
50-249 employees	2,083	34.87	469	37.13	2,552	35.26
250-999 employees	552	9.24	110	8.71	662	9.15
1.000-10.000 employees	216	3.62	37	2.93	253	3.50
More than 10.000 em-ployees	29	0.49	2	0.16	31	0.43
Total	5,974	100	1,263	100	7,237	100
Pearson Chi2(5) = 8.6957		Pr = 0.122				

Note: This table shows descriptive data on the firm size comparing regions with a university and regions without universities. Firm size is measured by the number of employees. The results indicate that there is no statistically significant relation between firm size and the existence of at least one university in the respective region (Pearson chi-squared with five degrees of freedom=8.6957; p=0.122).

Appendix 4: Descriptive statistics – Firm revenue

	University		No University		Total	
Firm revenue	Freq.	Percent	Freq.	Percent	Freq.	Percent
Less than 500,000 Euro	168	3.25	28	2.54	196	3.13
500,000 to 2 million Euro	1,111	21.51	243	22.01	1,354	21.60
2 million to 10 million Euro	1,873	36.26	429	38.86	2,302	36.72
10 million to 50 million Euro	1,301	25.19	287	26.00	1,588	25.33
50 million to 100 million Euro	299	5.79	55	4.98	354	5.65
More than 100 million Euro	413	8.00	62	5.62	475	7.58
Total	5,165	100	1,104	100	6,269	100
Pearson Chi2(5) = 11.3517		Pr = 0.045				

Note: This table shows descriptive data on the firm size comparing regions with a university and regions without universities. Firm revenue is measured by million Euro. The results indicate that there is a statistically significant relation between firm revenue and the existence of at least one university in the respective region (Pearson chi-squared with five degrees of freedom=11.3517; p=0.045).

Appendix 5: Robustness tests

	Model IX *Monetary motivation*	**Model X** *Non-monetary motivation*	**Model XI** *Monetary engagement*	**Model XII** *Non-monetary engagement*
University dummy	5.667*	2.778	-0.466	3.627
	(3.097)	(3.342)	(2.829)	(2.643)
Firm age	-0.041	-0.008	0.126***	0.113***
	(0.025)	(0.026)	(0.023)	(0.022)
Firm size	6.969***	17.834***	9.786***	16.861***
	(1.591)	(1.631)	(1.379)	(1.352)
Firm revenue	-2.129*	2.388*	4.889***	3.056***
	(1.259)	(1.319)	(1.122)	(1.071)
Firm focus	14.791***	14.808***	12.388***	4.454**
	(2.234)	(2.387)	(2.016)	(1.832)
Regional wealth	0.0000	0.0003**	0.0002**	0.0000
	(0.0000)	(0.0001)	(0.0001)	(0.0000)
Regional density	-0.002	-0.006	-0.008***	-0.005*
	(0.003)	(0.004)	(0.003)	(0.003)
Regional entrepreneurial activity	0.120	0.461	0.572*	0.811**
	(0.367)	(0.384)	(0.330)	(0.319)
Regional innovation activity	-0.043	-0.025	-0.031	-0.029
	(0.036)	(0.040)	(0.033)	(0.031)
Regional education level	17.782	-28.096	-32.356*	-11.746
	(19.035)	(20.903)	(17.609)	(16.662)
Regional age structure	-97.192*	-92.699*	27.198	-24.768
	(49.637)	(53.177)	(45.727)	(40.488)
Industry dummies	Yes	Yes	Yes	Yes
Observations	5,421	5,662	5,884	5,861
R-squared	0.041	0.078	0.077	0.117

Note: This table reports the results of our linear regression (OLS). We rely on a sample of more than 7,000 firms included in the CC-Survey. The dependent variables consist of firms' monetary and non-monetary motivation to engage in social activities (Model IX and X) as well as firms' monetary and non-monetary engagement in social activities (Model XI and XII).
*Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01.*

Appendix 6: Robustness checks

	Model XIII *Monetary motivation*	**Model XIV** *Non-monetary motivation*	**Model XV** *Monetary engagement*	**Model XVI** *Non-monetary engagement*
University mission teaching	0.167**	0.174**	0.047	0.136*
	(0.081)	(0.086)	(0.073)	(0.071)
University mission research	-3.149	-5.763	-5.116	-1.470
	(4.535)	(4.885)	(4.090)	(3.764)
University mission transfer	-0.008	-0.008	-0.006	-0.016**
	(0.008)	(0.008)	(0.007)	(0.007)
Firm age	-4.003	-0.808	12.346***	11.087***
	(2.529)	(2.629)	(2.335)	(2.249)
Firm size	692.563***	1780.882***	984.264***	1684.979***
	(159.010)	(163.062)	(137.745)	(135.120)
Firm revenue	-213.760*	238.900*	491.096***	306.394***
	(125.768)	(131.797)	(112.216)	(107.083)
Firm focus	1484.196***	1482.049***	1232.381***	445.192**
	(223.489)	(238.526)	(201.629)	(183.257)
Regional wealth	0.000	-0.033**	-0.022*	0.008
	(0.013)	(0.014)	(0.012)	(0.011)
Regional density	-0.362	-0.643*	-0.885***	-0.777**
	(0.353)	(0.379)	(0.319)	(0.305)
Regional entrepreneurial activity	14.658	59.773	69.618**	87.136***
	(37.238)	(38.718)	(33.580)	(32.357)
Regional innovation activity	-8.219*	-5.108	2.049	-2.757
	(4.584)	(5.107)	(4.211)	(3.871)
Regional education level	1586.216	-3814.189*	-3575.030**	-998.792
	(1947.786)	(2164.118)	(1815.014)	(1691.331)
Regional age structure	-9137.044*	-10222.620*	1548.340	-1758.267
	(5061.375)	(5380.646)	(4634.939)	(4115.400)
Industry dummies	Yes	Yes	Yes	Yes
Observations	5,421	5,662	5,884	5,861
R-squared	0.041	0.079	0.078	0.118

Note: This table reports the results of our linear regression (OLS). We rely on a sample of more than 7,000 firms included in the CC-Survey. The dependent variables consist of firms' monetary and non-monetary motivation to engage in social activities (Model XIII and XIV) as well as firms' monetary and non-monetary engagement in social activities (Model XV and XVI).
*Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01.*

Appendix 7: Robustness checks

	Model XVII *Monetary motivation*	**Model XVIII** *Non-monetary motivation*	**Model XIX** *Monetary engagement*	**Model XX** *Non-monetary engagement*
Mission teaching	0.159***	0.136**	0.069	0.093**
	(0.042)	(0.056)	(0.056)	(0.045)
Mission research	0.793**	0.245	-0.198	0.616**
	(0.312)	(0.343)	(0.390)	(0.268)
Mission transfer	-0.016***	-0.012	-0.013	-0.017***
	(0.005)	(0.008)	(0.008)	(0.004)
Firm age	-3.757	-0.578	12.264***	10.985***
	(2.371)	(2.864)	(2.636)	(2.318)
Firm size	662.594***	1762.564***	982.572***	1670.510***
	(136.406)	(172.912)	(157.019)	(146.733)
Firm revenue	-209.534**	243.768*	490.808***	322.518***
	(99.138)	(129.431)	(124.087)	(120.314)
Firm focus	1478.370***	1457.259***	1214.851***	438.620**
	(231.830)	(235.074)	(218.507)	(176.432)
Regional wealth	0.007	-0.026**	-0.017	0.011
	(0.009)	(0.011)	(0.011)	(0.009)
Regional density	-0.620**	-0.886*	-1.068***	-0.856***
	(0.291)	(0.454)	(0.256)	(0.189)
Regional entrepreneurial activity	-11.184	59.274	82.287**	58.432**
	(35.974)	(54.849)	(39.296)	(28.681)
Regional innovation activity	-23.941***	-17.460***	-4.977	-11.510**
	(5.451)	(5.765)	(6.831)	(5.472)
Regional education level	2255.054	-3188.405*	-3344.635*	-279.445
	(1590.764)	(1769.186)	(1929.148)	(1552.219)
Regional age structure	-7792.679**	-9689.548**	1600.069	-314.686
	(3913.181)	(4267.702)	(5232.295)	(4332.552)
Constant	0.699***	1.540***	1.323***	0.0250
	(0.0941)	(0.0939)	(0.123)	(0.114)
Observations	5,393	5,634	5,855	5,833

Note: This table reports the results of our multilevel linear regression. We thereby change the operationalization of our main independent variables representing the three missions teaching (number of all graduates), research (number of highly cited publications) and transfer (amount of third-party funds from the private sector) of the overall higher education sector (universities and universities of applied sciences and research institutes). We rely on a sample of more than 7,000 firms included in the CC-Survey. The dependent variables consist of firms' monetary and non-monetary motivation to engage in social activities (Model XVII and XVIII) as well as firms' monetary and non-monetary engagement in social activities (Model XIX and XX).

*Robust standard errors in parentheses, * p<0.10, ** p<0.05, *** p<0.01.*

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III. Article 2: From technical to social innovation – The changing role of principal investigators within entrepreneurial ecosystems

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Abstract

Purpose – By taking a micro-level perspective, this paper aims to examine the influence of the ongoing paradigm shift from technological to social innovation on principal investigators (PIs) and thereby links the two emerging research fields of entrepreneurial ecosystems and social innovation. The purpose of this paper is to build the basis for future empirical analyses.

Design/methodology/approach – The paper is a conceptual paper and therefore focuses on theoretical considerations. Taking a quadruple helix approach, PIs are outlined as central actors of entrepreneurial ecosystems and transformative agents of the innovation process.

Findings – PIs can proactively shape the innovation process and thus the shift from technological to social innovation, through various channels. They can affect all other actors of the quadruple helix, e.g. by exerting influence on the process of scientific change, on the public opinion and/or on the industry partners. Further, the paradigm shift might change the universities' role in the quadruple helix, substantiating their importance in the process of social change.

Practical implications – As PIs are influencing all other actors of the quadruple helix, they are central actors of entrepreneurial ecosystems and thus crucial players in the innovation process. Hence, they need to be supported in fulfilling their role of transformative agents, accelerating and shaping the paradigm shift from technological to social innovation. Universities should therefore reconsider their missions and vision as well as their role within the society.

Originality/value – This paper considers the influence of an ongoing paradigm shift from technological to social innovation on entrepreneurial ecosystems. This work focuses especially on the PIs' role as transformative agents. Therefore, it builds a bridge from entrepreneurial ecosystems to social innovation and thus contributes to both research fields. Moreover, the paper shows the great potential of PIs to influence and shape social innovation.

1. Introduction

Scientists in the principal investigator (PI) role are lead researchers in large-scale publicly funded research projects and are often referred to as "scientific entrepreneurs," as they "are responsible for designing new knowledge architectures and producing new models from combinations of existing and new knowledge, shaping new paradigms, and brokering scientific activities" (Casati & Genet, 2014, p. 13). Moreover, PIs are crucial players of entrepreneurial ecosystems because they act as boundary spanners and coordinators among entrepreneurial ecosystem actors (Cunningham et al., 2019b). Consequently, PIs shape these ecosystems. As entrepreneurship is linked to the commercialization of knowledge (Audretsch & Keilbach, 2007), it constitutes a core contribution of the innovation and technology transfer process. Consequently, PIs also shape new scientific trajectories, create new knowledge and are thus key actors in the innovation and technology transfer process (Menter, 2016). Hitherto, this process has been focused on technological progress to promote economic growth an (Hasan & Tucci, 2010), with technological innovation outcomes as the core drivers of economic prosperity. However, there is an increasing awareness that economic growth is not the solution to all societal issues and might even be part of the problem. The so-called grand challenges, i.e. fundamental social and environmental issues that tackle large numbers of people worldwide, decisively affect the overarching innovation process, thus have induced a rethink with regard to innovation. The grand challenges cover various issues such as poverty, food and water security, gender equality or climate change and are "missions concerning the socio-economic system as a whole, even inducing (or requiring) system transformation" (Kuhlmann & Rip, 2014, p. 1). Different institutions have set up agendas to address these problems. For example, the United Nations (2015) published an "Agenda 2030," focusing on 17 sustainable

development goals, and the European Commission (2010, 2019) also strives for sustainable and inclusive growth.

The grand challenges cannot be solved by pure economic growth fueled by technological innovation (Giuliani, 2018). These challenges will not be completed like organizational, technological or mathematical problems but should rather be seen as open-ended missions (Kuhlmann & Rip, 2014). As a consequence, the grand challenges require more inclusive strategies, not only focusing on economic growth and technological innovation but on further aspects, i.e. social dimensions: "[Grand Challenges] pertain to heterogeneous elements and forces, which have to be mobilized, guided and integrated, and include social innovation" (Kuhlmann & Rip, 2014, p. 1). This call for inclusive approaches has received increasing attention, yet requires a fundamental rethink with regard to innovation activities (Giuliani, 2018; Schot & Steinmueller, 2018).

Finding new solutions that approach existing problems in a more inclusive way, developing new methods to tackle the grand challenges and evaluating existing measures against multidimensional issues is thereby the task of science. As PIs are highly respected and influential members of academia (Cunningham et al., 2019b), they are important players in the process of creating new solutions and methods. Moreover, PIs act as boundary spanners between different actors of the quadruple helix (Cunningham et al., 2019b). Consequently, they dispose of several opportunities to shape and accelerate the paradigm shift from technological to social innovation. However, despite the great potential that PIs reveal regarding social innovation, there is no work linking the emerging research fields of PIs and social innovation. Further, research on the relationship between entrepreneurship and social innovation has so far largely focused on social entrepreneurship and single actors that engage in social innovation. The role of entrepreneurial ecosystems in social innovation remains, therefore, largely under-explored.

This work addresses both research gaps. Taking a micro-level PI perspective, this paper determines the consequences of the paradigm shift from technological to social innovation as an external influence on PIs as central actors of entrepreneurial ecosystems. Hence, it provides the link between entrepreneurial ecosystems and social innovation with special respect to PIs. The focus is thereby on the PIs' role as transformative agents of innovation processes. According to O'Kane (2018), PIs proactively shape the innovation process. Hence, they are likely to not only react but also proactively shape this paradigm shift. They rather exert influence on the innovation process and therefore actively contribute to the transformation from pure technological to social innovation. For this purpose, PIs have various opportunities according to their role as boundary spanners between academia and industry as well as academia and government, i.e. all parts of the quadruple helix. To support them in doing so as well as to support the transmission from pure technological to social innovation, policy needs to foster a change of the academic sector to put academia more in charge for contributing to social change, hence giving something back to society as a whole. The remainder of the paper is structured as follows: Section 2 presents the theoretical background, which focuses on PIs as central actors of the innovation process, on the one hand, and the paradigm shift from pure technological to social innovation, on the other hand. Using the concept of the quadruple helix model, Section 3 then describes the consequences of this paradigm shift on PIs and their role within an entrepreneurial ecosystem. A final section concludes and provides practical implications.

2. Theoretical background

2.1 The role of principal investigators in an entrepreneurial ecosystem environment

Entrepreneurs exploit opportunities often provided by non-commercialized knowledge. Obviously, academic entrepreneurs should not suffer from a lack of knowledge, but there

are other inhibiting factors, of course. For example, (Hayter, 2016) highlights that academic entrepreneurs are typically limited by their inadequate social networks. Usually, a scientist's network is too homogeneous, including mainly other researchers. On the contrary, scientists in the PI role can be seen as "natural networkers." According to O'Kane (2018), they proactively shape the innovation process, primarily through knowledge. Further, they create value by simultaneously interacting with a multitude of actors. In their role as research group leaders, PIs influence and shape research projects and manage their implementation, which also involves working and communicating with multiple organizations, including industry partners (Mangematin et al., 2014). Hence, PIs are likely to overcome the network problem. Despite being naturally exposed to other inhibiting factors (see Cunningham et al., 2014), they make significant contributions to the entrepreneurial ecosystem.

While PIs exert great influence on the entrepreneurial ecosystem, they are also subject to several influences. To structure these kinds of impacts within an innovation system, this paper follows (Cunningham et al., 2018) and takes a quadruple helix approach, consisting of the academic sector, the industry, the government and the civil society/ customers. This approach is an extension of the triple helix model developed by Etzkowitz & Leydesdorff (e.g. 1995, 2000). More recently, the civil society was identified as a further influential stakeholder group and was subsequently added to the previous existing sectors of university, industry and government, resulting in a quadruple helix model (Carayannis & Campbell, 2009; Leydesdorff, 2012). As this paper considers the shift of the focus from economic to inclusive growth, or rather from pure technological to social innovation, the quadruple approach, which includes the civil society, seems to be well fitting.

As PIs exert great influence on the entrepreneurial ecosystem, their role in the innovation process can be described as transformative agents, as they are proactively shaping the process (Cunningham et al.). On the other hand, PIs are themselves shaped by various influences from inside and outside the ecosystem, leading to a reciprocal relationship between PIs and the other actors. External influences, i.e. from outside the ecosystem, can be of direct and indirect nature. Direct would mean that an external influence directly affects PIs in their decisions and actions. Indirect describes that the external influence affects another actor of the PI's ecosystem, e.g. a stakeholder of the PI's research group, who then subsequently influences the PI.

Because of their important and influential position in the entrepreneurial ecosystem, the factors that affect PIs – directly or indirectly – have a significant impact on the whole system. Therefore, influences that treat the PI are of particular interest. The PI's position is mainly characterized by PIs as leaders of a large-scale research group. Therefore, they mainly act in an academic environment, which can be seen as part of an entrepreneurial ecosystem. To describe the activities of such an ecosystem, various concepts have been developed (see Audretsch et al., 2019; Cantner et al., 2021). One of these frameworks is the quadruple helix model, which is well suited to outline entrepreneurial ecosystems and innovation processes (see Cunningham et al., 2018). In this model, external influences on PIs are defined as influences from outside the university sector and can hence originate from the other parts of the quadruple helix, which are the industry, government and customers.

Because of their leading position, PIs have numerous responsibilities beyond science, i.e. managerial tasks, ranging from coordinating the work of the corresponding research group, allocating the resources to communicating with stakeholders. Especially the latter one is important for the role PIs have within an entrepreneurial ecosystem. This

is the role of a transformative agent who proactively shapes new knowledge architectures and paradigms (Casati & Genet, 2014) as well as the whole innovation process (O'Kane, 2018). Therefore, the communication with various stakeholders is key to exert influence and fulfill this role. Because of the close collaboration with stakeholders of the whole quadruple helix, PIs affect almost all other actors of their ecosystem. But, at the same time, PIs are affected by them as well which constitutes a reciprocal relationship. This leads to another facet of their role because while proactively shaping the innovation process, PIs are subsequently shaped by the other actors. Consequently, they absorb influences from other actors, adapt to it and then shape the entrepreneurial ecosystem according to their adapted ideas.

As PIs are not only scientists but can be seen as institution leaders (Cunningham et al., 2019b) or project managers (Mangematin et al., 2014), they need to be extremely versatile regarding their capabilities. They have to be a "Jack of all trades" (Boehm & Hogan, 2014) and need to have several capabilities that allow them to address the specific needs of various actors (see Cunningham et al., 2019b). Beyond leadership and resource acquisition capabilities, Cunningham et al. (2019b) name envisioning. This aspect describes that PIs possess a clear vision, which is important, as PIs play a role as transformative agents of the entrepreneurial ecosystem. Hence, their vision does not only include scientific goals but also ideas how to change the innovation process to tackle current issues. Here, the influences of other actors are critical because PIs develop their ideas of how to shape the innovation process during the interaction with other stakeholders. Therefore, the stakeholders significantly affect the PIs' vision, i.e. their long-term strategy.

Because of their influential role and their versatile capabilities, PIs are central actors of entrepreneurial ecosystems. As research group leaders, they are, on the one hand, outstanding scientists. On the other hand, they have to deal with several tasks outside their

scientific environment, such as coordinating the interests of their research group, communicating with funders and policy makers as well as allocating resources. In doing so, PIs work closely with various actors from outside the academic ecosystem, which creates additional (reciprocal) relationships. Consequently, PIs are at the core of the quadruple helix and hence have a large and heterogeneous network, which (at least) reflects the numerous stakeholders of a large-scale research project, including industry partners, policy makers and other scientists. Because of these traits, PIs reveal great potential regarding the innovation process on the one hand. On the other hand, they are affected by various actors. Consequently, they are treated by numerous external influences while exerting great effort on the entrepreneurial ecosystem. Therefore, PIs can be seen as a natural gathering point for external influences.

2.2 The paradigm shift from technological toward social innovation

The interaction of the different quadruple helix actors creates economic growth, which has been one of the main goals of politics for the past decades. This growth paradigm was adequate for the mid-20th century to change an "'empty' world with abundant ecological resources" (Schmelzer, 2015, p. 270). Although this paradigm itself has helped to create and shape new conditions, it has hardly adapted to changing circumstances. Hence, it is at least questionable whether this paradigm is convenient to current challenges. More drastically, McNeill (2001) called the persistence of the growth paradigm almost 20 years ago as an increasing threat to the planet and future generations. The increasing share of people, scientists, politicians and customers, as well as numerous agents from industry, who warn against the climate change at least partly support this thesis. Further, there are several other current challenges, such as, inter alia, increasing inequality, endangered food security and securing social justice. All these issues are part of the so-called grand

challenges that “are pressing social and environmental issues that transcend national borders and have potential or actual negative effects on large numbers of people, communities, and the planet as a whole” (Wettstein et al., 2019, p. 54).

Especially science, technology and innovation policy are called up to tackle these challenges (Schot & Steinmueller, 2018). Programs, such as the Agenda 2030 (United Nations, 2015), a growing importance of green innovation management in praxis and academia (Schiederig et al., 2012) and, inter alia, an increasing awareness in the population for the climate change (Lee et al., 2015) as well as the population’s awareness of growing income inequality (Newman et al., 2018) show that the need for a paradigm change attracts more and more attention in all groups of society, i.e. all sectors of the quadruple helix.

In consequence, questions, such as what should be understood as progress, and who benefits and who bears the costs, came up. Further, the grand challenges belong to heterogeneous issues and hence require a multidimensional approach (Kuhlmann & Rip, 2014). Therefore, the call for more inclusive strategies, focusing not only on economic growth but on further, e.g. social, dimensions has received increasing attention. Hence, a rethink of innovation policy toward more inclusive policy strategies is necessary (Giuliani, 2018; Schot & Steinmueller, 2018). Here, inclusive means that progress should not only be measured by economic growth, but it should be secured that all classes of society benefit from it, that growth does not contradict environmental protection and sustainability, etc. In this context, particularly the concept of social innovation has attracted the interest of policy makers. It can be seen as a supplement to technological innovation. Just as technological innovation fosters technological change, social innovation aims at accelerating (beneficial) societal change (Edwards-Schachter et al., 2012). Therefore, the concept of social innovation is the expression of an ongoing policy target shift from pure

economic growth to inclusive growth because it highlights the social dimension of growth. However, social and technological innovation do not necessarily exclude each other. Rather, technological innovations can include a social part or be part of a social innovation.

Pol & Ville (2009, p. 881) define social innovations as a "new idea [that] has the potential to improve either the quality or the quantity of life." Consequently, every profit-seeking firm that develops new technological solutions to increase its sales satisfies social needs and thus contributes to the improvement of quality or quantity of life. Therefore, most innovations contribute to the social innovation process. However, technological innovations may also cause social problems. An example is given by Bruland (2004) who outlines the beginning of the industrial revolution that was closely related to a number of innovations in the cotton industry. The broad availability of cheap cotton clothes can be seen as an influential social innovation. As another consequence, a lot of workers were substituted by machines and experienced catastrophic social consequences.

Further, social innovation can go beyond technological solutions and stem from institutional or organizational change. Mulgan (2006) names, e.g. models of social care, women's right to vote or the welfare state as influential social innovations. He further highlights that social change is often driven by an individual. These leaders of a social innovation process can be "politicians, bureaucrats, intellectuals, business people, as well as NGO activists" (Mulgan, 2006, p. 148). Therefore, the main actors can act in all parts of the quadruple helix, and thus, social innovation can originate from all parts of society as well.

The paradigm shift from pure technological to social innovation changes the existing thinking toward value creation within the quadruple helix and sets new demands for all actors. As PIs are central nodes of such frameworks, they are especially treated by

this shift. Further, PIs proactively shape the innovation process (O'Kane, 2018). Consequently, the influences that are tackling PIs are particularly powerful because PIs adapt to these influences, modify their vision and subsequently shape the innovation process based on the changed ideas.

3. Analysis

3.1 Consequences of the paradigm shift on the principal investigators' role model

The described paradigm shift from technological to social innovation influences the society in various ways. The paradigm shift, or external influences in general, can basically have two different effects on the PI: direct and indirect. A direct impact can lead to an interest shift. This means that the external influence triggers the PI to rethink his/her motives, ideas and strategies. Thus, it tackles the intrinsic motives of the PI. Adapted intrinsic motivation would be equal to a changed utility function (Kreps, 1997). Therefore, it would be a very sustainable effect. Given an alteration of the intrinsic motives, the PI will rethink his/ her vision, which is the long-term scientific ambition (Cunningham et al., 2019b), and adapt it to the new interests, ideas and demands. Hence, the PI will pursue new or at least adapted long-term targets. The research interest shift could be a shift from interest in pure economic growth and pure technological innovation to inclusive growth and social innovation. This would subsequently result in adapted research questions.

Putting a vision into practice is equivalent to the strategy (see Cunningham et al., 2019b). Hence, a changed vision demands for a modification of the strategy. Here, the PI might encounter several problems. As envisioning is the framing of the "overall scientific ambition as series of projects which match the requirements of public authorities" (Casati & Genet, 2014, p. 16) and the requirements of public funding do not necessarily change with the PI's interest shift, the PI might be stuck on current projects that might not suit

the new interests and vision. This bond to "old" duties constitutes one of the major challenges of the PI as a transformative agent of the entrepreneurial ecosystem. They must be able to convince the other actors of the new ideas to shape the innovation process. How successful PIs are in doing so depends, inter alia, on their boundary spanning capabilities. The better PIs are in boundary spanning, the better they can bridge divergent interests and hence gain more autonomy in following their own (new) interests.

Further, excellent capabilities in resource acquisition will help them to find new funding sources that are suitable to the changed interests, ideas and research questions. But, as PIs can implement their vision the better, the more support they find, it is likely that they try to influence their existing stakeholders in the direction of their new interests. If they are successful, this would have the advantage that the PIs can build on existing networks and structures. As they are in an essential position of their academic and entrepreneurial ecosystem (Boehm & Hogan, 2014) and knowledge brokers who create value by bridging structural holes (Kidwell, 2013), they can make a significant impact and hence are likely to succeed in influencing their stakeholders. This shows that they are in the right position to fulfill their role as transformative agents of the innovation process.

P1. PIs actively accelerate and shape the transformation process from pure technological to social innovation by exerting influence on the other actors of the quadruple helix.

However, because the relationships between PIs and their stakeholders are reciprocal, the other actors can affect the PIs as well. Given that the PI is not directly treated by the paradigm shift but the stakeholders are, this could still lead to an impact on the PI. To structure these kind of reciprocal impacts within an entrepreneurial ecosystem, this paper follows Cunningham et al. (2018) and takes a quadruple helix approach, examining the academic sector, industry, government and civil society/ customers.

3.2 The effect of the paradigm shift on the academic sector

If the paradigm shift affects the actors of the academic sector but not the PI him/ herself, this can lead to an indirect effect of the paradigm shift because the actors probably influence the PI. Just as the paradigm shift might affect the PI's interests, it could influence the interests of every other scientist as well. Consequently, the other researchers who constitute the academic network of the PI would have incentives to influence the university sector and hence the PI in the direction of their interests, e.g. better support for these interests and better chances to get funds corresponding to the interest. The PI might even be in the focus of such effort as he/ she is a central node of the academic network. Hence, influencing the PI might be very beneficial.

Further, science is subject to changes over time, as methods and issues underlie trends and come into fashion or become less popular (Bueno, 2000). As a consequence of this scientific change, researchers who engage in popular topics might have better chances to get good publications and increase their scientific reputation, as well as they might have easier access to topic-related funds. This provides strong incentives for the PI to follow the scientific change. The shift from pure economic to more inclusive growth might cause such a change. This can be seen, as the number of publications on climate change since 1957 had been relatively constant but increased rapidly since 2007 (Donnelly & Yu, 2017). Similarly, the amount of articles on other topics related to the grand challenges significantly increased in recent years (Cavanaugh & Breau, 2018; Schiederig et al., 2012; Velasco-Muñoz et al., 2018). This shows that the grand challenges are already in the focus of science and hence shifted the focus of research topics. Therefore, PIs also are subject to this shift and the resulting changed research focus. They are consequently likely to adapt their vision to pursue their personal targets, such as scientific reputation or access to resources.

Subsequently, PIs also influence their academic colleagues, as they are highly respected in academia and are characterized by research excellence (Cunningham et al., 2019b). Consequently, if PIs change their interests and ideas, this might induce other scientists who are not yet affected by the paradigm shift to rethink their concepts even without further intervention of the PIs. But, as PIs act as transformative agents, they will put effort in actively influencing the interests of other researchers. For doing so, they might simply contribute to the academic discourse by publishing articles or participating at conferences. Furthermore, they might convince other scientists with whom they work particularly closely in personal discussions.

P2. To support social innovation, PIs exploit their reputation and large-scale networks for accelerating the process of scientific change.

Regarding the trends provided by Donnelly & Yu (2017), Cavanaugh & Breau (2018) or Velasco-Muñoz et al. (2018), it is noteworthy that the number of publications on issues related to the grand challenges will further increase. Unfortunately, these numbers only show the trends in publications. They do not express the way how research groups work on projects or how policy implications might have changed. Hence, the process of this paradigm shift is likely to be still ongoing.

3.3 Civil society as a starting point of social innovation

As the external influence considered in this work is a shift from pure technological to social innovation, the civil society is obviously an important stakeholder group. As social innovation is motivated by meeting social needs (Mulgan, 2006), the civil society can be seen as a starting point for social innovation. Further, civils in their role as customers and

voters significantly influence the industry and government; thus, it seems likely that the civil sector is the originator of the paradigm shift.

Within this civil sector, there is an increasing awareness of issues related to the grand challenges (e.g., Lee et al., 2015; Newman et al., 2018). Several movements, e.g. "Fridays for Future," against political inactivity regarding the climate change, continuing mass protests in Hong Kong or Chile against reducing civil rights and social injustice, respectively, show the population's awareness and willingness for change, putting pressure on politicians to act and constituting a clear call for social change. Further, this awareness combined with the motivation to do something against the prevalent grievances lead to shifted needs, which can manifest in a changing consumption behavior. This reflects another expression of the population's call for more inclusive strategies and social innovation. Indeed, such a consumption shift can be observed as the demand for environmental-friendly and ethical products increased significantly in recent years (e.g. Carlile et al., 2018 for the UK; Steinemann et al., 2017 for Germany). This changed consumption behavior might be in the focus of science and subsequently influence the scientific change and affect the PIs on the one hand. On the other hand, PIs could recognize the changed needs directly and then develop new or adapted interests. Further, the changed needs of the customers will attract industry actors to search for new solutions to satisfy these needs. This may have an impact on the industry–academic relations and therefore also influence the PIs. Additionally, if the PI has entrepreneurial intentions, this change of needs probably leads to various entrepreneurial opportunities that can be exploited by PIs or other actors of the entrepreneurial ecosystem. As mentioned above, another possible expression of the population's awareness of the paradigm shift is a direct call for change. As mentioned above, several mass movements, such as Fridays for Future and mass protests in Hong Kong, Chile and other countries, demand political changes regarding various issues

related to the grand challenges. This call is primarily addressed to the government, of course. But, the government subsequently affects the academic sector by funding requirements or research contracts. Therefore, such movements are likely to have an impact on PIs as well. Hence, the effect of the civil society on PIs is likely to be indirect but significant.

Because of their proactive attitude, PIs are not only reacting to the changed needs and behavior of the civil society. They rather adapt to the change very quickly and then specifically look for opportunities of collaboration with actors of the civil society. This cooperation can be of reciprocal nature, as PIs are shaped by the civil society but also influence the civil society in the context of this collaboration. For this purpose, they can publish their scientific findings. In this way, they might (further) increase the society's awareness and can provide well-substantiated arguments for the public discourse. By using media and social platforms, PIs can further increase their impact. By doing so, PIs again fulfill their role as transformative agents.

P3. As the civil society is the starting point for societal issues, PIs collaborate with actors from civil society in defining their research agenda to be at the forefront of current developments.

3.4 Implications of the paradigm shift for the industry sector

The paradigm shift from pure economic to more inclusive growth, i.e. from pure technological to social innovation, seems to affect industry in two ways. First, the industry sector targets to satisfy the customers' needs because it has a strong incentive to adapt to the shifted customers' interests to stay competitive (Chong & Chen, 2010). Additionally, the government can influence the industry by laws, regulations and incentives (Rodrigue et

al., 2013). Hence, politicians can affect the industry to address the grand challenges, e.g. producing more environmentally friendly or giving more of the profit to the employees for the purpose of fighting inequality. In both cases, the industry sector needs to provide new solutions and hence might approach the academic sector to commercialize university-based technologies (Siegel et al., 2003). As PIs, in their role as large-scale research group leaders, work closely with industrial partners, they are especially affected by the adapted interests of the industry. For example, they have to deal with shifted aims in industry-funded projects. They then might adapt to this interest shift and might consequently be shaped concerning their vision.

On the contrary, PIs who already have adapted to the paradigm shift exert a targeted influence to accelerate and shape the transformation from technological to social innovation in the industry sector. A faster transformation within the private sector would help the PIs to gain support from the industry that suits their adapted vision, such as access to third-party funding from the private sector, or university–industry collaborations, among others. For doing so, they can consult the industry actors who have already adapted to the shift to support them. Those industry actors who are not aware of the paradigm shift or do not expect advantages from adapting to it might be targets of the PIs' persuasion. PIs will put effort in convincing them of the necessity for the change. Further, as part of academia, PIs contribute to the knowledge base for new solutions that might provide advantages for firms that engage in the process of the paradigm shift. Moreover, PIs can indirectly have an impact on industry by influencing the government and the civil society and thus increasing the public pressure to change.

P4. As PIs exert greater influence on industry partners with close collaborative arrangements with academia, PIs make these partners adapt faster to address social innovation opportunities than other industry actors.

3.5 The consequences of the paradigm shift for the government–academic relation

As politicians want to be re-elected, the government is expected to satisfy the voters' needs (e.g. Grossman & Helpman, 1996). Hence, they react in a similar way to the population's shifted needs as the industry and have a strong incentive to look for new solutions to satisfy the shifted needs of the civil society. Additionally, programs of former governments or transnational organizations, such as the Agenda 2030 (United Nations, 2015) or a "Sustainable Europe 2030" (European Commission, 2019), can put pressure on current authorities. Therefore, the government might approach the academic sector to gain deeper insights in related topics or even to get concrete recommendations for action.

For the academic sector and hence the PIs, the result is similar to the interest shift in industry. University actors, especially PIs, have to adapt to new interests of important stakeholders of current and future research projects. Again, the PIs' role includes the active part of transformative agents, while PIs are shaped by other actors at the same time. They are influenced by the changed interests of the government but then adapt to this influence. Subsequently, they proactively contribute to the transformation from pure technological to social innovation to pursue their own goals, which are mainly scientifically shaped (Cunningham et al.). As every government has numerous scientific advisory boards, there are various opportunities for PIs to exert influence. Either directly by engaging in such boards or indirectly by influencing members of such committees.

A significant difference to the industry is the government's influence on universities. Politicians are not only funders, but they can provide incentives to shape the role of universities and thus influence future research directions. For example, to pursue the paradigm of economic growth, policy fostered a shift of the role of universities from knowledge accumulators to a central actor of technological innovation (Cunningham et

al., 2019a). In the case of the USA, this can be seen by the Bayh–Dole Act in 1980, strengthening universities' so-called "third mission," i.e. the commercialization and transfer of created knowledge. The currently ongoing shift from pure economic to inclusive growth may, hence, cause a new change of the universities' role putting them into charge for contributing more to social change.

P5. To pursue their scientific goals, PIs use their influence on the government to induce policy measures that accelerate the shift from technological toward social innovation in the academic sector.

4. Conclusion

The so-called grand challenges describe global societal and environmental problems, which demand for more inclusive approaches than pure economic growth, or rather pure technological innovation. To tackle these challenges, a system transformation is required (Kuhlmann & Rip, 2014). Consequently, the focus shifted from pure economic to more inclusive growth that also takes social dimensions into account. Indeed, the population's increasing awareness for the urgent need of more sustainable solutions can already be seen in a shifted consumption behavior toward more ethical products (Carlile et al., 2018; Steinemann et al., 2017). Additionally, a significant increase of the publications on issues related to the grand challenges (e.g. Cavanaugh & Breau, 2018; Donnelly & Yu, 2017; Schiederig et al., 2012; Velasco-Muñoz et al., 2018) shows that science also recognized the grand challenges and is affected by the paradigm shift. Therefore, there is an urgent need for a fundamental rethink of innovation policy (Giuliani, 2018; Kuhlmann & Rip, 2014; Schot & Steinmueller, 2018). PIs may thereby serve as a catalyst of this rethinking because they are at the core of the quadruple helix. Hence, they are subject to various

influences and are, thus, likely to be treated by the paradigm shift. Then they subsequently adapt to this change and proactively contribute to it in their role as transformative agents to pursue their changed ideas and goals.

Table 4: Possibilities of exerting influence on actors of the quadruple helix

Actor	Consequence of paradigm shift	PI's role
Academia	Process of scientific change; increasing focus on issues related to the grand challenges	Accelerating and shaping this process by exploiting their reputation and large-scale networks
Civil society	Increasing awareness for social needs; growing call for addressing the grand challenges	Collaborating with civil society in defining research agenda in order to be at the forefront of current developments
Industry	Increasing pressure to address social innovation	Make collaboration partners adapt faster to address social innovation
Government	Increasing demand for more inclusive approaches	Induce policy measures that accelerate and support the paradigm shift in the academic sector by using influence on government

As social innovation targets the satisfaction of social needs (Mulgan, 2006), the challenges for such an innovation process originate from the civil society. Consequently, the paradigm shift can be seen as an external influence treating academia. However, PIs can actively influence the other actors of the quadruple helix and hence accelerate and shape this transformation process, as shown in Table 1. As PIs are central actors of the quadruple helix, this paper has investigated the effect of the paradigm shift as an external influence on the PIs as important actors of entrepreneurial ecosystems focusing on their role as transformative agents.

An external influence will lead to a modification of the PI's interests and, subsequently, the PI's vision. Regarding the paradigm shift, this might not only include new scientific interests but also the adaption of the PI's role model as central actors of academia that proactively shape the innovation process (O'Kane, 2018). Therefore, it is likely that PIs are not only reacting to the transformation from pure technological to social innovation but proactively design this change and thus fulfill their role as transformative

agents. As boundary spanners between science and industry, they bring this change to the producing sector and contribute to implementing new solutions that satisfy the population's needs. Here, they can better support and influence firms with whom they work closely. Moreover, in their role as scientists, PIs can actively shape the process of scientific change. They can create solutions how to face the grand challenges and provide it to policy makers. As boundary spanners between university and government, they can further deliver concrete recommendations for action and thus also shape the political process of the paradigm shift. In general, it can be said that PIs quickly adapt to external influences and subsequently shape the transformation of the innovation process. In doing so, they exploit their well-developed network to proactively affect other quadruple helix actors. PIs thus act as a mediator within this transformation process. In shaping this transformation, PIs pursue own interests. PIs who have adapted to the shift from pure technological to social innovation have changed ideas and aims. For their realization, they need an environment that provides the best possible support. Consequently, PIs accelerate the transformation process in all parts of the quadruple helix to gain benefits in implementing their vision.

To support PIs in pushing forward the transformation of the innovation process, policy should reconsider the role of universities. The paradigm shift toward social innovation induces that the academic sector has to contribute more actively to social change. This would result in a fourth mission beyond research, teaching and commercialization. For doing so, it might be helpful to implement new organizational units, e.g. "social innovation offices," similar to the already existing technology transfer offices (TTOs). These offices would support academics who have ideas that contribute to social change and/or provide solutions to environmental problems. Of course, these ideas can be of technological nature and be thus covered by the existing TTOs. But, additionally,

organizational change and empowerment are key for social innovation (Moulaert et al., 2005). Hence, universities should also support these forms of change. This also includes an adaption of universities' architecture to opening up and expose themselves to these new ideas and influences (see Dolan et al., 2019).

Future research should determine how exactly the universities' architecture should be changed to support social innovation. Further, other measures and ideas to establish the fourth mission of actively contributing to social change have to be determined. Subsequently, these measures, including the idea of social innovation offices, have to be evaluated. On a macro level, different actors, such as universities and non-profit organizations, have to be explored in the light of social innovation to reach a deeper understanding of the social innovation process that is required to tackle the grand challenges. In the same line, the influences of social innovation on entrepreneurial ecosystems have to be determined. More specifically, the impact of social innovation on the attitudes and motives of actors of entrepreneurial ecosystems should be explored. Further, there might be a relationship between the paradigm shift toward social innovation and the "output" of entrepreneurial ecosystems that should be evaluated. For example, there has been a noticeable increase in social entrepreneurship in recent year (Rey-Martí et al., 2016), which might be a result of this shift.

Moreover, studies that examine how PIs can be supported in their role as transformative agents within entrepreneurial ecosystems are desirable. Further, PIs' contribution to social innovation should be determined empirically. A plurality of research methods should thereby be adopted to take into account the versatility of science and PIs and control for the respective context the PI is embedded in (see Cunningham et al., 2017).

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IV. Article 3: Radical innovation and objective well-being: Really such a harmonious relationship?

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Abstract

This research explores the complex and often overlooked relationship between innovation and well-being by disentangling the nuanced impacts of radical innovation on the objective well-being of regions. In order to do so, we create a unique database of 177 NUTS2 regions based on the EU-Social Progress Index as our objective well-being measure, patent data to capture radical innovation, and further data about regional structural characteristics, such as GDP per capita. To disentangle the nuanced impacts of radical innovation, we pursue a three-step empirical approach, where the first two steps (i.e., panel regression with fixed effects and system GMM) deal with the total effect of radical innovation on objective well-being and the third step decomposes the total effect into a direct and an indirect effect by applying an adapted Sobel mediation test complemented with a bootstrapping approach. The findings present a deviation from the prevalent, but often implicit, academic narrative, revealing a negative direct effect of radical innovation on objective well-being. Furthermore, this study underscores the mediating role of economic development, determining its capacity to mitigate roughly 31% of the adverse effects of radical innovations on well-being. Despite this mitigating effect, our analysis reveals a negative relationship between radical innovation and economic development, emphasizing radical innovation's (short-term) negative effects. This pioneering exploration contributes substantially to the academic discourse surrounding innovation's societal impacts by (i.) highlighting the frequently neglected non-economic impacts of (radical) innovation, (ii.) examining regional variations and trends in this context, and (iii.) disentangling the intricate link between radical innovation and objective well-being into direct and indirect effects.

1. Introduction

The ultimate goal of economics is to understand and improve social welfare[1] (Ali & Cantner, 2020; Hartmann & Pyka, 2013). Nevertheless, the dominant discussion in economics is still centered on production and consumption (Komlos, 2023). Therefore, economic growth, fueled by technological innovation, has been one of the main goals of politics for the last decades (Hasan & Tucci, 2010). However, in recent years, the focus shifted from pure economic targets to more inclusive goals. In fact, promoting people's well-being is seen as the main goal of all EU social and economic policies (Domínguez-Torreiro, 2016; Eurostat, 2015). Well-being should, therefore, no longer be equated exclusively with money or consumption (Komlos, 2023). The role of innovation may, thus, be reconsidered to improve people's quality of life instead of solely fueling pure economic growth (Phelps, 2013) – particularly given the potential "dark side" of innovation, i.e., environmental degradation and detrimental effects on society, which has recently been stressed (Biggi & Giuliani, 2022; Castellacci, 2023).

However, while the role of innovation as a driver of economic growth is well-established (e.g., Galor & Tsiddon, 1997; Pece et al., 2015; Verspagen, 2006; Wong et al., 2005), it is often only, if at all, implicitly assumed that innovation contributes indirectly to well-being through economic development. As a result, evidence of the direct link between innovation and well-being is scarce (Dolan & Metcalfe, 2012; Lenzi & Perucca, 2020), particularly for radical innovation (Binder, 2013). This type of innovation is more uncertain but, if successful, has a more far-reaching impact than incremental innovation (Ahuja & Morris Lampert, 2001; Fleming, 2001; Trajtenberg, 1990). Hence,

[1] In line with previous studies (e.g., Binder and Witt, 2011; Schubert, 2013), so-cial welfare and well-being are used here as synonyms.

policymakers (e.g., SprinD agency[2]) and researchers (e.g., Grashof & Kopka, 2023) alike have become increasingly interested in radical innovation. Moreover, in the few studies that address the relationship between (technological) innovation and well-being in general, the focus is primarily on subjective well-being (e.g., Dolan & Metcalfe, 2012) rather than objective well-being, which is a widely accepted measure of the quality of life in a community or societal context (Gasper, 2010). Despite its relevance, the focus on subjective well-being suffers from the problems of neglecting individual opportunities and underestimating the degree of deprivation due to hedonic adaptation (Binder & Witt, 2014; Sen, 1987), as well as being endogenous to the process of innovative change, i.e., the individual preferences by which subjective well-being is assessed are shaped by the innovative processes whose welfare effects they are supposed to assess (Binder & Witt, 2011). In addition to the lack of consideration of radical innovation and objective well-being, the uneven nature of the geography of innovation (e.g., Audretsch & Feldman, 1996) has so far been largely ignored by taking a national level perspective (e.g., Qureshi et al., 2020), thereby potentially oversimplifying the relationship between innovation and well-being (Lenzi & Perucca, 2020; Tomaney, 2017).

Consequently, there is a rather limited understanding of the relationship between radical innovation and objective well-being in regions. By empirically investigating the extent to which radical innovation influences the objective well-being in regions, we, therefore, close the three previously mentioned research gaps and thereby contribute to answering the still open question about the relationship between innovation and well-being (Binder & Witt, 2011; Metcalfe, 2001).

[2] For the explicit support of radical innovation, the German government founded the national agency "Agentur für Sprunginnovationen" (SprinD) in the year 2019. For more information about SprinD, please see https://www.sprind.org/en/.

To address this research question empirically, we use the multidimensional EU-Social Progress Index (SPI) to capture objective well-being. Compared to other objective well-being indices, such as the Human Development Index (HDI), the SPI does not include income-based indicators. The SPI, therefore, adequately captures social progress and allows it to be decoupled from economic developments (Annoni et al., 2016; Reig-Martínez, 2013), which we also consider with the GDP per capita. Complemented by patent data, which we use to measure radical innovation, we obtain a unique panel data set at the regional level (177 NUTS2 regions from 11 EU countries for the period between 2011 and 2018). Building on this, we pursue a three-step empirical approach, where the first two steps, i.e., fixed effects panel regression and dynamic panel regression (GMM), deal with the total effect of radical innovation on objective well-being. In the third step, we decompose the total effect into a direct and an indirect effect, the latter through GDP per capita, by applying an adapted Sobel mediation test complemented with a bootstrapping approach.

While confirming the well-established positive but indirect relationship between innovation and well-being via economic development, our results also show that the direct effect of radical innovation on objective well-being is statistically significant and negative. Hence, they also provide empirical evidence for the potential "dark side" of innovation.

With our results, we contribute to the existing literature in regional and innovation studies by (i.) shedding light on the often-overlooked non-economic consequences of (radical) innovation, (ii.) considering regional differences and patterns in this context, and (iii.) disentangling the complex relationship between radical innovation and objective well-being into direct and indirect effects. More generally, we, therefore, contribute to the need for a broader notion of human development in (innovation) economics, moving

"(...) from innovation for wealth creation to innovation for wellbeing" (Martin, 2013, p. 175), thereby also providing relevant insights for (regional) policymakers.

The remainder of this paper is structured as follows. In the next chapter, the concepts of well-being and radical innovation and their relationships are described based on extant literature. In addition, the underlying hypotheses are derived. Chapter 3 then outlines all variables relevant to the regression analyses and depicts our empirical strategy. Descriptive and econometric results are reported in the fourth chapter, followed by a discussion of the results and their implications in Chapter 5. A final chapter concludes the paper and gives some fruitful avenues for future research.

2. Literature Review

2.1 The concept of well-being

Traditionally, well-being has been equated with economic welfare, and, therefore, Gross Domestic Product (GDP) has been the most commonly used measure of well-being (D'Urso et al., 2020). Although GDP and related income-based measures remain central economic indicators, their dominant use as a measure of well-being has been increasingly criticized in recent years as too narrow and flawed (Fehder et al., 2018; Jones & Klenow, 2016)[3], leading to initiatives to move "beyond GDP" in both research (e.g., Fleurbaey, 2009; Stiglitz et al., 2009) and policy (e.g., Domínguez-Torreiro, 2016)[4].

However, defining well-being has been a challenging task, given its complexity and multidimensionality (D'Urso et al., 2020; Voukelatou et al., 2021). Generally, it can be differentiated between subjective and objective well-being (Binder & Witt, 2014;

[3] Even the creator of GDP itself, Nobel Prize winner Simon Kuznets, warned that "(...) [t]he welfare of a nation can, therefore, scarcely be inferred from a measurement of national income as defined above." Kuznets (1934, p. 7).
[4] See also "The Wellbeing Economy Governments" partnership initiate (https://weall.org/wego).

Castellacci, 2023; D'Acci, 2011). The former is based on a utilitarian conceptualization and uses measures of life satisfaction and happiness to capture the perceived (subjective) well-being or happiness of individuals (McGillivray, 2007). In contrast, objective well-being is a multidimensional concept that focuses on objective and observable factors, e.g., regarding health and education, that enable citizens to achieve key life functions and thereby ultimately give them the opportunities to reach their full potential in life (Alkire, 2016; Anand et al., 2005; D'Acci, 2011). While both approaches have their advantages and disadvantages (Binder & Witt, 2014), for our research focusing on (radical) innovation, we consider objective well-being to be the most appropriate for two reasons. First, objective well-being captures the dimensions of a good life in a much more comprehensive and objective way, thus avoiding underestimating the degree of deprivation due to hedonic adaptation (Binder & Witt, 2014; Sen, 1987). Second, compared to subjective well-being, objective well-being is less likely to be endogenous to the process of innovative change. Unlike in the case of objective well-being, the preferences by which subjective well-being is assessed are shaped by the innovative processes whose welfare effects they are supposed to assess. As a result, a person's subjective satisfaction with their preferences may not accurately reflect their objective situation (Binder & Witt, 2011).

The theoretical underpinnings of objective well-being lie primarily in the "capabilities approach" of Amartya Sen (Sen, 1985a, 1985b, 1987). With his capabilities approach, he stressed the importance of ends, e.g., decent standard of living, over means, e.g., income per capita (Sen, 1987). The two main notions of his approach are "capabilities" and "functionings". Functionings refer to the aspects of life that a person actually does, experiences, and values. They can include elementary aspects, such as being safe, well-nourished, and literate, to relatively complex achievements, such as being part of a community's life. These functions all have intrinsic value and cannot be reduced to each

other, making the approach multidimensional. Capabilities refer to the feasible opportunities to achieve various functionings and, thereby, well-being (Alkire, 2016; Anand et al., 2005; Binder & Witt, 2014). Or as Sen (1992, p. 40) defines it: "(...) the various combinations of functionings (beings and doings) that the person can achieve. Capability is, thus, a set of vectors of functionings, reflecting the person's freedom to lead one type of life or another. (...) to choose from possible livings". The capabilities approach, thus, goes beyond individual assessments, as in the case of subjective well-being, and conceives of welfare as a set of objective functionings in life that people are capable of achieving (Binder & Witt, 2014; Sen, 1985b).

2.2 Radical innovation and objective well-being: A conceptual frame- work

Nevertheless, the impact of innovation, one of the key factors for economic growth (e.g., Fagerberg & Mowery, 2006; Hasan & Tucci, 2010; Rosenberg, 2006), has been discussed primarily, if at all, in the context of subjective well-being (Aghion et al., 2016; Binder, 2013; Dolan & Metcalfe, 2012; Lenzi & Perucca, 2020). While these studies provide important insights (also for our study) and largely show a positive relationship, they remain limited to individual assessments and, thus, may suffer from a bias due to hedonic adaptation (see Section 2.1). Therefore, we look at objective well-being to better understand the overall relationship between innovation and well-being (Metcalfe, 2001).

Innovation is generally understood as the result of a cumulative process in which existing knowledge is (re)combined in a unique way to create something new (Arthur, 2007; Basalla, 1988). However, the degree of novelty and impact can be quite different in this context (Knuepling et al., 2022). On the other hand, incremental innovation reuse and refine existing combinations, referring to exploitative search processes (March, 1991; Mewes, 2019). Hence, they only consist of minor improvements and develop along well-

defined trajectories (Dosi, 1982; Schoenmakers & Duysters, 2010; Verhoeven et al., 2016). On the contrary, radical innovation can be characterized by the introduction of novel and disruptive technological approaches that can lead to a paradigm shift and ultimately to radical change (Arthur, 2007; Hesse & Fornahl, 2020; Verhoeven et al., 2016). They rely on exploratory search processes for and development of completely new combinations of knowledge pieces that have not been put together before (Fleming, 2001; March, 1991; Mewes, 2019). Because these exploratory search processes involve higher costs and risks of failure (both technological and commercial) than incremental innovation (Ayres, 1988; Fleming, 2007), they are relatively rare (Fleming, 2001; Hesse & Fornahl, 2020). When successful, however, they can lead to significant competitive advantages (e.g., Castaldi et al., 2015), and create whole new markets and industries while disrupting old ones (e.g., Henderson & Clark, 1990; Tushman & Anderson, 2018). As a result, they are an essential part of the process of creative destruction (Ahuja & Morris Lampert, 2001).

However, the impact of such disruptive innovation-driven change on objective well-being remains unclear, especially at the regional level. While innovation in general (e.g., Rosenberg, 2006), and radical innovation in particular (e.g., Ahuja & Morris Lampert, 2001), has been shown to be a key driver of economic development, the non-economic consequences have been largely neglected (Devaraj et al., 2021). This is despite the fact that there are also potentially negative aspects, such as environmental degradation and technological unemployment (Castellacci, 2023; Schubert, 2013), or as some recent studies define it, a “dark side of innovation” (Biggi & Giuliani, 2022). In fact, already Schumpeter spoke of a “(...) perennial gale of creative destruction” (Schumpeter, 1942, p. 84), indicating that the benefits and costs of innovation are not necessarily evenly distributed (Binder & Witt, 2011). This is also, and perhaps especially, true at the regional

level. There is strong evidence that knowledge tends to be sticky and spatially immobile (Jaffe et al., 1993), leading to spatial agglomeration of innovation processes (Audretsch & Feldman, 1996), also in terms of more radical ones (Kemeny et al., 2022), and ultimately to regional disparities in economic development (Iammarino et al., 2019). At the same time, however, (radical) innovation might promote the objective well-being of regions by enhancing the overall economic development and consumption opportunities (Binder, 2013). Therefore, we expect radical innovation to have a direct and indirect (through economic development) impact on the objective well-being of regions.

The direct link between innovation in general and objective well-being has only rarely been examined, despite some recent exceptions on the national level (e.g., Qureshi et al., 2020). However, innovation is argued to have multifaceted influences on key dimensions of well-being, such as education and health (Castellacci, 2023; Dolan & Metcalfe, 2012). Aiming at capturing people's material living conditions and the quality of their lives, the OECD (2020) and the UN (2023) identified health, job opportunities, environment, safety, and politics as major dimensions of objective well-being[5].

Health represents a significant influence on well-being (WHO, 2001). Good health implies many subsequent benefits, such as job opportunities, social relationships, reduced health care costs, and increased life expectancy (Voukelatou et al., 2021). It is, therefore, one of the aspects that create opportunities and abilities to choose (Alatartseva & Barysheva, 2015). Technological innovation can improve health care quality and systems whereby its successful implementation strongly depends on the framework conditions (Christensen et al., 2000; Cucciniello & Nasi, 2014). Overall, the existing literature

[5] Originally, socioeconomic development is also mentioned. However, since this dimension overlaps with the other dimensions, for the sake of readability, we do not present it here separately.

indicates that technological innovation is likely to positively affect health, as innovation increases the opportunities for improved treatment methods and a better healthcare system. However, in the case of more radical innovation, it is also likely that potential job displacement effects (see next dimension) can reduce life expectancy and health outcomes (Davis & Wachter, 2011). Despite these potential negative health implications, recent empirical findings on the county level in the US show that creative destruction is negatively associated with poor health outcomes (Devaraj et al., 2021). Further, Christensen et al. (2000; 2006) state that influential innovations with disruptive effects are needed to make health care in the US accessible for everyone. Other healthcare systems may, thereby, also benefit from induced changes, such as reduced costs, new technologies, and new business models that enhance the efficiency of implementing novel solutions. Thus, according to the existing literature, radical innovation seems to be positively associated with health.

Job opportunities have "obvious economic and societal benefits, contributing to people's health and societal, political, and economic stability" (Voukelatou et al., 2021, p. 281). They thus also contribute to the objective well-being of a region. Innovation, subsequently, is frequently found to enhance job opportunities by creating new jobs (e.g., Aghion et al., 2016; Ciriaci et al., 2016; Lachenmaier & Rottmann, 2011). However, to exploit the full potential of innovation, "transformative changes, the emergence of new growth sectors and a process of creative destruction" (Nübler, 2016, p. 23) are required. It again depends on the framework conditions, whereby policies are particularly challenged to shape these processes (Nübler, 2016). Nevertheless, there is also evidence in the literature for the opposite effect. New products can replace existing ones, making many occupations obsolete (Spiezia & Vivarelli, 2002). Moreover, innovation-induced

creative destruction is also associated with destroying existing structures, industries, and jobs, leading to unemployment and uncertainty (Binder, 2013). This holds particularly true for rather low-skilled workers performing routinized tasks (Acemoglu, 2002). Therefore, despite the positive impact of (radical) innovation on employment opportunities that tends to prevail in the literature, no definitive statement can be made about the resulting effect (Calvino & Virgillito, 2018).

Environment Despite some research gaps in the complex relationship between environmental influences and well-being, the existing literature suggests an overall positive association (Krefis et al., 2018). Innovation, subsequently, contributes to a healthy environment through increased efficiency in production (Sayer & Cassman, 2013), decreased emissions (Carrión-Flores & Innes, 2010; Lin & Ma, 2022), or improving a comprehensive water supply (O'Callaghan et al., 2020), among others. However, there is also the other side of the coin. "Beyond a certain level of innovation, higher innovation activities exacerbate environmental degradation" (Ibrahim & Vo, 2021, p. 2). Yet, the vast majority of research on this relationship has found a positive association between innovation and environmental performance. This is especially true for radical innovation, as this innovation type is perceived as an enabler for a shift from natural resource-intensive to technology-intensive activities (Reis et al., 2021). Therefore, we assume that radical innovation contributes to objective well-being by positively affecting the environmental dimension.

Safety is mainly determined by crime and violence but can also capture other risks, such as economic loss (Voukelatou et al., 2021). Technological innovation can significantly enhance the efficiency and efficacy of the criminal justice system. However, it could also redirect resources from conventional crime prevention and policing methods that might

offer greater safety (Byrne & Marx, 2011). Furthermore, Achim et al. (2021) found that improved technology reduces economic and financial crime. Contrarily, innovation can also provide new and enhanced opportunities for criminals. For example, the progression of information and communication technologies has resulted in a significant increase in crime rates (Nuth, 2008). Moreover, especially radical innovation is associated with increased inequality (Rubin & Segal, 2015) and job destruction (Spiezia & Vivarelli, 2002) which can, subsequently, induce increased crime (Costantini et al., 2018). The effect of innovation on crime is, therefore, ambiguous and cannot be clearly postulated.

Politics In light of several economic crises, the call for increased transparency from governments and public institutions has intensified. Equitable civic and political involvement not only directly enhances well-being, but also indirectly supports it by promoting more effective public policies, reducing transaction costs, and diminishing the potential for fraud (Voukelatou et al., 2021). There is no doubt in the literature that politics can shape and foster innovation. However, the opposite direction, i.e., how innovations influence politics is rarely explored. Clapp & Ruder (2020) state that technological lock-ins can lead to a reinforcing policy. A status that may be challenged by an innovation that calls the lock-in into question, such as radical innovation. In addition, the capability to technologically innovate has a positive effect on government assistance (Wei et al., 2011), and the relationship between political ties and innovation performance is moderated by technical turbulence (Farrukh et al., 2023). These findings indicate that innovation can influence politics in a positive way. Although the overall evidence is rather scarce, especially related to radical innovation, we therefore still assume a positive relationship between (radical) innovation and politics that ultimately contributes to a positive influence of (radical) innovation on objective well-being.

While these dimensions may not necessarily capture all potential channels through which innovation could affect objective well-being, it is argued that they capture the most important ones (OECD, 2020). Overall, the positive aspects of radical innovation seem to outweigh the potential negative effects. Thus, we propose the following hypothesis:

H1: Radical innovation has a positive influence on regional objective well-being.

In addition to the direct influence of radical innovation on objective well-being, we also assume an indirect (i.e., mediating) influence through the economic development of regions. In general, the relationship between innovation and economic development is a focal point of interest for scholars, making it a frequently discussed topic. The positive influence of innovation on economic growth has been demonstrated frequently and in various contexts (Galor & Tsiddon, 1997; Pece et al., 2015; Verspagen, 2006; Wong et al., 2005, among others). However, the different types of innovation are not always clearly distinguished in this context (Knuepling et al., 2022). Since the focus of this paper is on radical innovation, we take a more nuanced view before postulating the effect of this type of innovation on economic development.

According to the literature review by Knuepling et al. (2022), radical innovation is associated with high impact and strong market effects. It causes change and creation but is also related to external effects. Radical innovation is identified as an important factor for long-term economic growth (Castaldi et al., 2015; Verhoeven et al., 2016) and, therefore, often regarded as a positive phenomenon (Knuepling et al., 2022). However, due to the predominant focus on fostering economic growth, the downsides of innovation are often overlooked (Biggi & Giuliani, 2022; Coad et al., 2022; Dosi, 2013). Since radical innovation can lead to a paradigm shift and, consequently, induce massive change (Verhoeven et al., 2016), it also has the potential for significant downside effects. Dachs

et al. (2017) find that more technology-intensive innovations are associated with larger structural change, i.e., larger gains but also employment losses. Radical innovation is related to the emergence of new markets but this, subsequently, causes major replacements of existing markets (Colombo et al., 2015). Moreover, the high degree of novelty of radical innovations is related to a high degree of uncertainty as to whether they will have an economic impact in the future (Strumsky & Lobo, 2015). This evidence raises the question of whether the total effect of radical innovation on economic development is as positive as frequently assumed. On the other hand, the detrimental effects of innovation are mostly related to social and environmental downsides (Biggi & Giuliani, 2022). Given that radical innovation contributes significantly to creative destruction which is prominently believed to be a key driver of economic growth (Aghion et al., 2014; e.g., Aghion & Howitt, 1990; Akcigit & Kerr, 2018)), we, therefore, postulate that:

H2: Radical innovation has a positive influence on regional economic development.

Economic development is frequently used as the explanation for the assumed positive impact of innovation on well-being (e.g., Dolan & Metcalfe, 2012). However, the link between economic development and objective well-being is not as well-established as this frequent assumption suggests. This may be rooted in the fact, that a lot of measures for objective well-being, for instance, the HDI, include GDP as a variable for economic development, preventing a meaningful analysis of this relationship. However, a more developed economic level has manifold consequences that are likely to enhance objective well-being. Economic development is related to employment (Sawtelle, 2007), provides the potential for improved population health (Lange & Vollmer, 2017), or improved social safety (Kharazishvili et al., 2020). It is, therefore, likely that economic development contributes positively to objective well-being.

Moreover, even though the concepts of subjective and objective well-being differ substantially, both provide information about people's quality of life (Oswald & Wu, 2010) and show similar patterns and correlations (Schueller & Seligman, 2010). The evidence on the relationship between economic development and subjective well-being is relatively rich. Aghion et al. (2016) demonstrates that turnover-driven growth enhances well-being mediated by unemployment benefits. Highlighting the adverse relationship between economic growth and environmental degradation. Khan et al. (2020) find a positive link between growth and well-being that is affected by the detrimental effects on the environment, though. This emphasizes the manifold consequences of economic development with various effects on well-being. Nevertheless, the majority of studies on this topic found a positive association (e.g., Abbott & Wallace, 2014; Juknys et al., 2018; Mikucka et al., 2017; Zagorski et al., 2010). However, the effects do not appear to be linear, as richer countries and people do not benefit as much from economic growth as poorer people and people in poorer countries do (Mikucka et al., 2017; Zagorski et al., 2010). This implies diminishing returns to economic growth in terms of subjective well-being which may be rooted in the Easterlin paradox (Easterlin, 1974; Easterlin & O'Connor, 2022). Based on the above findings, we therefore propose the following hypothesis:

H3: Economic development has a positive influence on regional objective well-being.

As summarized in Figure 1, we therefore assume that radical innovation positively influences objective well-being in a direct way (see H1), but also positively influences objective well-being in an indirect way through economic development. Regarding the latter, radical innovation is assumed to foster the economic development of regions (see H2), which is then supposed to positively influence the objective well-being of regions

(see H3). In other words, we postulate that economic development is a relevant mediator in the relationship between radical innovation and the objective well-being of regions.

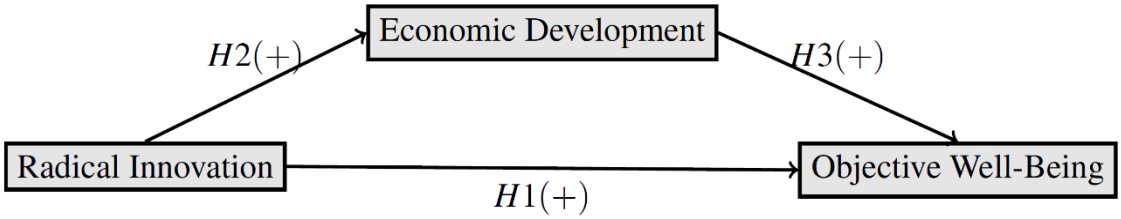

Figure 1: Conceptual framework about the relationship between radical innovation and objective well-being

3. Data and main variables

3.1 Dependent variable: Regional Social Progress Index (SPI)

In order to empirically test the hypotheses described above, we combine several databases, particularly for our main dependent variable: The Social Progress Index (SPI), which we use as a measure of objective well-being, consistent with previous studies (e.g., Fehder et al., 2018). Over the last three decades, there have been many efforts to develop new indicators 'beyond GDP' to better reflect societal developments (Barrington-Leigh & Escande, 2018; Domínguez-Torreiro, 2016). A prominent example of this is the Human Development Index (HDI), introduced by the United Nations in the 1990s (Beltrán-Esteve et al., 2023). However, there are typically two major problems with the HDI and other 'beyond GDP' indicators: (i.) They include GDP or other income-based indicators, which can therefore mask a lack of social progress in economically strong countries such as Saudi Arabia; (ii.) In addition to aggregated measures, there are also more domain-specific indicators that focus on specific aspects such as environmental sustainability (e.g. the Ecological Footprint introduced by Wackernagel & Rees (1998)) and, therefore, lack generality, despite being informative (Fehder et al., 2018). To avoid these issues, we use the SPI developed by the Social Imperative Network, which is only grounded on non-income-based indicators (Porter et al., 2014).

Because it does not conflate social and economic indicators, as the HDI for instance does, it allows for a systematic examination of the relationship between economic development (e.g., proxied by GDP per capita) and social development (Annoni & Bolsi, 2020). While previous versions of the SPI are primary on the national level, we use the regional EU-SPI version, which calculates the SPI for NUTS2 regions (Annoni et al., 2016). However, so far the regional EU-SPI is only available for the years 2016 and 2020 (Beltrán-Esteve et al., 2023). As our research focus tends to require longitudinal data, we, therefore, replicate the procedure by Annoni et al. (2016) for a longer time period[6]. Due to data limitations, this time period goes from 2011 to 2018.

Conceptually, the SPI largely follows the capabilities approach by Sen (1985b), presented in Section 2.1, and, therefore, significantly relates to the concept of objective well- being. The index defines social progress as "(...) the capacity of a society to meet the basic human needs of its citizens, establish the building blocks that allow citizens and communities to enhance and sustain the quality of their lives, and create the conditions for all individuals to reach their full potential." (Fehder et al., 2018, p. 479). As one can see from the definition, it is, therefore, a multidimensional and output-oriented measurement concept. It can be broken down into three distinct dimensions: (i.) Basic Human Needs, which encompasses the capacity of a country/ region to meet the basic human needs of its citizens; (ii.) Foundations of well-being, which go a step further by capturing the building blocks that enable citizens and communities to improve and sustain their quality of life; (iii.) Opportunities, which encompasses the opportunities for all individuals to reach their full potential (Annoni et al., 2016; Fehder et al., 2018; Scott et al., 2015). Each of these dimensions can then be divided into four components in accordance with

[6] Unfortunately, we had to adjust our procedure slightly due to missing information over time for some indicators. However, the changes are fairly minor and are noted throughout this section.

previous literature (e.g., Annoni & Bolsi, 2020; Fehder et al., 2018). Finally, each component is based on an aggregation of two to five indications[7]. Figure 2 provides a comprehensive overview of the three dimensions of the SPI, their four components, and the underlying indicators for each component.

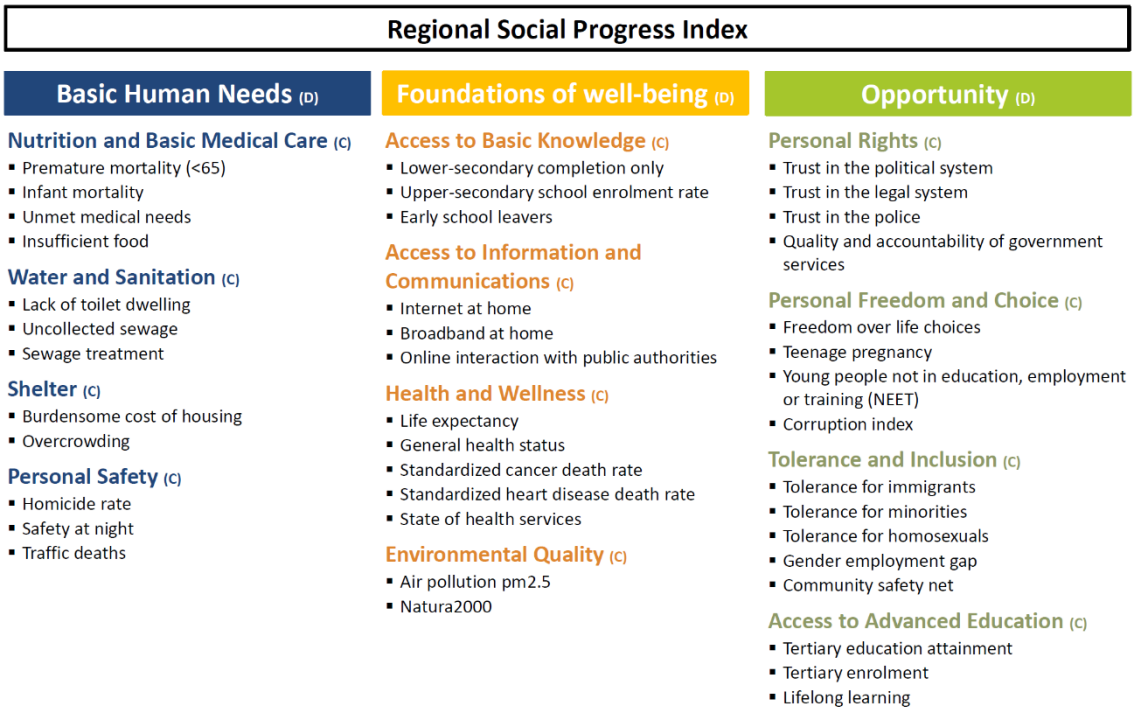

Figure 2: Framework for the Regional Social Progress Index (SPI) - Dimensions (D) and Components (C)

The underlying information for the indicators comes primarily from the following data sources: Eurostat, EU-SILC, EEA, European Social Survey, European Quality of Institutions Index Survey, and the European Value Survey. A detailed list of the different data sources can be found in the Appendix (see Table A3).

In order to construct the SPI in a transparent and consistent way, we use the previously described information sources and follow the step-wise methodology by Annoni et al. (2016). Firstly, the internal consistency of each of the twelve components is tested by verifying that there is a strong multivariate correlation among the underlying indicators

[7] 7Unfortunately, for two components, we can only use two indicators due to limited access to data from the EU-SILC database and the European Environment Agency (EEA). Since this is only a slight deviation from Annoni et al. (2016), we assume that our results are nevertheless reliable.

(Annoni et al., 2016; Beltrán-Esteve et al., 2023). Given that the majority of the indicators chosen are the same as in the case of Annoni et al. (2016), which already empirically show internal consistency, we are confident that this holds true for our case[8]. In particular, because the EU-SPI has been shown to be robust to different designs (Beltrán-Esteve et al., 2023). Nevertheless, similar to previous studies (e.g., Annoni et al., 2016), we also run a principal component analysis (PCA) for our indicators (Rencher & Christensen, 2012). The corresponding results presented in Appendix C, generally confirm the internal consistency. Secondly, the SPI scores at all levels (i.e., indicators, components, dimensions, overall) are normalized and range from a 0-100 scale by using the min-max transformation with indicator-specific boundaries (Annoni & Bolsi, 2020). In line with previous studies (e.g., Annoni et al., 2016; Beltrán-Esteve et al., 2023), these limits are based on theoretical utopian and dystopian values, or maximum and minimum values over a time series (where available). The corresponding transformation can be expressed as follows:

$$x_{normalized} = \begin{cases} \dfrac{100 * (x - x_{min})}{(x_{max} - x_{min})} & \text{if } x \text{ is positively oriented} \\ \dfrac{-100 * (x - x_{min})}{(x_{max} - x_{min})} + 100 & \text{if } x \text{ is negatively oriented} \end{cases}$$

Thirdly, we need to aggregate the indicators, which is a widely discussed issue in the literature (e.g., Annoni & Bolsi, 2020; Decancq & Lugo, 2013). Although composite indicators have their drawbacks, for example in disentangling the underlying mechanisms, they have been widely used in the case of well-being because they help to understand such a complex phenomenon (D'Urso et al., 2020; OECD, 2008). However, as

[8] The similarity can ultimately be seen by comparing our regional SPI measure with those for 2016 Annoni et al. (2016) and 2020 Annoni & Bolsi (2020). Indeed, there is a strong and almost perfect correlation between the mean of our SPI variable and the SPI for 2016 (correlation coefficient: 0.96) and 2020 (correlation coefficient: 0.96).

indicated in previous studies (e.g., D'Urso et al., 2020; Saisana & Tarantola, 2002), there is not a one-size-fits-all approach. In our specific research context, we use a hybrid aggregation method (Annoni & Bolsi, 2020; Decancq & Lugo, 2013) that includes the arithmetic mean within each component and the generalized mean across components and across dimensions (Annoni et al., 2016; Annoni & Bolsi, 2020). The good internal consistency of the indicators identified earlier (through PCA, see Appendix C) ensures that the arithmetic mean is an appropriate way of aggregating within dimensions, as the compensability effect, i.e., poor scores on some indicators being offset by high scores on others, is limited across indicators. Formally, the score within each component *c* in region *r* and year *t* can, therefore, be defined as:

$$c_{rt} = \overline{x}_{rt} = \frac{1}{n}\sum_{i=1}^{n}(x_i)$$

where c_{rt} is the arithmetic mean of all underlying indicators of component *c* in region *r* and year *t*.

However, the compensatory effect is generally more pronounced across components, and especially across dimensions. Hence, in these two cases, we use an inequality-adverse type of aggregation by calculating the generalized mean, which lies between the arithmetic (p=1) and the geometric average (p=0), helping to mitigate the compensatory effect (Annoni et al., 2016; Annoni & Bolsi, 2020; Decancq & Lugo, 2013). By using the generalized mean, the score for dimension *j*, i.e., basic human needs, foundations of well-being, or opportunities, in region *r* and year *t* can be computed as:[9]

[9] The same applies to aggregation across dimensions.

$$D_{jrt}^{(\beta)} = \begin{cases} \left(\frac{1}{n}\sum_{i=1}^{n} C_{irt}^{\beta}\right)^{\frac{1}{\beta}}, & \text{for } \beta \neq 0 \\ \left(\prod_{j=1}^{n} C_{irt}\right)^{\frac{1}{n}}, & \text{for } \beta = 0 \text{ (geometric mean)} \end{cases}$$

where $D_{jrt}^{(\beta)}$ is the underlying component *i* within dimension *j* in region *r* and year *t*. The β (of *n* components) is a parameter that can be used to control the level of compensability. While in the case of β = 1, the generalized mean is equal to the arithmetic, for β = 0, it is the geometric mean (Annoni et al., 2016; Annoni & Bolsi, 2020; Beltrán-Esteve et al., 2023). When β < 0 and β > 1, the generalized mean is said to be inequality-adverse (Ruiz, 2011). Following the results of the Monte-Carlo simulation about the influence of different values of β by Annoni et al. (2016), we set β = 0.5, allowing the index to be partially non- compensatory (Annoni & Bolsi, 2020).

Moreover, given the variety of indicators from different sources, one of the main challenges is to reach the NUTS2 level. To achieve this, we follow the rule proposed by Annoni et al. (2016) that within and across components at least half of the respective indicators must be at the NUTS2 level. For example, if at least 50% of the indicators in the Water and Sanitation component are available at the NUTS2 level then the resulting component is considered to be representative at the NUTS2 level. In the case of the remaining indicators, which are unavailable at the NUTS2 level, a less aggregated level, such as NUTS1 level or the national level, is then used. As a result, the within-country variability of the resulting SPI and the underlying sub-indices is underestimated (Annoni et al., 2016). However, in general, this "50%" rule only had to be applied to 3 out of 12 components.

A related challenge is that of missing values. Although we try to minimize this problem, in some cases it is unfortunately not possible. In line with (Scott et al., 2015), our final dataset, therefore, excludes regions with more than two missing values in more

than three components. As a result, we were able to calculate the regional SPI for 177 NUTS2 regions from eleven European countries.

3.2 Mediating variable: GDP per capita

As indicated in section 2, radical innovation might also indirectly affect objective well-being through economic development. Further, economic development has far-reaching consequences and implications. GDP affects private and public decisions causing long-term effects for economies and society (van den Bergh, 2009). Moreover, GDP information is found to influence climate policies (Tol, 2008; Zhang & Zhang, 2018), demonstrating the interrelatedness between economic development and the environment. Such a complex relationship can also be observed for multiple other aspects, such as traffic fatalities (Dadgar & Norström, 2017; Yannis et al., 2014), health system (Jakovljevic et al., 2020; Stepovic, 2019), or education (Rahman, 2011; Solaki, 2013). Consequently, the manifold effects of economic development, operationalized by GDP per capita, are far-reaching, complex, and frequently bi-directional and interrelated. It is, therefore, likely that economic development affects objective well-being not only directly but has numerous indirect implications. Further, the significant relationship between innovation and economic development (Aghion et al., 2014; Akcigit & Kerr, 2018; Verspagen, 2006) implies that economic development serves as a powerful mediator in the relationship between innovation and objective well-being. Traditionally, researchers have used GDP per capita to measure and compare the economic development (Costanza et al., 2018; Fehder et al., 2018; Giovannini & Rondinella, 2018). Following this tradition, we use information from Eurostat to add GDP per capita in NUTS2 regions to our dataset (*GDP per capita*).

3.3 Independent and control variables

We further enrich this data with regionalized patent data from the OECD Regpat database and patent quality data derived from the OECD Patent Quality Indicators database (Squicciarini et al., 2013). We combine these two datasets in order to derive our main independent variable, radical innovation, at the NUTS2 level. Although there are some well-known drawbacks of patent data (Griliches, 1990), we follow previous studies frequently relying on patent- based indicators (e.g., Grashof & Kopka, 2023; Hesse & Fornahl, 2020). In general, previous measures of radical innovation can be divided into two perspectives: emergence and diffusion or impact (Hesse & Fornahl, 2020). While the former rather focuses on the novelty aspect of radical innovation by considering backward citations (e.g., Dahlin & Behrens, 2005) or new combinations of previously unconnected technology classes (e.g., Fleming, 2007), the latter refers to the (future) impact of an innovation, which is for instance proxied by forward citations (e.g., Trajtenberg, 1990). Given our research focus on objective well-being, we concentrate here on the impact side and follow the definition by Ahuja & Morris Lampert (2001), which has often been used to measure radical innovation as the top 1% cited patents (e.g., Hesse & Fornahl, 2020; Schoenmakers & Duysters, 2010).

Based on the rich information provided by the OECD Patent Quality Indicators database, we consider in this context X-I-Y forward citations, which indicate that the cited patent has a higher technological value (Squicciarini et al., 2013)[10]. As described in Squicciarini et al. (2013), the number of these forward citations is determined for a five-year moving window, a given filing date and technology field, thereby also accounting for the time lag of a patent's publication in the patent database (Hesse & Fornahl, 2020).

[10] However, the results remain robust when we consider all categories of citations. The corresponding results can be provided upon request.

By counting the previously identified top 1% cited patents per region and year, we then construct our final radical innovation variable (*Radical Innovation*).

Moreover, we estimate the weighted number of patents based on the share of inventors (*Regional Inventor's Share*), also from OECD Regpat, in order to control for the overall knowledge stock of a region. In addition, we also consider the technological diversity within regions. Following previous studies (e.g., Garcia-Vega, 2006; Grashof, 2020), we therefore calculate the Gini-Simpson index, also known as the Blau index (Blau, 1977) or the inverse Herfindahl-Hirschman Index (HHI), which takes the following form:

$$D_i = 1 - \sum_i p_i^2$$

where p_i is the proportion of inventive activities (inventor-based) in a region in each technological field i. $D_i$ranges thereby from zero (no diversity) to one (maximum technological diversity) (Hesse, 2020). For the technological fields we use the classification of Schmoch (2008), which groups patents into 35 technological fields (*Gini-Simpson*).

In order to control for further non-patent-related regional characteristics, we again use information from Eurostat. Since the employment situation within a region is assumed to be important for the objective well-being (de Witte et al., 2015; Stiglitz, 2002), we consider the regional unemployment rate (*Unemployment*), which represents the percentage of unemployed persons in the economically active population. Furthermore, we also control for the regional age structure, by considering the median age (in years) of the regional population (*Age of Population*).

The resulting final dataset consists of 177 NUTS2 regions from 11 EU countries (for the time period between 2011 and 2018)[11].

3.4 Empirical strategy

Examining the link between innovation and objective well-being is subject to several obstacles that we need to adequately address in our econometric approach. Firstly, we cannot exclude an omitted variable bias or endogeneity in general due to the multifaceted nature of this relation. Secondly, the relationship between objective well-being and innovation is unlikely to be one-directional. When examining the influence of innovation on objective well-being, we, therefore, have to deal with reverse causality[12]. Thirdly, as the current level of objective well-being is likely dependent on previous levels of itself, we face the problem of autocorrelation.

In order to properly examine the relationship between innovation and objective well-being, we consider the above issues and, therefore, follow a three-step approach. In the first step, given our unbalanced panel database, we run a linear panel regression with region-fixed effects and a dummy variable to capture the consequences of the European debt crisis (from 2011-2014)[13]. In general, fixed-effects models are known to be a solid choice to deal with endogeneity (Semykina & Wooldridge, 2010). Therefore, such a model seems well-fitting in our research context. We further do a Sargan-Hansen test for

[11] For an overview about the descriptive statistics of all used variables please see Appendix A1. Moreover, as can be seen from the pairwise correlation matrix (see Appendix A2), the correlation between these variables is rather low to medium, indicating that multicollinearity is not a serious problem in our concrete empirical analysis.

[12] As a first simple check, we swapped our dependent variable, SPI, with our main independent variable, radical innovation. As shown in Table A4 in the Appendix, the influence of SPI on radical innovation is statistically insignificant, providing a first indication that the problem of reverse causality may not be too severe.

[13] The year 2014 is regarded as the ending of the European debt crisis because most countries exited until then the European assistance programs Copelovitch et al. (2016). As can be seen in Appendix B1, our dependent variable, the SPI, has been largely affected by the European debt crisis, making it necessary to control for it in order to minimize omitted variable bias.

which we can reject the null hypothesis indicating a good fit of the approach compared to a random effects regression. Moreover, we use a one-year time lag for our explanatory variables because the respective variables' effects on objective well-being will likely need some time to unfold. In addition, this also addresses the problem of reverse causality.

Our baseline model can therefore be formulated in the following stylized way:

$$SPI_{it} = \beta_1 Radical\ Innovation_{it} + \beta_j crisis_{it} + \beta_k controls_{k,it} + \gamma_i + u_{it}$$

where *SPI* is the Social Progress Index in the region *i* at year *t*, whereby the regional level is given by NUTS2 classification. Radical Innovation depicts the number of top 1% cited patents in the respective time and region. Since the euro crisis is likely to significantly affect objective well-being, we further include crisis as a dummy variable to consider if a region is affected by the crisis or not (*Euro Crisis Dummy*). The controls include regional inventor's share, unemployment, GDP per capita, the regional Gini-Simpson coefficient, and the population's median age. γ_i denotes the region fixed effects and u_{it} reflects the error term.

To further account for endogeneity, autocorrelation, and reverse causality, in the second step, we apply a more robust dynamic panel model using a generalized method of moments (GMM). Considering that the process of innovation and the realization of well-being are dynamic, i.e., that current values are influenced by past ones, we use a system GMM approach (Blundell & Bond, 1998) with two-step robust standard errors (Arellano & Bond, 1991; Windmeijer, 2005), which is also in line with previous studies (e.g., Damioli et al., 2021). This method deals especially well with panel data that covers a relatively short time span and where the independent variables are not strictly exogenous. For the implementation, we used the Stata command xtabond2 (Roodman, 2009). As the system GMM allows the inclusion of time-invariant regressors (Roodman, 2009), we additionally

include country dummies to capture differences in terms of institutions, but also with respect to the European debt crisis. In our system GMM approach, we treat these country dummies as strictly exogenous, together with the median age of the regional population, the euro crisis dummy, and the technological diversity of a region. In general, this regression approach can be seen as a robustness check to ensure meaningful and unbiased results.

In the third step, we then aim to decompose the total effect into the direct effect of radical innovation on objective well-being and the indirect effect mediated by GDP per capita. For this purpose, we estimate a Sobel mediation test. Since this test is usually applied for cross-sectional data, we adjusted it for panel data. Using our fixed-effects model in this test ensures a proper comparability of the results in this paper. Since Sobel tests usually suffer from low statistical power, we use bootstrapping re-sampling, which is a commonly recommended solution in this context (Preacher & Hayes, 2004, 2008; Zhao et al., 2010).

4. Results

4.1 Descriptive results

To provide first insights about the relationship between the objective well-being, economic development, and radical innovation, Table 1 presents the mean of the SPI, GDP per capita, and the number of radical innovations[14]. As can be seen in Table 1, radical innovation seems to be a rather rare event on average in the countries of our sample, which is in line with previous findings at the firm (e.g., Grashof et al., 2019) and regional level (e.g., Hesse & Fornahl, 2020). While in our sample, Denmark reaches the highest

[14] For the summary statistics of all variables included in the regression, please see Appendix A1.

average score for radical innovations and Poland the second lowest one, they notably show the same pattern in the case of the SPI. With a value of 76.57, Denmark possesses the highest average of the SPI in our sample, while Poland, with 59.19, reports the lowest score, although Italy is relatively close (59.44). This may already indicate a relationship between the ability to produce radical innovations and objective well-being. Furthermore, Denmark and Poland also have the highest and lowest levels of GDP per capita, suggesting that there may also be a relationship between economic development and objective well-being.

Table 1: Descriptive Statistics by Country

	SPI		GDP per Capita [€]		Radical Innov.		
	Mean	Sd	Mean	Sd	Mean	Sd	NUTS2
Austria	70.25	1.07	39,071	6,121	0.71	1.33	14
Belgium	68.18	2.51	35,547	12,196	0.69	1.37	77
Germany	69.91	1.44	35,585	8,361	2.64	5.16	286
Denmark	76.57	1.58	43,177	9,491	3.80	5.97	30
Spain	67.77	2.34	22,982	4,682	0.34	1.94	136
France	69.34	1.82	29,607	6,687	1.26	5.00	105
UK	71.56	1.90	30,649	6,868	1.04	2.56	210
Italy	59.44	3.37	26,603	8,033	0.26	0.83	62
Netherlands	74.13	2.28	37,883	8,107	1.49	3.69	83
Poland	59.19	2.46	10,115	1,681	0.05	0.28	75
Portugal	62.21	2.83	17,494	3,616	0.03	0.17	33
Total	68.75	4.74	30,216	10,752	1.33	3.74	1,111

This table reports the mean and standard deviation of the SPI, the GDP per capita, the number of radical innovations and the number of NUTS2 regions per country.

For a better illustration of this relationship, we created a scatter plot with a fractional polynomial fitting line (Figure 3). It shows an almost inverted U-shaped curve, generally confirming the positive relationship between GDP per capita and the SPI shown in Table 1[15]. Moreover, it illustrates diminishing returns to GDP, indicating that further economic development does not necessarily lead to higher objective well-being, which

[15] As can be seen in Table A2 in the Appendix, GDP per capita is relatively strongly correlated with the SPI (correlation coefficient of 0.74).

corresponds to the Easterlin paradox found in the case of subjective well-being (see Easterlin, 1974; Easterlin & O'Connor, 2022).

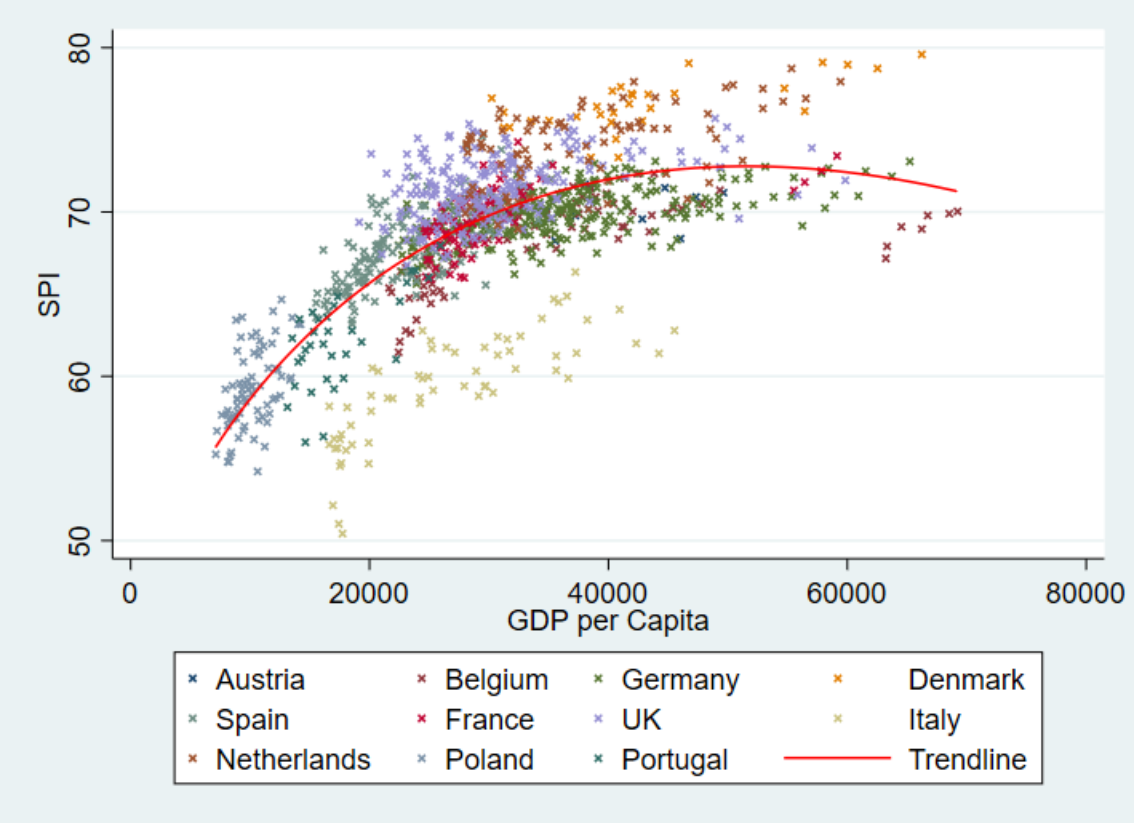

Figure 3: The relationship between economic development and objective well-being by NUTS2 regions

The fitting line even tends to show a negative relationship between economic development and objective well-being for the NUTS2 regions with the highest values of GDP per capita. This suggests that further economic development seems to have some adverse effects regarding objective well-being. It therefore supports the need to move beyond GDP as an indicator for well-being (Fleurbaey, 2009; Stiglitz et al., 2009). This holds even more true, when looking at the outliers. While Italian regions show SPI values that are significantly below the fitting line, Danish and Dutch regions seem to perform significantly above the average. Thus, on average, objective well-being increases with GDP per capita, but this is apparently far from the whole story (Fehder et al., 2018). To consider the regional variety and to make more (statistically) substantiated conclusions,

especially about the rather rare phenomenon of radical innovation, we, therefore, turn to the results of our regression analyses.

4.2 Econometric results

The results of our baseline fixed effects model are presented in Column (1) of Table 2. Our findings show that the number of radical innovations has a statistically significant negative effect on objective well-being. It is further noteworthy that the coefficient of GDP per capita is statistically highly significant and positive. These results can be interpreted as a first indication that the creative destruction induced by radical innovations causes a decline in objective well-being. However, since the contribution of innovation to economic growth is well-known (e.g., Rosenberg, 2006) and, as our results show, GDP is positively related to objective well-being, the indirect effect could also be relevant for the relationship between radical innovation and objective well-being.

To check the robustness of these results, we estimated a system GMM with two-step robust standard errors (Arellano & Bond, 1991; Blundell & Bond, 1998; Windmeijer, 2005). The results of this dynamic regression approach, reported in Column (2) of Table 2, show that the coefficient of the lagged number of radical innovations remains negative and statistically significant. The result for GDP per capita can also be confirmed, as the coefficient is again positive and highly significant. Since the estimation results for our variables of interest are very similar in the fixed effects and system GMM approaches, we are confident that the reported coefficients show robust and unbiased results. Thus, we can conclude that radical innovation has a negative effect on objective well-being. Consequently, H1 has to be rejected.

To decompose the overall effect of radical innovation on objective well-being into a direct effect and an indirect effect, which is moderated by economic growth, we

Table 2: Results from fixed effects and GMM regressions.

	(1) Fixed Effects	(2) GMM
Dependent Variable	SPI	SPI
SPI		0.258***
		-0.0567
Radical Innovation	-0.0193*	-0.0153*
	(0.00829)	(0.00693)
Regional Inventor's Share	0.000841	-0.000433
	(0.000791)	(0.000305)
Unemployment	-0.0259	-0.0235
	(0.0392)	(0.0389)
GDP per Capita (ln)	6.243***	6.874***
	(1.255)	(1.106)
Gini-Simpson	-0.965	0.538
	(0.867)	(0.965)
Age of Population	0.878***	0.217***
	(0.127)	(0.0516)
Constant	-31.84*	-29.51*
	(12.86)	(11.78)
Euro Crisis Dummy	Yes	Yes
Region Fixed Effects	Yes	Yes
N	821	821
R^2	0.33	
AR(1)		0
AR(2)		0.766
Hansen Statistic		0.233

This table shows the results of a fixed effects regression in column (1) and a system GMM regression in column (2) using the SPI as dependent variable. A one-year time lag is applied for all independent variables.
Standard errors in parentheses, p-values in parentheses for the AR(1), AR(2),and Hansen test statistics. $* p < 0.05$, $** p < 0.01$, $*** p < 0.001$

compute the Sobel mediation test based on the "product of coefficients" approach (MacKinnon et al., 2002). This commonly used approach to mediation suggests that a variable may be considered a mediator to the extent to which it carries the influence of a focal independent variable (IV) to a given dependent variable (DV). A schematic diagram is presented in Figure 4, where the independent variable is determined by the number of radical innovations, the mediating variable is given by GDP per capita as a proxy for

economic development, and the dependent variable is represented by SPI as a measure of objective well-being.

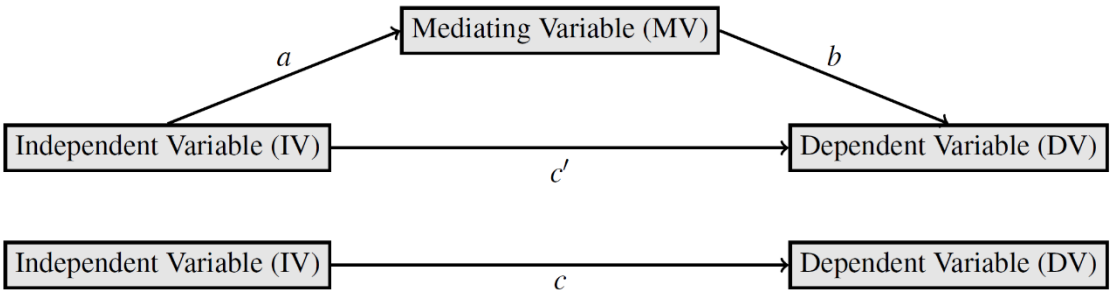

Figure 4: Mediation relations

However, the Sobel tests are known to have low statistical power. In this context, a commonly recommended solution is to use bootstrapping as a resampling method to obtain meaningful standard errors (Preacher & Hayes, 2004, 2008; Zhao et al., 2010). The bootstrapping results are shown in Table 3.

Table 3: Results from adjusted Sobel mediation test.

	(1)
Total Effect (Path *c*)	-0.0273** (0.00935)
Direct Effect (Path *c'*)	-0.0193* (0.00945)
Innovation on Economic Development (Path *a*)	-0.00133*** (0.000284)
Economic Development on OWB (Path *b*)	6.376*** (1.270)
Indirect Effect (*a*×*b*)	-0.00848*** (0.00232)
N	821

This table shows the results of a Sobel mediation test adjusted to panel data and boot- strapped with 1,000 repetitions. Paths refer to Figure 4. Standard errors in parentheses, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

The estimated mediation effect (indirect effect in Table 3, $a \times b$ in Figure 4) is negative and statistically significant. The negative sign of this coefficient means that the effect is opposite to the effect of radical innovation on objective well-being (Direct Effect in Table 3, c' in Figure 4). It suggests that the negative effect of radical innovation on

objective well-being is reduced by about 31% when including the path of economic growth. This so-called mediation effect corresponds to the share of the indirect effect in the total effect (= path $a \times b$/ path c). However, the results also reveal a (short-term) negative relation between radical innovation and economic development (path a in Figure 4), leading to a rejection of H2. We will discuss this result in Section 5. Overall, the findings point to the mediating role of economic development in the relationship between innovation and objective well-being. Hence, we can confirm H3.

5. Discussion

Our findings reveal that radical innovations have a negative direct effect on the objective well-being of regions. Consequently, we have to reject H1. Contradictory to our hypothesis, the adverse effects of radical innovation described in Section 2.2 outweigh the positive ones. While the direct relationship between innovation, especially radical innovation, and objective well-being has rarely been examined, our results tend to counter previous findings on the national level (e.g., Qureshi et al., 2020) and subjective well-being (e.g., Aghion et al., 2016; Dolan & Metcalfe, 2012). The most likely explanation for our deviating result is that, to the best of our knowledge, this study is the first that takes a differentiated look at the relationship between radical innovation and objective well-being on the regional level. For instance, Lenzi & Perucca (2020) distinguish the technology intensity of innovations but do not consider the degree of radicalness. However, radical innovations are associated with strong and far-reaching effects (Knuepling et al., 2022) and can take on a distinct role. Moreover, because objective and subjective well-being do not necessarily go hand in hand (Binder & Witt, 2011; Sen, 1987), previous findings on subjective well-being may tell only part of the story. Finally, as shown, for instance, in

Figure 3, there is a relatively high degree of regional heterogeneity, which can be easily overlooked from a national perspective.

In addition, our findings suggest that economic development is a significant mediator between radical innovation and objective well-being. According to our estimations, it mediates about 31% of the overall effect, i.e., economic development mitigates the negative influence of radical innovations on objective well-being by this amount. Therefore, we can support H3. This finding is in line with existing literature stating that innovation, in general, positively influences economic development (e.g., Pece et al., 2015; Wong et al., 2005), subsequently increasing objective well-being (e.g., Haq & Zia, 2013; OECD, 2020).

Despite this mitigating effect in the mediator role of GDP per capita, our results also show a statistically significant negative relationship between radical innovation and economic development (path *a* in Figure 4 and Table 3), which seems paradoxical at first glance. However, a reasonable explanation for this is the time horizon. Radical innovations are mostly unsuccessful in the short-term and unfold their potential and far-reaching consequences only after several years (Kaplan, 1999). In our adjusted Sobel mediation test, we apply a one-year time lag in the regression of radical innovation on GDP per capita, ignoring the long-term potential of radical innovations. Unfortunately, we cannot control for larger time lags due to the relatively short period of our data. Hence, we must reject H2 in the context of this study.

6. Conclusion

This research aimed to elucidate the previously implicit connection between innovation and well-being (Castellacci, 2023; Metcalfe, 2001) by disentangling the nuanced impacts of radical innovation on the objective well-being in regions. Based on a unique database

of 177 NUTS2 regions (including information about the multidimensional EU-Social Progress In- dex, patents, and further regional structural characteristics), we, therefore, pursue a three-step empirical approach, where the first two steps, i.e., fixed effects panel regression and dynamic panel regression (GMM), deal with the total effect of radical innovation on objective well- being. The third step decomposes the total effect into a direct and an indirect effect (mediated through GDP per capita) by applying an adapted Sobel mediation test complemented with a bootstrapping approach.

Contrary to the dominant narrative in existing literature, which often associates innovation with improved well-being, our empirical findings show a negative direct effect of radical innovation on the objective well-being in regions. Thus, while innovation may generally be beneficial, its disruptive facet can introduce complexities not previously accounted for in extant literature.

Moreover, our results underscore the mediating role of economic development. More specifically, economic development mediates about one-third of the total effect, providing a cushion against the potentially adverse effects of radical innovations on objective well-being. Intriguingly, while economic growth stands as a positive mediator, we also unearthed a statistically significant negative link between radical innovation and economic growth, which potentially requires a more prolonged temporal lens for comprehensive understanding (see Kaplan, 1999).

Nevertheless, when considering our results, it is important to address certain limitations that could serve as valuable starting points for future scientific research. First, in line with previous studies (e.g., Arant et al., 2019) we use patent data for the identification of radical innovations, which have some well-discussed drawbacks (e.g., Griliches, 1990). Future research may, therefore, consider the usage of alternative and non-patent-based data (e.g., Kinne & Lenz, 2021). In addition, while the diffusion or impact

perspective on radical innovation is argued to be most appropriate for our concrete research focus, future research could also consider radical innovations in terms of their degree of novelty, e.g., backward citations (Dahlin & Behrens, 2005). Moreover, since no individual approach is fully capable of capturing well-being (D'Urso et al., 2020; Maggino, 2016), future studies could combine our measure of objective well-being with measures of subjective well-being, e.g. life satisfaction (Castellacci, 2023)[16]. Lastly, while the complexity of well-being appears to require a multidimensional measurement approach (D'Urso et al., 2020), and composite indices offer a useful way to compromise this information (Beltrán-Esteve et al., 2023; McGillivray, 2007), especially when the overall goal is to provide a first statistically robust impression, as in our study, future studies may want to take a more nuanced look at the individual dimensions or indicators. The same is true for our patent measure, where future studies could also differentiate between the underlying technologies. Therefore, future research should further differentiate between these two aspects to extend our research and identify the underlying effect mechanisms of action more precisely.

Despite these limitations, our study contributes to the existing literature in regional and innovation research literature in several ways. First, by examining the relationship between radical innovation and objective well-being, we shed light on the often-overlooked non-economic consequences of (radical) innovation. We, therefore, enrich the previous discussion of innovation and subjective well-being (e.g., Dolan & Metcalfe, 2012) by considering objective well-being, thereby avoiding potential problems in terms of hedonic adaptation (Binder & Witt, 2014; Sen, 1987), and focusing on radical innovation, which has far more wide-ranging consequences and implications than incremental

[16] Although it could be argued or criticized that our measure of objective well-being also relies in part, especially in the opportunity dimension, on citizens' subjective perceptions Beltrán-Esteve et al. (2023).

innovation (Ahuja & Morris Lampert, 2001; Knuepling et al., 2022). Both aspects add to the previous literature that has primarily, if at all, looked at subjective well-being and innovation in general. Second, we additionally accounted for the uneven nature of (radical) innovation (e.g., Asheim et al., 2011; Audretsch & Feldman, 1996) and objective well-being across regions by using NUTS2 regions as the level of analysis. Thus, we enrich previous research at the national level (e.g., Qureshi et al., 2020) by providing a more nuanced perspective that explicitly considers regional heterogeneity. Third, we decompose the relationship between radical innovation and objective well-being into direct and indirect (i.e., mediated by economic development) effects. We, therefore, add to the previous literature in regional and innovation studies, which has largely oversimplified this relationship (Lenzi & Perucca, 2020; Tomaney, 2017).

Overall, this study contributes significantly to understanding the multifaceted relationship between innovation and well-being. By differentiating radical innovation and highlighting its (short-term) consequences, it urges policymakers, stakeholders, and researchers to adopt a more nuanced view. While radical innovations promise transformative potential, their immediate repercussions on objective well-being and economic development must be acknowledged and properly addressed.

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Appendix A: Tables

Table A1: Summary Statistics of Regression Variables.

Variable	Operationalization	Obs.	Mean	Sd	Min	Max
Objective Well-being	SPI	1,111	68.7	4.7	50.4	79.6
Radical Innovation	Top 1% cited patents	1,111	1.3	3.7	0.0	35.0
Regional Knowledge	Regional Inventor's share	1,111	306.8	469.9	0.6	3578.0
Unemployment	Regional unemployment share	1,111	8.3	5.9	1.8	36.2
Economic Development	GDP per Capita	1,090	30,215.5	10,752.3	7,100	69,200
Technological Diversity	Gini-Simpson	1,111	0.9	0.1	0.3	1.0
Age of Population	Regional median of population's age	1,111	43.1	3.0	35.4	51.5

Table A2: Correlation Matrix of Variables Included in the Regressions.

	SPI	Radical Innovation	Regional Inventor's Share	Unemploy-ment	GDP per Capita	Gini-Simpson	Age of Population
SPI	1.0000						
Radical Innovation	0.1799	1.0000					
Regional Inventor's Share	0.2423	0.5530	1.0000				
Unemployment	-0.3855	-0.1358	-0.2672	1.0000			
GDP per Capita	0.7404	0.2838	0.4647	-0.3964	1.0000		
Gini-Simpson	0.1345	0.1345	0.2649	-0.3192	0.2957	1.0000	
Age	0.0867	-0.0442	0.0390	-0.2010	0.1424	0.0783	1.0000

Table A3:

Dimension	Component	Max(utopian)/ Min(dystopian)	Indicator	Description	Geographical Level	Source
1. Basic Human Needs	1.1 Nutrition and Basic Care	0.07/0.36	Premature Mortality (<65)	Mortality rate before age 65	NUTS2	Eurostat
		0/18.1	Infant Mortality	Ratio of the number of deaths of children under one year of age during the year to the number of live births in that year. The value is expressed per 1000 live births	NUTS2	Eurostat
		0/21.6	Unmet Medical Needs	Percentage of people declaring having experienced unmet medical needs because: cannot afford (affordability) or long waiting list (efficiency) or too far (accessibility) or didn't know a good doctor (trust/quality)	NUTS2	EU-SILC
		0/68	Insufficient Food	Percentage of people declaring their inability to afford a meal with meat, chicken, fish (or vegetarian equivalent) every second day	NUTS0	EU-SILC
	1.2 Water and Sanitation	0/62	Lack of Toilet in Dwelling	Share of total population not having indoor flushing toilet for the sole use of their household	NUTS0	EU-SILC
		0/100	Uncollected Sewage	Urban wastewater not collected by collecting systems nor treated by individual or other appropriate systems as % of generated load	NUTS2	EEA
		100/0	Sewage Treatment	Urban wastewater with more stringent treatment as a percentage of collected wastewater	NUTS2	EEA
	1.3 Shelter	0/100	Burdensome Cost of Housing	Percentrage of people living in a dwelling where housing costs (mortage repayment or rent, insurance, and service charges) are a financial burden	NUTS0	EU-SILC
		0/67	Overcrowding	Percentage of people living in an overcrowded dwelling, as defined by the number of rooms available to the household, the household's size, as well as its members' ages and family situation	NUTS0	EU-SILC
	1.4 Personal Safety	0/9.49	Homicide Rate	Rate of homicides per 100 thousand inhabitants (homicide is defined as the intentional killing of a person including murder, manslaughter, euthanasia, and infanticide. It excludes death by dangerous driving, abortion, and assisted suicide)	NUTS0	Eurostat
		0/7530	Traffic Deaths	Number of road traffic accident fatalities per million inhabitants	NUTS2	Eurostat
		1/4	Safety at Night	Feeling of safety of walking alone in local area after dark (ranging from 1 [very safe] to 4 [very unsafe]). The average is calculated for each NUTS2 region	NUTS2	ESS
2. Foundations of Well-Being	2.1 Access to Basic Knowledge	1/0	Upper-Secondary Enrolment Rate	Enrolment rates of age group 12-18 in upper-secondary or post-secondary non-tertiary education (ISCED 3-4) corrected for population size (aged 15-19)	NUTS2	Eurostat
		0/84.3	Lower-Secondary Completion Only	Percentage of people aged 25 to 64 who have successfully completed at most lower secondary education (ISCED 0-2)	NUTS2	Eurostat
		0/68.1	Early School Leavers	Percentage of people aged 18-24 with at most lower secondary education (ISCED 0-2) and who were not in further education or training during the last four weeks preceding the survey	NUTS2	Eurostat
		100/0	Internet at Home	Percentage of households with access to the internet at home	NUTS2	Eurostat
		100/0	Broadband at Home	Percentage of households with broadband connection	NUTS2	Eurostat

	2.2 Access to Information and Communications	100/0	Online Interaction with Public Authorities	Percentage of individuals who used the Internet for interaction with public authorities	NUTS2	Eurostat
	2.3 Health and Wellness	86.02/71.70	Life Expectancy	Life expectancy at birth is the mean number of years that a newborn child can expect to live if subjected throughout his life to the current mortality conditions (age-specific probabilities of dying)	NUTS2	Eurostat
		1/5	General Health Status	Self-perceived general health (ranging from 1 [very good] to 5 [very bad]). The average is calculated for each NUTS2 region	NUTS2	ESS
		0/169.1	Standardized Cancer Death Rate	Standardized death rates for less than 65 years old due to cancer (code C) by 100 000 inhabitants. The standardization adjusts the death rate to a standard age distribution. The standardized death rates are calculated on the basis of a standard European population, as defined by the World Health Organization	NUTS2	Eurostat
		0/217.4	Standardized Heart Disease Death Rate	Standardized death rate for less than 65 years old due to ischaemic heart diseases (code I) by 100 000 inhabitants. The standardization adjusts the death rate to a standard age distribution. The standardized death rates are calculated on the basis of a standard European population, as defined by the World Health Organization	NUTS2	Eurostat
		10/0	State of Health Services	Perceived state of health services in country nowadays (ranging from 0 [extremely bad] to 10 [extremely good]). The average is calculated for each NUTS2 region	NUTS2	ESS
	2.4 Environmental Quality	0/107.64	Air Pollution PM2.5	Air Pollution in PM2.5 (average level in µg/m³ experienced by the population)	NUTS2	EEA & OECD
		40/0	Natura2000	Share of area covered by Natura 2000, an European Union wide network of nature protection areas established under the 1992 Habitats Directive	NUTS0	EEA
3. Opportunity	3.1 Personal Rights	10/0	Trust in the Political System	Trust in politicians (ranging from 0 [No trust at all] to 10 [Complete trust]) and Trust in country's parliament (ranging from 0 [No trust at all] to 10 [Complete trust]). The average is calculated for each NUTS2 region	NUTS2	ESS
		10/0	Trust in the Legal System	Trust in the legal system (ranging from 0 [No trust at all] to 10 [Complete trust]). The average is calculated for each NUTS2 region	NUTS2	ESS
		10/0	Trust in the Police	Trust in the police (ranging from 0 [No trust at all] to 10 [Complete trust]). The average is calculated for each NUTS2 region	NUTS2	ESS
		100/0	Quality and Accountability of Government Services	Quality of the government	NUTS2	European Quality of Institutions Index Survey
	3.2 Personal Freedom and Choice	1/5	Freedom over Life Choices	Perceived freedom to decide how to live my life (ranging from 1 [Agree strongly] to 5 [Disagree strongly]). The average is calculated for each NUTS2 region	NUTS2	ESS
		0/0.09	Teenage Pregnancy	Ratio between births from mothers 15-19 and the female population of the same age cohort	NUTS2	Eurostat
		0/53.2	Young People not in Education. Employment or Training (NEET)	Young people, aged between 15 and 24, neither in employment nor in education and training	NUTS2	Eurostat

		100/0	Corruption Index	Perceived level of corruption	NUTS2	European Quality of Institutions Index Survey
		100/0	Impartiality of Government Services	Level of impartiality of government services	NUTS2	European Quality of Institutions Index Survey
	3.3 Tolerance and Inclusion	10/0	Tolerance for Immigrants	Perceived tolerance for immigrants (based on questions (i.) whether immigration is bad or good for country's economy; (ii.) country's cultural life is undermined or enriched by immigrants; (iii.) immigrants make country worse or better place to live. Each question ranging from 0 (worst) to 10 (best). The average is calculated for each NUTS2 region	NUTS2	ESS
		0/1 (4. wave); 2/1 (5. wave)	Tolerance for Minorities	Tolerance to become neighbors if they are of a different race, migrants, homosexuals, Jews or Gypsies. Question: don't like as neighbors (…). The average is calculated for each NUTS2 region	NUTS2	EVS
		1/5	Tolerance for Homosexuals	Perceived evaluation whether gays and lesbians are free to live life as they wish (ranging from 1 [Agree strongly] to 5 [Disagree strongly]). The average is calculated for each NUTS2 region	NUTS2	ESS
		0/58.5	Gender Employment Gap	Difference between female and male employment rates	NUTS2	Eurostat
		65.8/0	Community Safety Net	Impact of social transfers (excluding pensions) on poverty reduction	NUTS0	Eurostat
	3.4 Access to Advanced Education	74.7/0	Tertiary Education Attainment	Percentage of population aged 25-64 with tertiary education (ISCED 5-8) attainment.	NUTS2	Eurostat
		9.7/0	Tertiary Enrolment	Ratio of tertiary students (ISCED 5-6) to the total population.	NUTS2	Eurostat
		36.2/0	Lifelong Learning	Percentage of persons aged 25 to 64 who stated that they received education or training in the four weeks preceding the survey with respect to the total population of the same age	NUTS2	Eurostat

Table A4: Test for Reverse Causality.

	(1) Radical Innovation
SPI	-0.0462 (0.0822)
Regional Inventor's Share	-0.0112** (0.00356)
Unemployment	0.0342 (0.0576)
GDP per Capita (ln)	-1.168 (2.122)
Gini-Simpson	-0.588 (1.326)
Age of Population	0.739** (0.258)
Constant	-12.27 (23.95)
Euro Crisis Dummy	Yes
Region Fixed Effects	Yes
N	821
R^2	0.33

This table shows the results of a fixed effects regres- sion using Radical Innovations as dependent variable. A one-year time lag is applied for all independent variables.
Standard errors in parentheses, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$

Appendix B: Figures

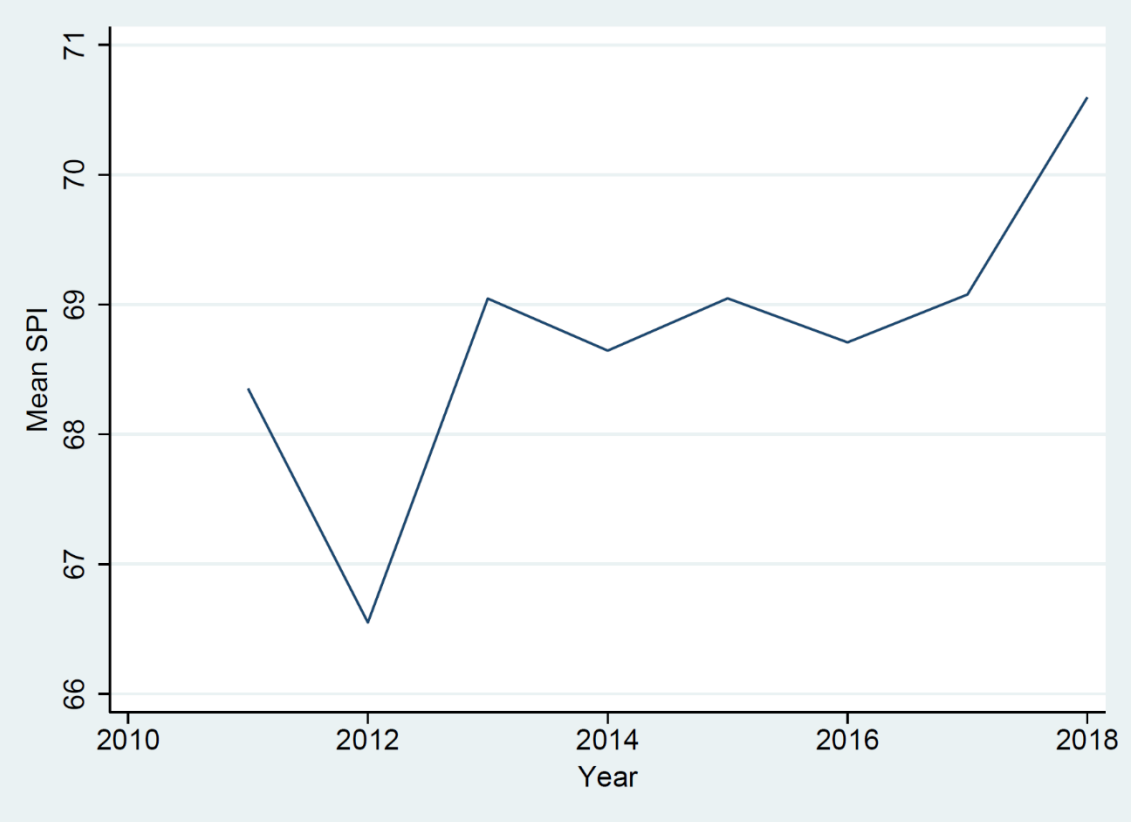

Figure B1: The average development of the SPI across all regions from 2011-2018.

Appendix C: Scree Plots

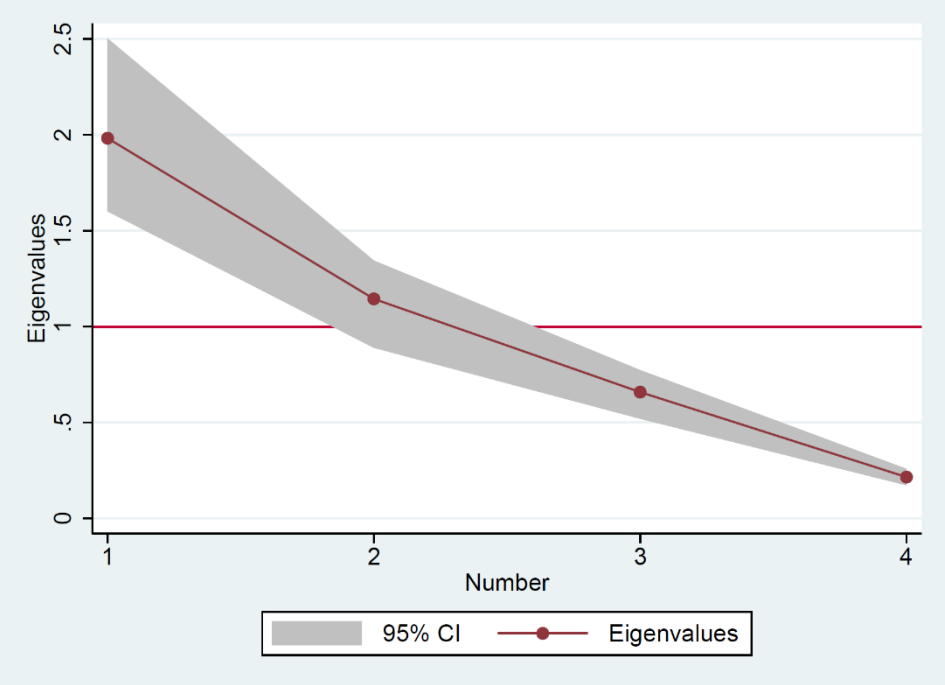

Figure C1: Indicators of component "Nutrition and Basic Medical Care" (Scree plot of eigenvalues)

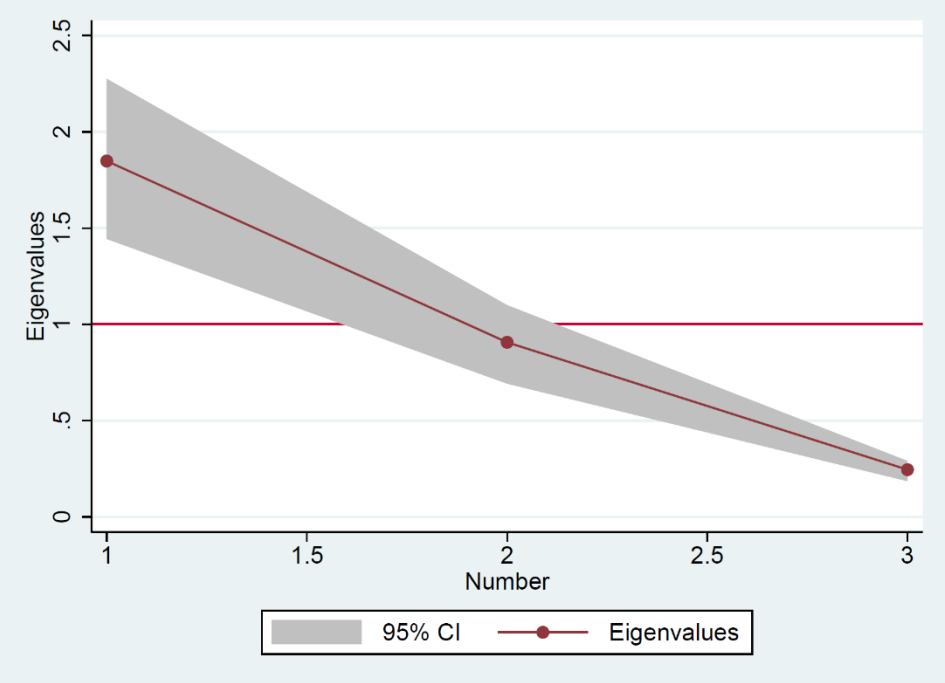

Figure C2: Indicators of component "Water and Sanitation" (Scree plot of eigenvalues)

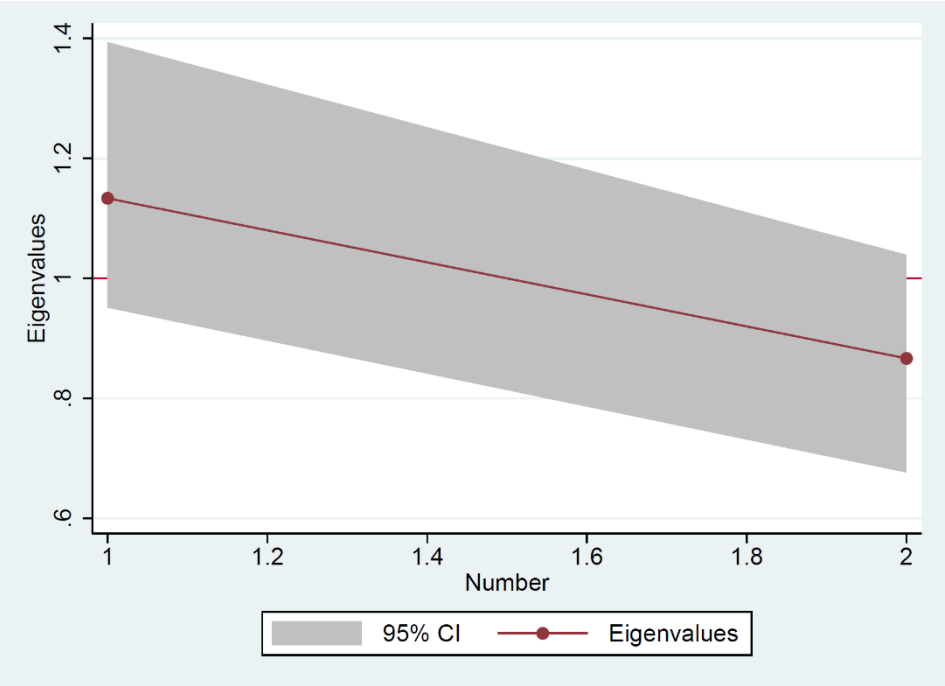

Figure C3: Indicators of component "Shelter" (Scree plot of eigenvalues)

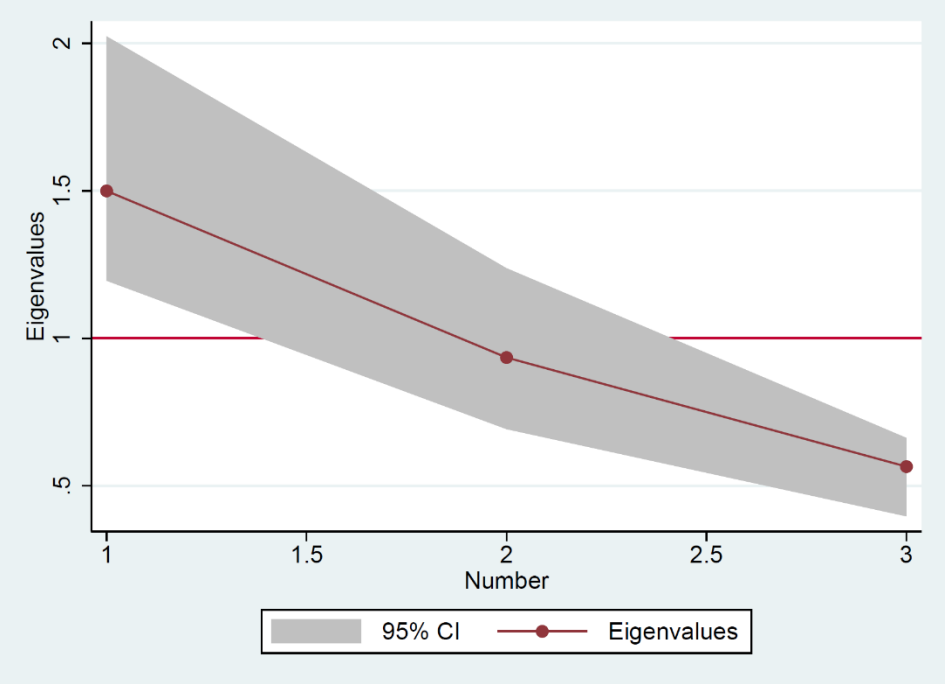

Figure C4: Indicators of component "Personal Safety" (Scree plot of eigenvalues)

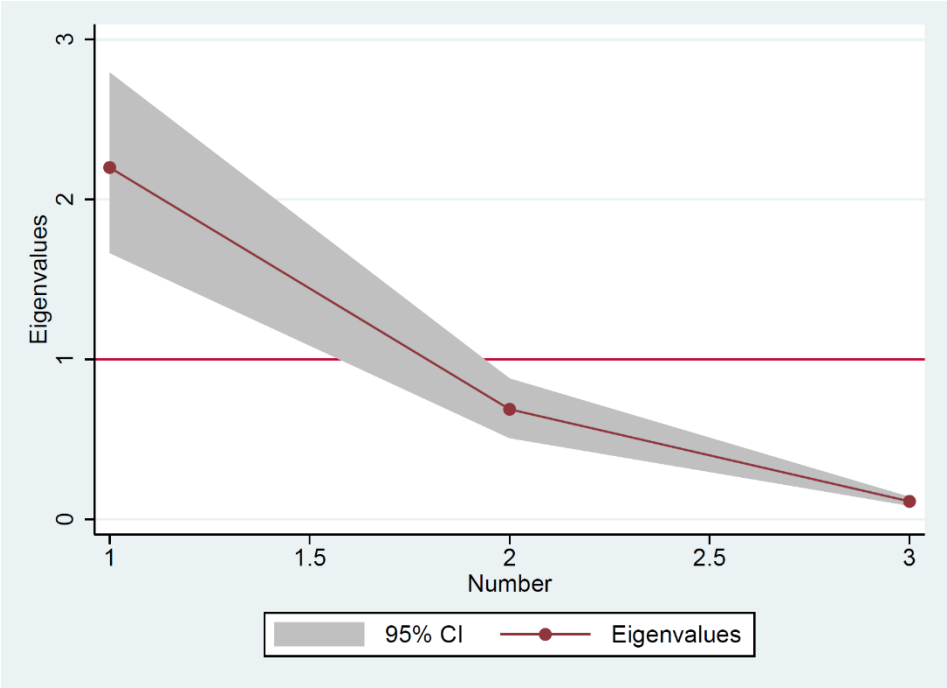

Figure C5: Indicators of component "Access to Basic Knowledge" (Scree plot of eigenvalues)

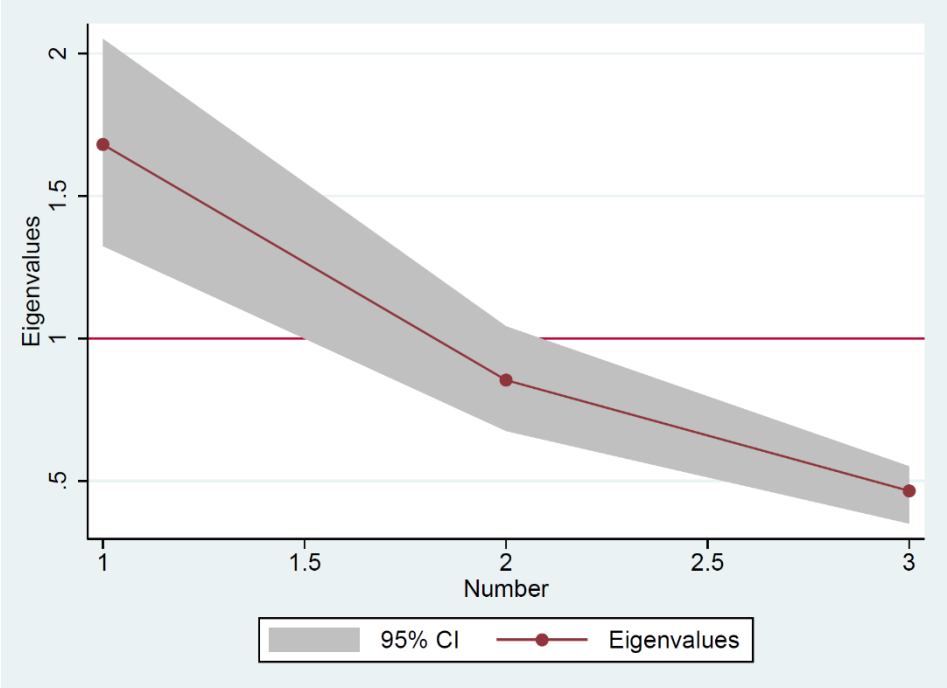

Figure C6: Indicators of component "Access to Information and Communications" (Scree plot of eigenvalues)

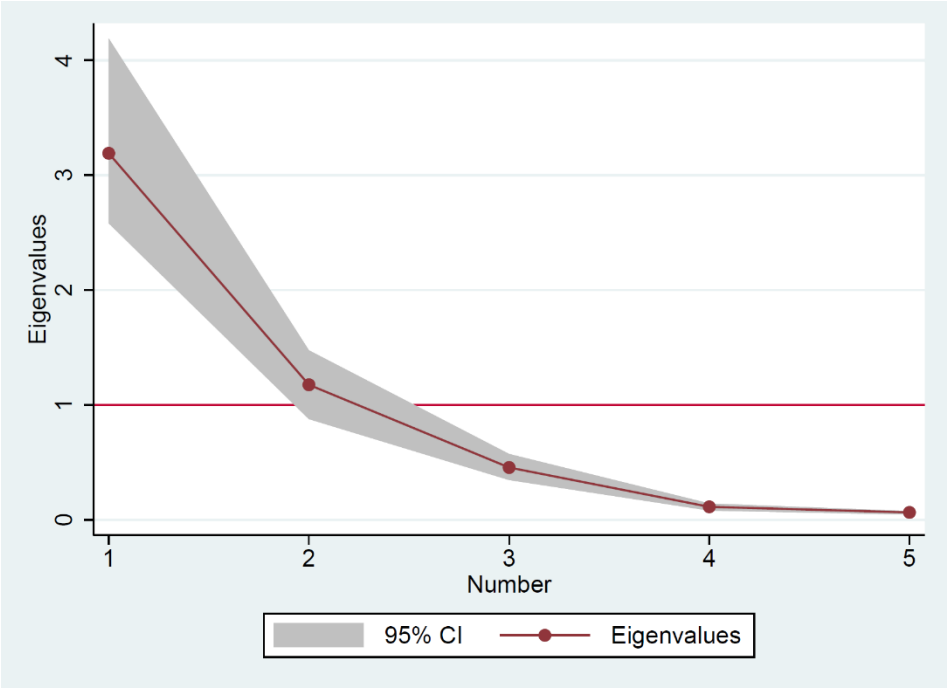

Figure C7: Indicators of component "Health and Wellness" (Scree plot of eigenvalues)

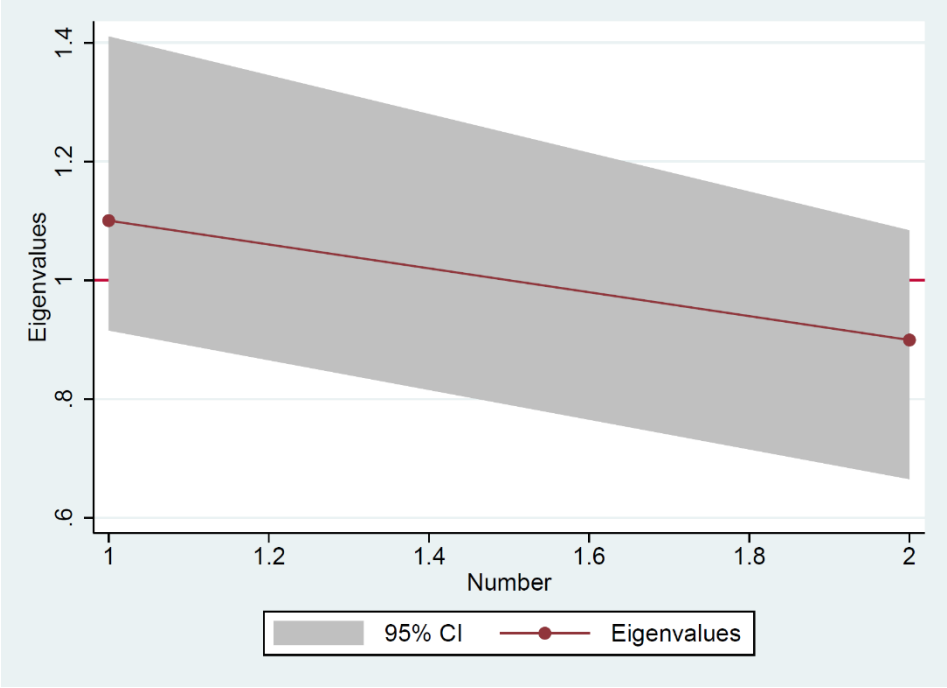

Figure C8: Indicators of component "Environmental Quality" (Scree plot of eigenvalues)

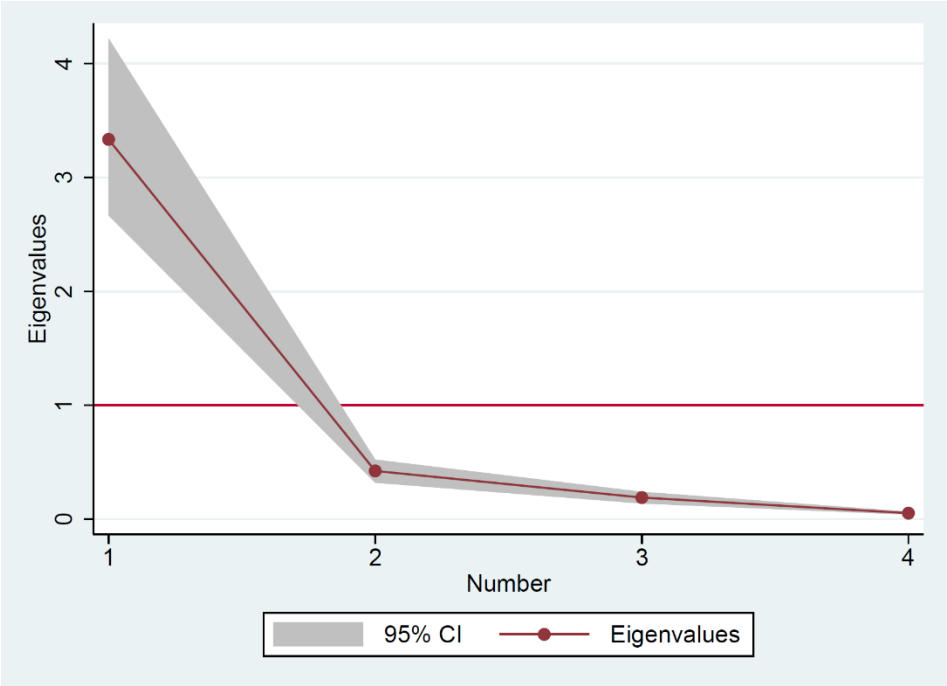

Figure C9: Indicators of component "Personal Rights" (Scree plot of eigenvalues)

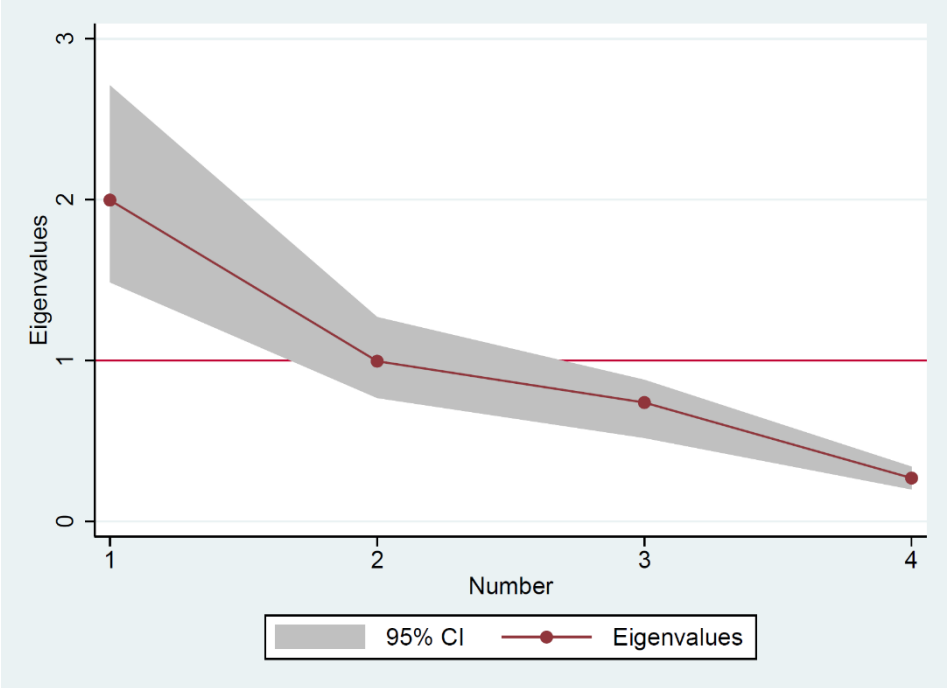

Figure C10: Indicators of component "Personal Freedom and Choice" (Scree plot of eigenvalues)

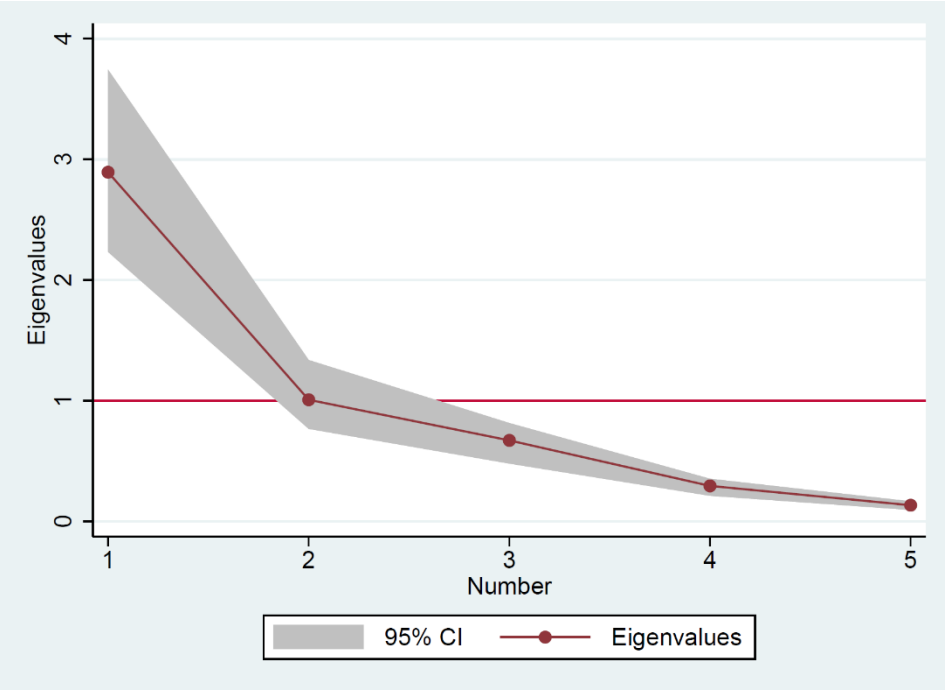

Figure C11: Indicators of component "Tolerance and Inclusion" (Scree plot of eigenvalues)

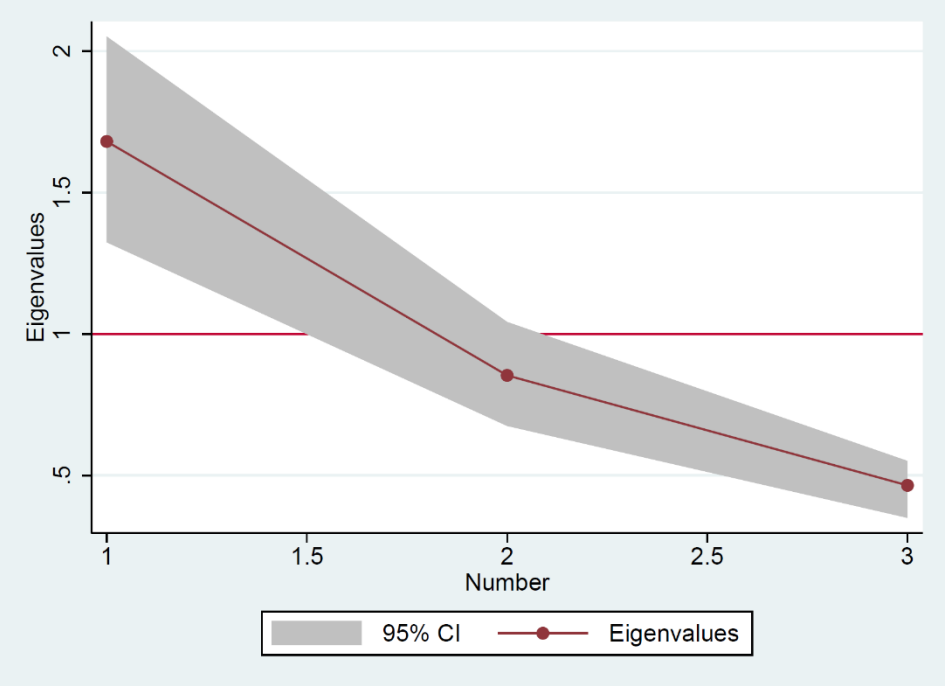

Figure C12: Indicators of component "Access to Advanced Education" (Scree plot of eigenvalues)

V. Article 4: Bridging the Gap: A Scalable Approach to Measuring Regional Social Innovation Capacities

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Status: Submitted to *Research Policy*

Abstract

Economic growth paradigms have evolved to encompass technological innovations and inclusive societal and environmental goals. Despite the recognized importance of social innovations in achieving these objectives, measuring social innovation remains challenging due to its multifaceted nature and regional specifics. This paper addresses the issue of measuring social innovation by focusing on the inputs for social innovation, i.e., social innovation capacities. Aiming at the combination of regional specificity and scalability, we construct an index that incorporates multiple dimensions of social innovation capacities and provide detailed explanations of the dimensions and calculations. Externally validated, our approach fills a significant research gap. Our paper contributes to the literature by providing a measure for social innovation that combines detailed regional data with national metrics, paving the way for a more robust measure applicable to different contexts and countries. Hence, it allows for zooming out from locally embedded initiatives, broadening the focus to regional and national social innovation ecosystems and enabling manifold empirical work on social innovation. The paper concludes with a discussion of the implications and future research directions.

1. Introduction

In the past years, the policy focus shifted from pure economic growth, driven by technological innovations, to more inclusive development, considering societal and environmental challenges (Kuhlmann & Rip, 2014). Since social innovations are perceived as the silver bullet to cope with these challenges (Nicholls et al., 2015), they seem decisive in this process. However, whereas technological innovations are well-established and shape the landscapes of private companies (Audretsch et al., 2014; Nathan & Rosso, 2022) and higher education institutions (Cunningham et al., 2019, 2021), social innovations are primarily implemented and promoted by non-profit organizations (Butzin & Terstriep, 2018). A possible explanation may be that the social outcomes of profit-oriented firms or higher education institutions must be sufficiently rewarded by their respective stakeholders to create sufficient incentives for social innovation activities (Carl & Menter, 2021). However, the prevalent incentive structures may suffer from the lack of salience of social outcomes to stakeholders, rooted in a missing convincing measure (Mihci, 2020).

Measuring social innovations can be challenging due to their complex and multifaceted nature, making identifying and measuring their impacts difficult. Further, social innovations involve creating societal change, which can be challenging to quantify (Cunha et al., 2022). Additionally, social innovations are highly context-dependent, as they are often strongly regionally embedded but also driven by specific values and goals, such as social justice or environmental sustainability, making it difficult to generalize the impact of social innovation projects (Terstriep et al., 2020).

A significant part of existing measures on social innovations aims to evaluate the outcome of specific projects or initiatives (Cunha et al., 2022). Other attempts examine the social innovation outcomes in a particular region (such as IndiSI+[1]). These approaches

[1] https://www.si-metrics.eu/

have been valid and fruitful in exploring and understanding social innovation processes and defining local social innovation actors. However, they have the problem of not being scalable – or at least with enormous effort. On the other end of the spectrum, some projects, such as the "Atlas of Social Innovation,"[2] apply a large-scale approach of counting and mapping social innovation initiatives but lack detailed regional or initiative-level information.

In this paper, we address this challenge by developing an approach to measuring social innovation that is both detailed on a regional level and scalable. For this purpose, we construct an index capturing the regional social innovation capacities. The concept of innovation capacities is well-established in the technological innovation literature (e.g., Furman et al., 2002) but not yet developed in the context of social innovation. Following the literature on technological innovation, we define regional social innovation capacities as a region's persistent ability to develop and implement social innovations. Further, we externally validate this index using data from the "Atlas of Social Innovation."

This paper contributes to the literature by conceptualizing a new measuring approach that may serve as the next step toward a robust measure for social innovations applicable to different contexts and countries. By making social innovations more visible, it provides incentives for policymakers and local authorities to engage in social innovations. Making social innovations measurable at a large scale further contributes to the social innovation research field by broadening the focus from region-specific approaches to broader social innovation ecosystems, trans-local networks, and hegemonic socio-political contexts (Moulaert & MacCallum, 2019). Moreover, the measurability enables bridging the gap between the differing social innovation scholarships, such as social economy, social studies, urban/ community development, and innovation studies, by making

[2] https://www.socialinnovationatlas.net/

the capacities for social innovation tangible and comparable across fields (Pel et al., 2020). Hence, this paper contributes toward unifying the field and addresses the urgent call to bring the field forward (Cajaiba-Santana, 2014).

The remainder of this paper is structured as follows. Section 2 outlines the existing literature on social innovation and its measurement and demonstrates the research gap this paper addresses. Section 3 describes the data we used to calculate our index and gives detailed information on the dimensions of the index and its sub-indices. Section 4 presents our findings and outlines our validation approach. Section 5 discusses the results and their implications. Finally, Section 6 concludes the paper.

2. Extant Literature & Research Gap

2.1 The current state of social innovation research

The expansive trend in innovation literature, which now delves into innovative phenomena beyond the classic focus on new technologies and products (Giuliani, 2018; Kuhlmann & Rip, 2014), induces a growing academic interest in social innovations (Pel et al., 2020). This manifests, among others, in entering innovation journals (van der Have & Rubalcaba, 2016) and increased interest from policymakers (Fougère et al., 2017). However, social innovation is still a fuzzy concept suffering from ambiguities in the literature (Mihci, 2020; van der Have & Rubalcaba, 2016). For example, Moulaert & MacCallum (2019) state that there is an Anglo-American entrepreneurship tradition and a European-Canadian social economy tradition. Both schools are, subsequently, theoretically diverse and cover various aspects from differing perspectives. Mapping the results of a comprehensive and systematic literature review, Edwards-Schachter & Wallace (2017) found that social innovations are shaped by three interrelated strands of literature: processes of social change, sustainable development, and the services sector. They further

state that social innovations differ by the actors involved in the process. A crucial question that is not yet clarified is whether social innovations differ utterly from technological innovations (e.g., Howaldt & Schwarz, 2010) or if these innovation types overlap (e.g., Pol & Ville, 2009).

These issues and open questions in the field lead to the situation that there is no commonly agreed definition, despite significant efforts that have been made (Edwards-Schachter & Wallace, 2017; Pol & Ville, 2009). For this paper, we use the definition of Caulier-Grice et al. (2012, p. 12):

> *"Social innovations are new solutions (products, services, models, markets, processes, etc.) that simultaneously meet a social need (more effectively than existing solutions) and lead to new or improved capabilities and relationships and better use of assets and resources. In other words, social innovations are both good for society and enhance society's capacity to act."*

Despite the described dissent in social innovation research, the existing literature made several findings about social innovation processes, the actors involved, and the drivers of social innovation (e.g., Howaldt et al., 2018; Lettice & Parekh, 2010; Mulgan, 2021). One decisive aspect is the regional context (MacCallum et al., 2016; Terstriep et al., 2020). Regional framework conditions, primarily depicted by political governance and financial resources, are essential to inducing and facilitating sustainable social innovations (Bund et al., 2015; Galego et al., 2022). Political and economic stability contributes to enabling social innovation by its direct support (Moulaert et al., 2007). Further, it frees the individual's capacities by providing personal safety for the respective population (Schumann & Kuchinke, 2020). Additionally, education is found to be another structural key indicator (Bund et al., 2015) since it equips individuals with the ability to think creatively and discover innovative solutions to prevalent issues (Elvira et al., 2015).

Another highly relevant dimension highlighted by the literature is the ability to address unmet needs, find innovative solutions, and, finally, implement these solutions. For instance, Unceta et al. (2016, p. 197) highlight the "capacities to convert and exploit knowledge," i.e., the ability to create innovations. These abilities are often reported as entrepreneurial capabilities (e.g., Bund et al., 2015). This demonstrates the significant overlap between technological and social innovation and shows that similar competencies are needed to successfully innovate in both types (Bulut et al., 2013; Krlev et al., 2014; Pol & Ville, 2009). Consequently, indicators that are well-known from the technological innovation literature, such as knowledge flows, knowledge stock, or entrepreneurial activities (e.g., Roper & Hewitt-Dundas, 2015), significantly influence the social innovation process as well.

However, there are, apparently, still significant differences between technological and social innovation. These differences are primarily rooted in differing actors (Edwards-Schachter & Wallace, 2017) and the goal to address social needs instead of market gaps (Bund et al., 2015; Pol & Ville, 2009). Consequently, another key dimension of social innovation is the awareness of social needs and the willingness to address them (Kleverbeck et al., 2019). This is often perceived as the starting point of social innovation (Carl, 2020; Mulgan, 2006). The ability to recognize unmet social needs and the intention to address them is, thus, essential to social innovation (Murray et al., 2010).

2.2 Measurement of social innovation

In the literature on measuring social innovations, there is extensive agreement that the multifaceted and complex nature of social innovations must be captured (Cunha & Benneworth, 2020; Kleverbeck et al., 2019). It is unlikely that a single variable can serve as an adequate proxy for social innovations, such as patents for technological innovations. To

represent social innovation in all its complexity, the awareness of social issues, the intention to act, and the ability to act must be captured (Kleverbeck et al., 2019).

Several attempts have been made to measure social innovation in recent years, e.g., the RESINDEX by Unceta et al. (2016), the TEPSIE project[3], the IndiSI+, and the Atlas of Social Innovation. Additionally, there is much theoretical literature on how to measure social innovations (e.g., Bund et al., 2015; Cunha & Benneworth, 2020; Krlev et al., 2014) and on evaluating existing measuring approaches (e.g., Cunha et al., 2022; Mihci, 2020).

As described above, one major problem of the literature is that the rapidly growing field of social innovation suffers from ambiguities and fuzziness in the literature (Mihci, 2020). Apart from the various streams of social innovation research, this is also due to the complexity and multifacetedness that can be embedded in a change in social practices and traditional innovation outcomes (Edwards-Schachter & Wallace, 2017). When measuring social innovations, this complexity results in the additional challenge of keeping the measure as simple as possible without losing the main pattern (Mihci, 2020). This is highly challenging as social innovations have unique characteristics, such as improving societal outcomes and well-being, which are difficult to materialize and capture in measurements.

Moreover, a shortcoming of existing social innovation measures, such as the RESINDEX by Unceta et al. (2016), is that it consists of multiple questionnaires given to numerous actors in the respective region. This approach obtained valid results in the investigated region and contributed to understanding social innovation processes by examining them in detail. However, these approaches cannot be upscaled, leading to a lack of comparability and, thus, restricted informative value for other countries and regions.

[3] https://www.youngfoundation.org/

Other approaches, such as the Atlas of Social Innovation or the European Cluster Collaboration Platform[4], are mainly based on self-subscription. Those approaches are increasing their numbers year by year and might be valid to represent the numbers of social innovations in the future. However, these approaches currently suffer from relatively low subscription numbers and are, hence, not (yet) representative, especially on a regional level.

To overcome these shortcomings, existing measures, metrics, and concepts in social innovation need to be further developed (Cunha et al., 2022). A concept that reveals such potential is social innovation capacities. It is a frequently applied aspect of several approaches to measuring social innovation (Bund et al., 2015; Economist Intelligence Unit, 2016; Krlev et al., 2014; TEPSIE, 2014; Unceta et al., 2016), but is not yet worked out in detail. Implicitly, this concept is built on the similarities between social and technological innovations (Bulut et al., 2013; Bund et al., 2015). Regarding technological innovations, the concept of innovation capacities is well-established on the firm level (Cantner et al., 2010; Koc & Ceylan, 2007) but also on the regional and national levels (Furman et al., 2002; Novillo-Villegas et al., 2022; Porter & Stern, 2001). It depicts the ability to "produce and commercialize a flow of new-to-the-world technologies over the long term. [It] is not the realized level of innovative output per se but reflects more fundamental determinants of the innovation process" (Furman et al., 2002, p. 900). Analogously, social innovation capacities are considered as the persistent ability to develop and implement social innovations.

Without paying attention to the theoretical foundation, the Economist Intelligence Unit (2016) applied this approach to social innovation, creating a social innovation index depicting the social innovation capacities of 45 countries. While delivering fruitful comparisons of the framework conditions between numerous countries, this approach fails to

[4] https://reporting.clustercollaboration.eu/

pay attention to the regional context. In conclusion, there is a literature gap in meaningful scalable approaches reflecting the regional level simultaneously. We aim to address this gap and ensure scalability and reproducibility, following the suggestion by Mihci (2020) to use data from trusted institutions that are readily available. Applying social innovation capacities as the basis, this study should be seen as a step toward a robust measure of social innovations. By bridging the gap between local and national measures, it addresses calls for approaches to overcome current barriers to measuring social innovation and its impact (Cunha et al., 2022).

3. Methodological Approach

To meet the requirement of capturing the whole complexity of social innovations, we create an index including three dimensions that aim to capture the aspects considered to be relevant by the existing literature (Bund et al., 2013; Bund et al., 2015; Kleverbeck et al., 2019; Krlev et al., 2014; TEPSIE, 2014; Unceta et al., 2016, among others). Notably, our approach targets measuring social innovation capacities since social innovations can only be measured by counting realized social innovations. This would, however, be very cumbersome and contradict our goal to provide a scalable measure for social innovations. As already explained, the concept of innovation capacities is well-established for technological innovations but lacks a theoretical foundation in the context of social innovation. Based on the literature on technological innovation, we define social innovation capacities analogously as the persistent ability to develop and implement social innovations. Even though social innovation capacities may be influenced by the output dimension (Bund et al., 2013), they do not reflect the realized level of social innovation but refer to more primal determinants of the social innovation process.

In the context of technological innovations, innovation capacities demonstrate a high correlation with traditional innovation measures, such as patents. Further, other well-known indicators induced by successful innovation, e.g., competitiveness or GDP, also show statistically significant correlations. These correlations were found in different countries and contexts, demonstrating the high robustness of the measuring approach based on innovation capacities and further showing that this approach is an effective way of measuring technological innovation (Furman et al., 2002; Oura et al., 2016; Porter & Stern, 2001). Considering the interrelatedness of technological and social innovation (Bulut et al., 2013), we allow for an overlap between the two types of innovation. Based on this evidence of the explanatory power of innovation capacities, we pursue an analogous approach to measure social innovation based on regional social innovation capacities. We hence call our index the Social Innovation Capacities Index (SICI).

3.1 Data

One primary source of our data is the German Socio-Economic Panel (SOEP), a large and long-running multidisciplinary household survey representative of German households. Individuals are asked annually about their economic situation, concerns, attitudes, behavior, etc. This survey is, hence, exceptionally well-suited to capture the awareness of social issues. The second significant data source is the German Statistical Office, which provides extensive administrative data, such as public expenditure, the amount of public staff, or the GDP per capita.

Data on innovation indicators, such as the start-up rate or the regional competitiveness of essential industries for the future (e.g., IT, optics, solar technology), are drawn from the IAB Establishment Panel. Finally, we gathered patent data from the OECD REGPAT database and complemented the data with some hand-collected variables.

Overall, we constructed a large data set comprising consistent data from 1996 to 2018 at a regional level represented by regional planning areas ("Raumordnungsregionen"; RORs). RORs are large, functionally delimited spatial units for federal spatial planning reporting. They comprise German NUTS 3 regions but are smaller than NUTS 2 regions. There are 96 RORs in Germany, all covered by our data.

3.2 The dimensions of the social innovation capacities index

Existing literature on measuring social innovation found various aspects to be relevant that slightly differ depending on the focus of the respective work (e.g., Bund et al., 2013; Bund et al., 2015; Kleverbeck et al., 2019; Krlev et al., 2014; Unceta et al., 2016). Abstracting from this, three dimensions demonstrate overarching relevance. The first dimension reflects the framework conditions, constituted by the most critical enablers of the social innovation process that stimulate the creation of social innovation (Bund et al., 2013). These conditions are depicted by the resources, societal, political, and institutional framework (Krlev et al., 2014).

Entrepreneurial and innovative activities and abilities reflect the second dimension. They "can be best understood as types of actions taken, which are motivated by entrepreneurial preferences or motivations" (Bund et al., 2013, p. 31) and include traditional elements from the entrepreneurship and innovation literature, including pro-activeness, risk-taking, problem-solving, and implementing ideas (TEPSIE, 2014), and absorptive capacities or, more generally, abilities that are required to transfer knowledge to innovations (Unceta et al., 2016).

The third dimension represents the awareness of social needs and the willingness to address them. This can be seen as a prerequisite for social engagement (Carl & Menter,

2021) and, hence, is frequently perceived as a starting point of social innovation processes (Carl, 2020; Mulgan, 2006, 2019).

Overall, we align with the suggestions made by the conceptual literature on measuring social innovation. Taking these suggestions into account, we developed the SICI with three sub-indices: (1) Regional Framework Conditions, (2) Entrepreneurship & Innovation, and (3) Social Awareness & Engagement. These dimensions will be presented in detail below. Additionally, Table 1 provides a comprehensive breakdown of the sub-indices, including their components, how they have been put into practice, the source of the data, and the research that supports their significance in the realm of social innovation.

Table 1: Overview of the Social Innovation Index

		Element	Operationalization	Data Origin	Significance for Social Innovation Supported by
Social Innovation Capacities Index	Regional Framework Conditions	Political Determinants	Total Public Expenditure	German Statistical Office	Moulaert (2016); Moulaert et al. (2005); de Souza João-Roland & Granados (2020)
			Public Staff per 1000 Habitants	German Statistical Office	Moulaert (2016); Lukesch et al. (2020); Moulaert & Nussbaumer (2005)
		Economic Determinants	Wealth (GDP per Capita)	German Statistical Office	Akgüç (2022); Wilkinson & Pickett (2009)
			Economic Sustainability (Competitiveness of Essential Industries)	IAB Establishment Panel	Akgüç (2022)
			Job Perspectives (Self-Reported Answers on this Topic)	SOEP	Wilkinson & Pickett (2009)
		Education	Average Number of Years of Education in the Region	SOEP	Harrison et al. (2007); Elvira et al. (2015)
	Entrepreneurship & Innovation	Knowledge Stock	Number of Patents	OECD REGPAT	Roper & Hewitt-Dundas (2015)
			Number of Social Innovation Related Publications from Universities of the Region	Scopus	Howaldt et al. (2016a)
		Knowledge Flows	R&D Employees per Employee	IAB Establishment Panel	Sánchez de la Vega et al. (2019)
		Entrepreneurial activities	Entrepreneurial Mindset (Self-Reported Answers on this Topic)	SOEP	Obschonka (2017); Danish et al. (2019)
			Number of Start-Ups per Employee	German Social Insurance Statistics	Bulut et al. (2013); Bund et al. (2013)
	Social Awareness & Engagement	Social awareness	Dissatisfaction (Self-Reported Answers on this Topic)	SOEP	Dawson & Daniel (2010); Rohrer et al. (2021)
			Pro-Social Attitudes (Self-Reported Answers on this Topic)	SOEP	Tilman et al. (2019); Dixit & Levin (2017)
		Social Engagement	Volunteerism (Self-Reported Answers on this Topic)	SOEP	de Wit et al. (2019); Cravens (2014); Metcalf (2010)
			Political Engagement (Self-Reported Answers on this Topic)	SOEP	Galego et al. (2022); de Wit et al. (2019)

Notes: This table provides an overview of the sub-indices and elements of the SICI. For more information about the items drawn from the SOEP, please see Appendix 1.

3.2.1 Regional Framework Conditions

It is an "indisputable fact that social innovation activities mostly arise in a local context and often remain embedded in situ" (Terstriep et al., 2020, p. 2) and pointed out by numerous studies (Howaldt et al., 2016b; Nicolopoulou et al., 2017; Unceta et al., 2022, among others). Regional framework conditions are essential in inducing and facilitating social innovation, whereby political governance, economic determinants, and education are the key dimensions (Akgüç, 2022; Kleverbeck et al., 2019; Moulaert et al., 2005).

The political climate of a region can significantly influence the level of support for social innovation initiatives (Akgüç, 2022; de Souza João-Roland & Granados, 2020; Lukesch et al., 2020). Regions with stable political environments and explicit social innovation governance, including bottom-up approaches, may be more conducive to successful social innovation initiatives and foster regional development (Galego et al., 2022; Moulaert et al., 2005; Moulaert, 2016; Moulaert & Nussbaumer, 2005). As indicators for political context, we apply the total public spending per habitant on the municipal level complemented by public employees per 1000 inhabitants. This data is drawn from the German Statistical Office and reflects that regions with higher public spending are more likely to invest in social programs, education, and infrastructure. Such areas have a more extensive public workforce to deliver these services.

The second dimension of this sub-index is economic determinants. Regional wealth is a significant influencing factor in social innovation (Akgüç, 2022). It can influence policies since income positively correlates with voting behavior (Kasara & Suryanarayan, 2015). Additionally, it is likely to increase the public budget and, hence, the public spending for social innovation policies. Further, higher-income individuals may have more resources to engage in social activities, leading to more social innovation initiatives, volunteerism, and political engagement (Wilson, 2012). Moreover, wealth and

education are correlated. Education subsequently increases the awareness of social innovation and the ability to find creative solutions and, thus, is likely to affect the amount and quality of social innovations positively (Elvira et al., 2015). The same may be true for other determinants that are affected by wealth and might impact social innovation, such as health or various norms and attitudes. However, wealth may also negatively impact social innovations since wealthy people are less likely to be affected by social problems (Wilkinson & Pickett, 2009). Consequently, they are less aware of such issues, decreasing engagement in social innovation. We yet assume that the positive aspects of regional wealth predominate (see Akgüç, 2022). Hence, we include local wealth as a factor of the sub-index with a positive sign.

We capture regional wealth by GDP per capita. However, since GDP does not exclusively explain the mechanisms described, we add job perspectives and economic sustainability. Both indicators aim at capturing safety for the current and future individual financial situation. This safety may lead to fewer concerns about the future (Schumann & Kuchinke, 2020), freeing resources to care about societal problems. Consequently, people with higher personal safety tend to have more capacities for social innovation. Job perspectives are drawn from the SOEP, where the respondents are asked about their opportunities in the job market. To operationalize economic sustainability, we use data from the IAB Establishment Panel that reflects the regional competitiveness of essential industries, especially high-tech and knowledge-intensive sectors.

As a final component for this sub-index, we apply the regional education level measured by the average years of education among the population (as reported in the SOEP). Education is found to be a crucial enabler of social innovation (Akgüç, 2022; Krlev et al., 2014). It provides a deeper understanding of the causes and effects of social inequality (Harrison et al., 2007). Thus, education will likely increase awareness of social

problems, leading to more social activities (Carl & Menter, 2021). However, it can also present alternative solutions to societal problems, which can help resolve existing social issues. Further, education empowers people to think outside the box and find new, creative solutions to existing problems (Elvira et al., 2015). Thus, education increases not only the number of social activities but also their quality.

3.2.2 Entrepreneurship & Innovation

The second sub-index targets capturing a region's ability to create innovation, i.e., to transfer knowledge to innovative solutions that address existing problems. This sub-index is strongly related to the ability to act, as described by Kleverbeck et al. (2019). To reflect this substantial ability, we cover the aspects of knowledge flows, knowledge stock, and entrepreneurial activities.

The knowledge stock can be seen as potential opportunities that can be transferred to innovative solutions (Acs et al., 2013). It is, thus, the prerequisite for innovation processes and is found to be essential in a regional context (Audretsch & Lehmann, 2005). We capture the knowledge stock by the number of patents drawn from the OECD REGPAT database. While there are possible shortcomings encountered in utilizing patents as an indicator of innovation, the amount of patents is well-suited to reflect a region's knowledge stock (Roper & Hewitt-Dundas, 2015). Further, to capture the specific knowledge stock for the context of social innovation, we complement the patent data with the number of scientific publications related to social innovations obtained from Scopus data.

Knowledge flows are also essential to exploit the knowledge stock (Acs et al., 2009). They refer to the knowledge that spills over from institutions that create and accumulate knowledge, i.e., primary universities and other research institutes. Subsequently,

private actors absorb and exploit this knowledge to seize opportunities and find innovative solutions to unmet needs (Acs et al., 2013). Since human capital reflects a major part of knowledge flows (Faggian & McCann, 2006), we capture knowledge flows by the share of R&D employees among the regional workforce. This data is drawn from the IAB Establishment Panel.

The final dimension of this sub-index is given by entrepreneurial activities, which are perceived as a significant component in social innovation measurement (Bund et al., 2013). An entrepreneurial mindset that implies pro-activeness, risk-taking, problem-solving, and putting ideas into practice suggests a high willingness to pursue innovative solutions, i.e., a significant intention to act given an observed social need. Further innovative behavior frequently induces change beyond technological consequences (Danish et al., 2019; Obschonka, 2017). Referring to Kleverbeck et al. (2019), entrepreneurial activities capture an essential part of the ability to act and include aspects of the intention to act. In our index, we capture this by the entrepreneurial mindset in the population, depicted by several self-reported individual traits from the SOEP data, such as risk-taking, creativity, openness, stress resistance, or thirst for knowledge. We calculate the mean of these traits among the regional population to capture the regional mindset for innovative behavior. To extend the explanatory power, we include the regional start-up rate related to the workforce in this sub-index. A high start-up rate demonstrates a region's ability to exploit and transfer knowledge to innovative solutions (Audretsch & Lehmann, 2005).

3.2.3 Social Awareness & Engagement

The third sub-index captures social awareness and engagement within a region. Social awareness, i.e., the ability to recognize unmet social needs, is a key factor in social innovation (Murray et al., 2010). We use pro-social attitudes in the population to capture this

awareness. Pro-social individuals often possess a heightened awareness of social issues and needs in their residential regions. They are more likely to observe and understand the challenges faced by others, especially marginalized groups or individuals. This empathetic perspective enables them to identify gaps in existing systems or services and recognize opportunities for innovation (Humphrey, 2013). Further, pro-social attitudes highlight empathy, which is the ability to understand and share the feelings of others. This empathetic understanding helps generate innovative solutions that directly address the needs and aspirations of the community, resulting in more effective and sustainable social innovations (Montonen et al., 2014). Moreover, pro-social attitudes add to channel scientific knowledge towards fruitful contributions to society, helping exploit a region's innovative potential (Iorio et al., 2017). They are, consequently, adequate to reflect the role of social awareness in the social innovation process.

To comprehensively capture social awareness, we complement the pro-social attitudes with dissatisfaction. Dissatisfaction is highly correlated with worries and concerns and can, therefore, be seen as an observation of a social need (see Rohrer et al., 2021). Consequently, dissatisfaction is a key driver in developing and applying new ideas to solving problems and improving social conditions, i.e., inducing social innovation (Dawson & Daniel, 2010). We operationalize pro-social attitudes and dissatisfaction with several items from the SOEP (see Appendix 1 for more detailed information).

To capture engagement, the second dimension of this sub-index, we consider volunteerism and political engagement. Both can profoundly influence social innovation (de Wit et al., 2019). Volunteers often work closely with communities and individuals affected by social issues. Their hands-on experience provides valuable grassroots insights into the challenges faced and the community’s needs. This firsthand knowledge can inform the design and development of innovative solutions that directly address those needs

(Cravens, 2014). Volunteers bring diverse skills and perspectives to the table. They come from different backgrounds and possess a wide range of expertise. This diversity enriches the innovation process by bringing fresh ideas, creative problem-solving approaches, and alternative viewpoints, leading to more robust and innovative solutions (Metcalf, 2010).

Political engagement allows individuals or organizations to advocate for policy changes supporting social innovations. By engaging with policymakers, activists, and relevant stakeholders, individuals can highlight social issues, propose innovative solutions, and influence the development and implementation of policies that encourage and support social innovations (de Wit et al., 2019). Moreover, political engagement can influence resource allocation decisions. Individuals involved in political processes can advocate for increased funding, grants, or other resources for social innovation initiatives. By supporting allocating resources to social innovations, removing barriers, encouraging experimentation, and providing incentives for social innovations, politically engaged individuals shape a supportive and enabling environment for social innovation (Galego et al., 2022). Overall, the literature indicates that volunteerism and political engagement complement each other in forming social innovation. We operationalize both aspects with items drawn from the SOEP.

3.3 The calculation of the Social Innovation Capacities Index

In the first step of calculating our index, we normalized all included variables by a min-max normalization. This approach guarantees that all features will have the exact same scale. However, one downside of this method is that outliers remain outliers after the transformation, which might squish the remaining data. In our opinion, this is still the best approach since social innovations are relatively scarce, which implies that exceptional social innovation capacities are required to create social innovations. Hence, the

'rewarding' of outliers may even benefit the explanatory power of our index. In the second step, the sub-indices were calculated as the mean of the included variables. Finally, the SICI reflects the mean of the three sub-indices.

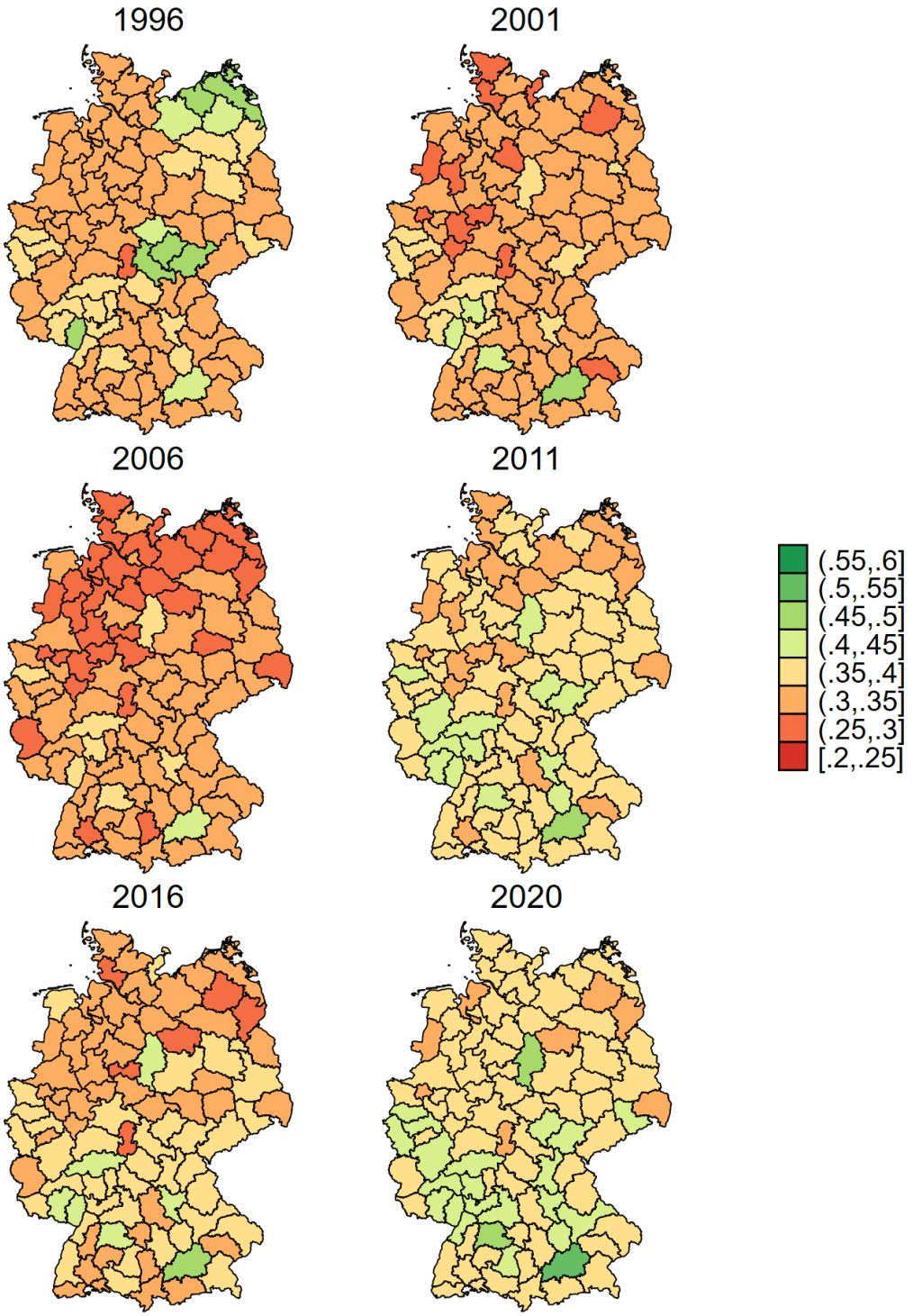
We deliberately did not weigh single variables, items, or sub-indices for three reasons. First, popular statistical methods to obtain index weights, such as factor analysis, are usually based on maintaining a maximum variance or correlation in the sample. Factor analyses are well-suited for variables that contain similar information, meaning that the variables shall be highly correlated. However, due to the multifaceted character of social innovations, the variables we found relevant in the literature were not highly correlated, so we did not consider factor analyses for the SICI. Second, to the best of our knowledge, the literature does not value one of our three dimensions higher than the others. Instead, they are interdependent and significantly meaningful. Third, since social innovations and associated social innovation capacities are multifaceted and complex, it is more adequate to build the index based on theoretical assumptions instead of pure statistical construction. This aligns well with existing literature on measuring social innovation, where statistical constructions are hardly considered (Bund et al., 2013; Bund et al., 2015; Cunha et al., 2022; Kleverbeck et al., 2019).

4. Findings

4.1 Descriptive Statistics

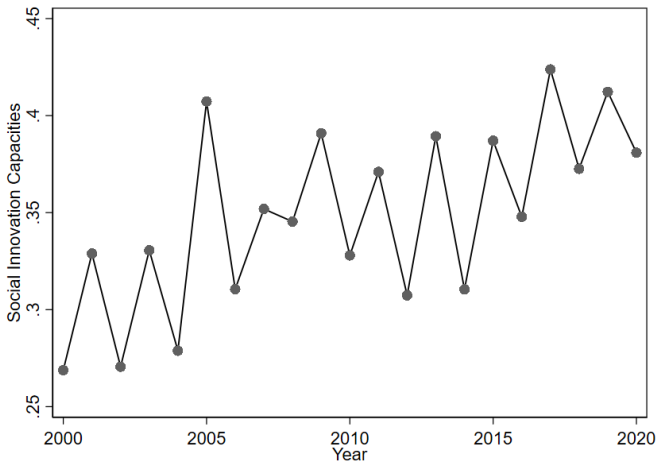
Our SICI, scaled from 0 to 1, shows values between 0.217 and 0.558 with a mean of 0.349 and a standard deviation of 0.053. Since most variables have a similar range, this is a reasonable variance. This variance effectively demonstrates regional differences, as shown in Figure 1.

Figure 1: Social innovation capacities in Germany in selected years



These differences yield several insights into the social innovation capacities landscape in Germany. First, the social innovation capacities, represented by our index, are relatively persistent over time. For example, regions such as Munich, Stuttgart, Frankfurt a.M., or Braunschweig perform quite well every year. This demonstrates the similarity of social and technological innovation (Bulut et al., 2013) since innovativeness and entrepreneurial activities persist over a long time (Cefis & Orsenigo, 2001; Fritsch & Wyrwich, 2014). However, cities such as Berlin, Hamburg, or Hannover do not perform significantly better than the surrounding regions, demonstrating that our index is not solely driven by innovation or urban agglomeration effects. Another aspect revealed by the maps is that the south of Germany performs better than the north. This may be driven by regional wealth. As argued in Section 3, we assume a positive impact of wealth on social innovation. Consequently, the increasing economic gap between southern and northern Germany (Wolf, 2016) may affect social innovation outcomes.

Figure 2: Social innovation capacities - time trend



Further, a trend is apparent over time (see Figure 2). Despite yearly fluctuations, the index values are consistently increasing, resulting in higher values in recent years than 20 years ago. On the one hand, an increased awareness of social and environmental issues in recent years is observable (Lee et al., 2015; Newman et al., 2018), which may cause

higher values in our index. On the other hand, this may show the development of society, which shows rising inclusiveness over time (Dörffel & Schuhmann, 2022).

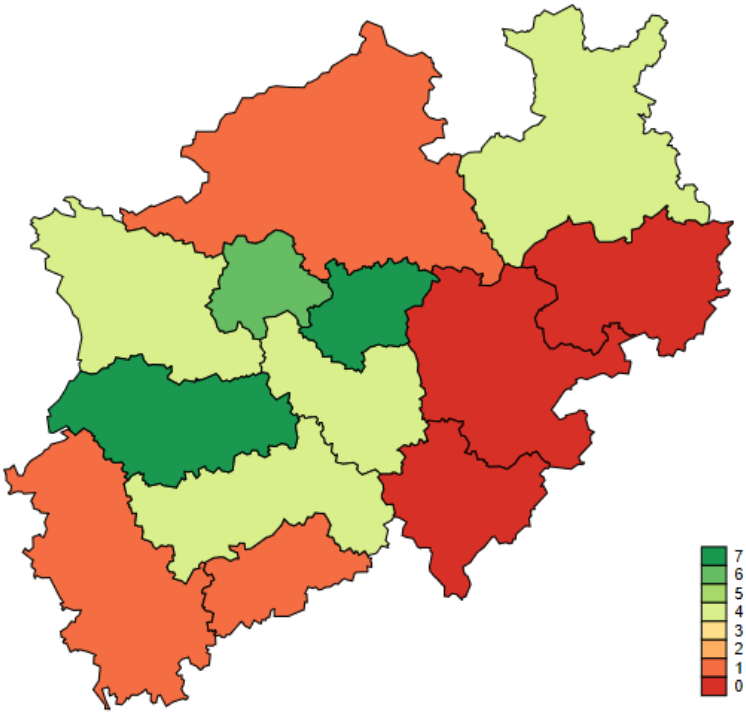
Overall, the SICI works quite well in demonstrating a heterogeneous picture of Germany's social innovation capacities landscape. However, supplementary to our careful theoretical evaluation of the variables, we validate the index by statistical methods to ensure its representativeness.

4.2 **Validation and robustness**

4.2.1 Validation

We need an external measure for social innovations to validate the index and test how well our SICI can explain it. However, no such measure is currently representative on a broad regional level. Our attempt at a solution is the Atlas of Social Innovation, a map of social innovation initiatives based on self-subscription. However, studying the numbers of the social innovation initiatives according to the Atlas of Social Innovation, it is suspicious that roughly half of the German initiatives are located in North Rhine-Westphalia (NRW), one of the 16 German federal states. The most likely explanation is that the Atlas of Social Innovation was developed in NRW, causing a good coverage of this state. Further, the institutions in charge of the Atlas of Social Innovation are also located in NRW, reinforcing the good quality of this specific coverage over time. We chose to exploit this bias regarding national representativeness and focus on NRW when validating our index. NRW consists of 13 RORs so that we still obtain sufficient regional variance. Further, the Atlas of Social Innovation also reports the founding date of the social innovation initiatives to cover a period from 2000 to 2018. Consequently, we can exploit the variance of 13 RORs in 19 years. Figure 3 presents the overall number of social innovations according to the Atlas of Social Innovation in NRW.

Figure 3: Overall number of social innovations according to the ATLAS OF SOCIAL INNOVATION



Our index aims to capture a region's social innovation capacities, i.e., the potential to create social innovations. To validate the SICI, we estimate the impact of our index on the realized social innovations according to the Atlas of Social Innovation. A statistically significant effect would indicate that the SICI captures the social innovation capacities well. We apply random and fixed effects panel regressions with clustered standard errors for this estimation. Since we want to exploit the explanatory power of within- and between-effects, we ran both models. Further, neither a Hausman nor a Sargan test showed clear evidence to prefer one of these models for our data.

We control for population density to capture whether the region is relatively urban or rural.[22] Since the potential captured by the SICI likely needs some time to unfold, i.e., to be transformed into actual social innovations (Lettice & Parekh, 2010), we apply different time lags. The results of this exercise can be seen in Table 2.

[22] We refrain from further controls for two reasons. First, most valid control variables are highly correlated with at least one sub-index of the SICI

The results reveal a statistically significant coefficient for fixed and random effects without a time lag. Further, both regression models report significant coefficients for a two-year time lag, whereas applying a one-year lag shows no significant results in both models. These findings indicate a relevant relation between the index, i.e., regional social innovation capacities, and the realized number of social innovations.

Table 2: Estimation Results

	(fe.1)	(fe.2)	(fe.3)	(re.1)	(re.2)	(re.3)
	No. SIs	No. SIs	No. SIs	No. SIs	No. SIs	
L.SICI	-0.211			-0.198		
	(0.432)			(0.362)		
L2.SICI		0.908*			0.720**	
		(0.423)			(0.360)	
L3.SICI			0.437			0.360
			(0.750)			(0.646)
Population Density	-0.00133	-0.00124	-0.00126	0.000323***	0.000301***	0.000309***
	(0.215)	(0.214)	(0.000907)	(0.000)	(0.000)	(0.0000313)
Constant	1.081*	0.651	0.819	0.0260	-0.265**	-0.151
	(0.095)	(0.283)	(0.475)	(0.843)	(0.022)	(0.200)
N	237	237	237	237	237	237
R2	0.007	0.014	0.008	0.083	0.077	0.072

*Notes: This table reports the results of fixed effects (fe) and random effects (re) panel regressions applying different time lags. The dependent variable is the number of social innovations per year, according to the ASI. Robust standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

4.2.2 Robustness

We developed our index based on theoretical assumptions and did not apply popular statistical methods, such as factor analyses, to determine weights. However, to ensure robustness, we applied a regression coefficient-based scoring approach to examine from a statistical perspective which variables shall be included in the index and with which respective weight. To ensure that the chosen variables are sufficiently meaningful for regional social innovation capacities, we applied this method within our sample of theoretically substantiated variables, i.e., the variables the SICI consists of.

For the regression coefficient-based scoring approach as applied by Furman et al. (2002), Porter & Stern (2001), or Hu & Mathews (2005), we first check whether a variable is statistically significantly related to the number of social innovations in NRW. For this purpose, we conduct a bilateral regression for each variable. Only significantly related variables ($p < 0.1$) were included in the adjusted index in the second step. Only eight variables were chosen for the adjusted index by this procedure, namely volunteerism, political engagement, satisfaction with standard of living, satisfaction with school education and vocational training, satisfaction with health, satisfaction with work, satisfaction with household income, and satisfaction with personal income. In the final step, these variables were weighted by the respective regression coefficient and compiled into an index.

Table 3: Robustness test using the coefficient-based scoring approach.

	(fe.1) No. SIs	(fe.2) No. SIs	(fe.3) No. Sis	(re.1) No. SIs	(re.2) No. SIs	(re.3) No. SIs
L.Adj. SICI	1.098**			1.445***		
	(0.502)			(0.487)		
L2.Adj. SICI		1.456**			1.770***	
		(0.632)			(0.655)	
L3.Adj. SICI			-0.0966			0.422
			(0.638)			(0.668)
Population Density	-0.00125	-0.00121	-0.00133	0.000300***	0.000291***	0.000311***
	(0.215)	(0.218)	(0.00100)	(0.000)	(0.000)	(0.0000337)
Constant	0.560	0.406	1.045	-0.548***	-0.660***	-0.187
	(0.347)	(0.539)	(0.633)	(0.001)	(0.003)	(0.221)
N	237	237	237	237	237	237
R^2	0.014	0.020	0.007	0.084	0.091	0.0721

*Notes: This table reports the results of fixed effects (fe) and random effects (re) panel regressions applying different time lags. The dependent variable is the number of social innovations per year, according to the ASI. Robust standard errors in parentheses. * p<0.1, ** p<0.05, *** p<0.01*

The adjusted SICI ranges from 0.253 to 0.522, with a mean of 0.367 and a standard deviation of 0.044. The variance is slightly reduced compared to the SICI. Still, it is fair to say that the regression coefficient-based scoring did a good job maintaining the

variance because the number of variables included was reduced to roughly one-fifth. We ran the same fixed and random effects regressions for further validation, now with the adjusted SICI as the explanatory variable. The results are reported in Table 3.

The findings show a statistically significant relation for all regressions. Further, the regression coefficients are larger than the coefficients of the original SICI. Consequently, the regression coefficient-based scoring approach worked well regarding the statistical findings. Since the results are similar to the results of the regression using the original SICI, our index can be confirmed by this robustness check.

5. Discussion and Implications

The SICI reveals several insights into the German social innovation capacities landscape. First, the social innovation capacities are relatively persistent over time. This finding aligns well with the technological innovation literature, where different measures and indicators also demonstrate a significant persistence (Castellacci & Natera, 2013; Cefis & Orsenigo, 2001; Fritsch & Wyrwich, 2014). This highlights the similarity of technological and social innovation, which seem to be shaped by similar processes (Bulut et al., 2013; Bund et al., 2013; Krlev et al., 2014). It implies that the contributing factors to social innovation capacities, i.e., abilities, capabilities, and knowledge, can be accumulated over time, just like technological innovation capacities (Castellacci & Natera, 2013). Further, the emphasized similarity to technological innovation suggests, that other popular concepts from innovation research, e.g., absorptive capacities and spillover effects, may play a significant role in creating social innovation (Unceta et al., 2016). Such concepts may receive increasing attention in the context of social innovation by future research.

Another aspect revealed by the SICI is that Germany's south possesses higher social innovation capacities than the north. This finding may be driven by regional wealth aligning with our assumption that wealth positively impacts social innovation. However, this total effect of wealth is subject to several influencing and contradicting factors on the relation between wealth and social innovation. On the one hand, wealth frees capacities for engagement in social issues. On the other hand, it decreases the awareness for social needs. These influences may differ over regional, economic, and societal contexts in other countries, highlighting the context-dependency of social innovation (Terstriep et al., 2020). Consequently, disentangling the relationship between wealth and social innovation may perceive more detailed attention prospectively.

Further, the SICI demonstrated a statistically significant relationship to the number of social innovations per year and region provided by the Atlas of Social Innovation. This external validation confirms that our measuring approach is legitimate. Moreover, it demonstrates that there is indeed a significant relationship between social innovation capacities and implemented social innovation. Further, the statistical significance of the regression analysis with lagged values shows that social innovation capacities need some time to unfold and be transferred to implemented social innovations (Lettice & Parekh, 2010). These findings may seem apparent but were not yet empirically tested. Moreover, this evidence may encourage policymakers to engage in social innovation since it demonstrates empirically that regional framework conditions, which adequate policies can shape (Galego et al., 2022; Lukesch et al., 2020; Moulaert et al., 2007), contribute significantly to the creation of social innovation.

The contribution of this paper is threefold. First, we enhance the literature by deepening the concept of social innovation capacities. This may help to better clarify the input and output of social innovation without ignoring the interrelatedness of these

dimensions (Bund et al., 2015). Hence, it contributes to reducing the fuzziness and ambiguities in the literature. Moreover, by introducing an entirely input-focused measurement approach, we significantly enhance the methodology for measuring social innovation. Therefore, it may serve as the next step toward a robust measure of social innovation.

Second, we develop one of the first approaches to measuring social innovation at a large scale, paying attention to regional contexts simultaneously. It may, therefore, bridge the gap between approaches focusing on the local or regional level and measurements on a national level. This enables zooming out from "locally embedded social innovation initiatives, focusing instead on the broader social innovation 'ecosystems' of national welfare regimes and social policies, trans-local networks, discursive structures, and hegemonic socio-political contexts" (Pel et al., 2020, p. 11).

Consequently, a third contribution of this work is enabling future empirical work on social innovation. The scalability of the SICI facilitates cross-regional empirical analyses focusing on various determinants of the social innovation process, such as actors, institutions, regional culture, and other drivers in creating social innovation. Therefore, it allows for empirical examinations of many social innovation aspects that are hitherto only conceptually developed. Evaluating these concepts empirically may deliver further insights that move the field forward.

6. Conclusion

This study addresses the challenge of measuring social innovation by applying the concept of social innovation capacities. To the best of our knowledge, this paper is the first that pursues such an approach and can, therefore, be seen as pioneering work. The constructed index includes detailed information on regional characteristics while ensuring

scalability. It comprises three dimensions: Regional Framework Conditions, Entrepreneurship & Innovation, and Social Awareness & Engagement.

This pioneering work suffers from limitations caused by the current state of social innovation research. For example, the Atlas of Social Innovation is increasing its numbers yearly, working toward improved representativeness. Consequently, more comprehensive validations of the SICI will be possible prospectively. The possibility of reproducing the SICI for other countries and validating it in the respective context may also offer additional validation potential. Further, future work may benefit from increased clarity and consider new or deeper developed approaches.

Moreover, it will remain arguable whether including further variables or dropping some is beneficial. Constructing a composite index, the data selection process is inevitably quite subjective as there is no single definitive set of indicators (OECD, 2008). In the context of social innovation, this problem is severe as the field is shaped by fuzziness and ambiguity (Mihci, 2020). Despite diligent literature research and variable selection, other researchers may, therefore, include or exclude slightly differing variables since there is no one best way to measure social innovation (Bund et al., 2013). However, this debate is necessary as social innovation measures "should undergo a 'creative destruction'" (Mihci, 2020, p. 356) to develop indicators and methods reasonable for most academia.

However, the results of the external validation report a statistically significant relation to the number of social innovations in 13 German RORs. Therefore, the SICI shall be seen as one step toward a robust measure of social innovation. A simple mapping of the index in Germany illustrated three core insights. First, the south of Germany performs better than the north. Second, the regional values demonstrate persistence over time, which is also found in similar concepts such as innovativeness and entrepreneurial activities (Cefis & Orsenigo, 2001; Fritsch & Wyrwich, 2014). Third, the values of the index

are increasing over time, which may demonstrate increasing inclusiveness (Dörffel and Schuhmann 2022) and raising awareness of social and environmental topics in recent years (Lee et al. 2015; Newman et al. 2018).

This work contributes to the existing literature by bridging the gap between detailed regional surveys on social innovation on the one hand and large-scale mapping approaches on the other hand. Our index may serve as the next step toward a robust measure for social innovation that is easily applicable but captures detailed information on a regional level. The SICI may further enable future work examining various topics about social innovations. Doing so may contribute to the emergence of more empirical literature on social innovations – a strand of social innovation literature that is currently underresearched. For instance, the SICI may be used to examine the influence of different institutions, regulations, or local actors on social innovation capacities, whereby the scalability allows for cross-regional analyses. Further, other determinants and actors of the social innovation process may be explored. Cross-country analyses may be enabled by exploiting similar data in other countries, e.g., the EU-SILC, the Panel Study of Income Dynamics in the US, or the British Household Panel Study. An empirical evaluation of theoretical concepts so far may enable further insights and enhance the qualitative and conceptual social innovation research. This evaluation may accelerate the 'creative destruction' among concepts (Mihci, 2020, p. 356) and, consequently, reduce fuzziness and ambiguities in the field of social innovation. Hence, this work does not only directly contribute to the existing literature. It may also serve as a manifold enabler for future social innovation research.

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Appendix

Appendix 1: Overview of items used from SOEP

Element of SICI	Data Origin	Items in SOEP	Question/ Instrument
Job Perspectives	SOEP	plb0443	Difficulty of finding new job
		plh0042	Worried about job security
Average Education	SOEP	pgbilzeit	Amount of education or training in years
Entrepreneurial Mindset	SOEP	plh0204_h	Self-assessment of risk taking [harmonized]
		plh0212	Thorough worker
		plh0213	Am communicative
		plh0215	Am original
		plh0226	Deal well with stress
		plh0255	Inquisitive
Pro-Social Attitudes	SOEP	plh0105	Importance: To help others
		plh0206i01	I return favors
		plh0206i06	Undergo costs to help somebody who helped before
Volunteerism	SOEP	plh0263_h	Member of trade union [harmonized]
		plh0265	Member of employees' council
		plh0266	Member environmental interest group
		pli0096_h	Voluntary work in clubs, associations, ... [harmonized]
Political Engagement	SOEP	plh0007	Interest in politics
		plh0111	Importance: To be socially and politically active
		pli0097_h	Part. parties, local politics, citizens' initiatives [harmonized]
Dissatisfaction	SOEP	plh0155	Satisfaction with social security
		plh0157	Satisfaction with availability of goods
		plh0160	Satisfaction with environment
		plh0162	Satisfaction with standard of living
		plh0164	Satisfaction with school education and vocational retraining
		plh0171	Satisfaction with health
		plh0172	Satisfaction with sleep
		plh0173	Satisfaction with work
		plh0174	Satisfaction with housework
		plh0175	Satisfaction with household income
		plh0176	Satisfaction with personal income
		plh0177	Satisfaction with dwelling
		plh0178	Satisfaction with amount of leisure time
		plh0179	Satisfaction with child care
		plh0180	Satisfaction with family life

Notes: This table reports items used from SOEP. All items were min-max normalized before entering the respective sub-index. Items used for "Dissatisfaction" were reversed, i.e., the lower the reported satisfaction, the higher the dissatisfaction value included in the sub-index. More information on each item can be found at https://paneldata.org/ *or on the webpages of the German Institute for Economic Research, which is in charge of the SOEP (*https://www.diw.de/en*).*

VI. Conclusion

Innovation has been considered a key engine for economic growth and prosperity in past decades (Hasan & Tucci, 2010). This perspective has served society well in past decades and has therefore developed considerable persistence (Kallis et al., 2018). Consequently, the dominant discussion in economics is still focused on production and consumption (Komlos, 2023). This growth paradigm was suitable for the mid-20th century to transform a world perceived as an "empty' world with abundant ecological resources" (Schmelzer, 2015, p. 270) and has been instrumental in creating and shaping new conditions. However, it has shown limited adaptability to evolving circumstances. Therefore, it's debatable whether this paradigm remains appropriate for addressing today's challenges (Kallis et al., 2018). More drastically, more than two decades ago, McNeill (2001) already described the continued adherence to the growth paradigm as a growing threat to the planet and future generations. Overall, there is a broad agreement that current grand societal challenges, i.e., urgent social and environmental issues, cannot be solved by pure technological progress (e.g., Kuhlmann & Rip, 2014; Schot & Steinmueller, 2018; Wettstein et al., 2019). Notably, science, technology, and innovation policy are responsible for tackling these challenges (Schot and Steinmueller, 2018). Consequently, a rethink in innovation policy and research is necessary, whereby inclusive and social considerations must complement technical solutions (Giuliani, 2018).

This dissertation makes several contributions to this urgent call. First, it evaluates the social impact of the academic sector. By considering the organizational level, i.e., universities, and the micro level, i.e., principal investigators, this exploration takes a comprehensive perspective and captures several aspects. The findings demonstrate the considerable unused potential of academia regarding their social outcomes (Anderson et al., 2018; Cinar & Benneworth, 2021). Consequently, the sole focus of policymakers on

technology transfer (Cunningham & Menter, 2021) might be counterproductive regarding universities' social impact. Hence, university managers should broaden the transfer mission to include more social aspects, enabling augmented contributions to society and inclusive growth. This reorientation might also be helpful for university managers to address the tensions caused by increasing expectations to deliver more returns to society beyond the economic agenda (see Cinar, 2019).

Further, while the field of technological innovations' non-economic consequences is very heterogeneous and dispersed (Biggi & Giuliani, 2022), this dissertation enables a comprehensive view of this topic by examining the impact of radical innovation on quality of life. The results suggest that the adverse effects of innovation may short-termly outweigh the benefits from the obtained technological progress. Moreover, the findings answer urgent calls for a more inclusive concept of social welfare in economics, moving from innovation for wealth creation to innovation that aims to improve quality of life (Komlos, 2023; Phelps, 2013).

Finally, with the creation of a robust and scalable measure for social innovation, this dissertation contributes to addressing limited empirical evidence in the respective literature (Cunha & Benneworth, 2020). Moreover, the possibility of measuring social innovation has the potential to bridge the gap between the differing social innovation literature strands since it makes the capacities for social innovation tangible and comparable across fields (Pel et al., 2020). Additionally, empirically assessing existing theoretical concepts could lead to deeper insights and strengthen both the qualitative and conceptual dimensions of social innovation research. Such an evaluation might accelerate the 'creative destruction' process among these concepts (Mihci, 2020, p. 356), thereby clarifying and diminishing the uncertainties and ambiguities prevalent in social innovation

research. Hence, this work addresses the urgent call to bring the field forward (Cajaiba-Santana, 2014).

In the following, the findings of the individual chapters are summarized, and the contribution and implications for theory and practice are discussed.

Chapter II contributes to the research on the social impact of universities. This work makes several contributions. First, it investigates the social influence of universities and the mechanisms enabling them to enhance private firms' social engagement, considering all three university missions – research, teaching, and transfer. The findings indicate that universities positively influence the social engagement of co-located private firms. Disentangling the overall influence into the effects of the three missions reveals that the positive impact is primarily driven by teaching activities. This observation aligns with the existing body of research on university education, which suggests that higher education offers diverse paradigms and viewpoints, fostering students' ability to think creatively (Harrison et al., 2007). Therefore, university students gain enhanced cognitive skills, improving their ability to recognize social needs, conceive solutions for them, and emerge as agents of change in the future. These students may bring their heightened social awareness to local businesses in various roles, such as interns, employees, managers, consumers, or stakeholders. Moreover, the impact of the university's teaching mission on the non-financial involvement of companies in social activities is positive and statistically significant. This finding aligns with the work of van den Wijngaard et al. (2015), who identified social engagement as an educational outcome. The effect of the teaching mission may comprise two factors. Firstly, as motivation spurs people into action (Markus, 2016), heightened motivation can lead to increased participation in social activities. Secondly, education can broaden awareness of new opportunities for social involvement (Crosling et al., 2015), thereby enhancing social engagement.

The second contribution of Chapter II is the enhancement to our understanding of universities' evolving roles, missions, and values (Miller et al., 2014), highlighting the need for a greater focus on social factors to fully realize their societal potential. The university's role in knowledge and technology transfer seems to influence private firms' non-monetary social engagement negatively. This may be rooted in an overemphasis on technology transfer that insufficiently conveys social considerations to firms (see Benneworth & Jongbloed, 2010). The negative regression coefficient implies that focusing on technological aspects might even suppress awareness of social needs. This insight underscores the significance of recognizing social needs and calls for reorienting the university's transfer mission. Such a redefinition should be considered part of universities' broader evolving role (see Benneworth & Fitjar, 2019; Cinar, 2019). This dissertation, therefore, expands the discourse on the roles, missions, and values of universities, providing insights into managing the challenges that arise from the increasing expectation for universities to make societal contributions (Cinar, 2019). Further, emphasizing the distinct role of monetary and non-monetary incentives may help policymakers address university managers and stakeholders better and, thus, improve the efficiency of higher education policies.

Chapter III contributes to the existing literature by connecting the two emerging fields of principal investigators and social innovation. Applying a quadruple helix model, it examines the influence of the paradigm shift on principal investigators and, subsequently, how they adapt to the changed demands and proactively shape the transformation process. Due to their central position in the quadruple helix, principal investigators may act as catalysts in this rethinking process. As a result of the paradigm shift, they adapted their visions and objectives. Subsequently, they pursue their revised ideas and proactively contribute to the paradigm shift in their role as transformative agents (O'Kane, 2018). Therefore, it is likely that principal investigators are not just reacting to the shift from

purely technological to social innovation but are actively designing this change, thereby fulfilling their role as key actors in entrepreneurial ecosystems. As intermediaries between science and industry, they bring this change to the production sector and contribute to implementing new solutions that meet societal needs. Furthermore, in their capacity as scientists, principal investigators can actively guide the process of scientific change (see Bueno, 2000). Moreover, as intermediaries between universities and the government, they can also provide concrete policy recommendations, thus influencing the political aspects of the paradigm shift based on their scientific findings.

To aid principal investigators in advancing the transformation of the innovation process, policies should reconsider the role of universities. The shift towards social innovation implies that the academic sector must be more active in social change. This reinforces the implications of Chapter II that universities' third mission, transfer, must be revised to comprise more social considerations. Since universities' organizational practices, i.e., the institutionalization of specific targets, are found to substantially impact the target-specific outcomes (Siegel et al., 2003), establishing new organizational units, such as 'social innovation offices,' might be beneficial. These offices would mirror the idea of technology transfer offices in the technological innovation process and assist academics with ideas contributing to social change or environmental solutions. Future research should investigate how university architecture can be modified to foster social innovation.

The findings also highlight the need for further research linking the literature on social innovation and entrepreneurial ecosystems. Particularly the paradigm shift's impact on the attitudes and motives of ecosystem actors. Referring to the calls for more comprehensive innovation concepts (e.g., Giuliani, 2018; Phelps, 2013; Schot & Steinmueller, 2018), studies that unify 'traditional' and social entrepreneurship are

required to burst the structure of two separated fields and work towards one comprehensive entrepreneurial ecosystems research.

Chapter IV examines the influence of radical innovations on the quality of life. It enables new insights by disentangling the complex and multifaceted relationship between radical innovation and objective well-being into direct and indirect effects. The findings indicate a statistically negative relationship between radical innovation and objective well-being. Economic development significantly mediates this influence, mitigating it substantially. While the findings confirm the well-established positive, albeit indirect, connection between innovation and well-being via economic growth, they simultaneously indicate that the direct effect of radical innovation on objective well-being is statistically significant and negative. Therefore, this finding adds to the literature on the 'dark side' of innovation and emphasizes the importance of considering innovations' consequences beyond economic growth. Since the literature on non-economic effects of innovation is currently very heterogeneous and separated into various fields that address single aspects of those consequences (Biggi & Giuliani, 2022), the finding adds to this literature by providing an approach that captures the aggregated effect on the quality of life. The negative relationship highlights thereby the need for social considerations in innovation processes beyond economic growth. By differentiating radical innovation and highlighting its short-term consequences, it urges policymakers, stakeholders, and researchers to adopt a more nuanced view. While radical innovations promise transformative potential, their immediate repercussions on objective well-being and economic growth must be acknowledged and addressed.

Moreover, Chapter IV contributes to the research on regional development by considering regional differences and patterns in radical innovation and objective well-being. Therefore, it addresses a potential oversimplification in the literature on innovation

and objective well-being by taking the uneven nature of innovation above regions into account (e.g., Asheim et al., 2011; Audretsch & Feldman, 1996).

Chapter V addresses the challenging task of measuring social innovation. It, therefore, answers one of the most urgent calls of the respective research field (Terstriep et al., 2021). For this purpose, this work develops an index based on the concept of social innovation capacities, thus building on the similarities to technological innovation (Bulut et al., 2013; Bund et al., 2013). Regarding technological innovation, the capacities approach has demonstrated effectiveness in measuring technological innovation (Furman et al., 2002; Oura et al., 2016; Porter & Stern, 2001). The created index, the *Social Innovation Capacities Index* (SICI), shows a statistically significant relationship to the realized social innovation counted by the *Atlas of Social Innovation* in North Rhine-Westphalia. This indicates that the index sufficiently captures the regional social innovation capacities. Chapter V, thus, adds to the literature by creating a new measuring approach for social innovations. It may serve as progress toward a robust measure applicable to various contexts. By addressing the missing measurement of social innovation and, hence, making social innovation increasingly visible, this work provides incentives for policymakers and local actors to engage in social innovation. It further contributes to social innovation research by extending the focus from region-specific approaches to broader social innovation ecosystems and national contexts (Moulaert & MacCallum, 2019). Moreover, the possibility to measure social innovation has the potential to bridge the gap between the differing social innovation literature strands, such as social economy, social studies, urban development, and innovation studies, since it makes the capacities for social innovation tangible and comparable across fields (Pel et al., 2020). Additionally, empirically assessing existing theoretical concepts could lead to deeper insights and strengthen both the qualitative and conceptual dimensions of social innovation research. Such an evaluation

might accelerate the 'creative destruction' process among these concepts (Mihci, 2020, p. 356), thereby clarifying and diminishing the uncertainties and ambiguities prevalent in social innovation research. Hence, this work addresses the urgent call to bring the field forward (Cajaiba-Santana, 2014).

As with all research, this dissertation is subject to some limitations. For example, applying specific data for specific countries leads to limited generalizability. The results of Chapter II are based on German data. However, varying higher education systems in other countries may lead to deviating results and mechanisms. Future work may, therefore, exploit different countries and contexts to test the robustness of these findings. Further, mixed methods may be employed to mitigate the limitations of qualitative and quantitative research (Halcomb & Hickman, 2015).

In Chapter III, the paradigm shift from pure technological innovation to more social considerations is treated as an exogenous influence on the academic sector. However, given that a core function of research is the creation of new knowledge that often leads to new discoveries and the reevaluation of predominant mindsets, it is likely that academia is significantly involved in the emergence of this paradigm shift. Consequently, it is crucial for future research to understand the mechanisms that lead to this reconsideration to allow for a more complete picture of principal investigators' role in shaping a dynamic environment. The emergence of new paradigms may, therefore, be endogenously modeled in future research.

Another point to address is the time horizon. As several concepts applied in this dissertation demonstrate a significant persistence, e.g., social innovation capacities, objective well-being, or the ability to produce radical innovations, a longer time frame may provide further insights into the relationship between these concepts and their influencing factors. Especially regarding the established links between radical innovation, objective

well-being, and economic development in Chapter IV, this may address the paradox of the negative relation between radical innovation and economic development, as suggested by the respective findings.

Moreover, the external validation of the SICI in Chapter V is subject to limited data availability on realized social innovations. On the one hand, this highlights the need for alternative measures, such as the SICI. On the other hand, this paradox may be resolved prospectively as growing numbers of initiatives aim to depict social innovation more comprehensively in a regional context. These may enable a more robust validation in different contexts and regions in future research. Notably, scalable measures of social innovation will maintain their importance since counting social innovation on a large scale is very cumbersome and thus demands an enormous effort. Consequently, such counting will remain unfeasible for large regions or countries.

Furthermore, the SICI is a purely input-based measure. However, the mechanisms that translate these underlying determinants into realized social innovations remain a black box. Consequently, even though the SICI may facilitate policies in creating targeted support for social innovations, understanding the emergence of social innovations more fundamentally may increase the efficiency of this policy support and is a focal point of prospective social innovation research. Further, the creation of social innovation capacities may be examined to provide insights into the long-term support for regional social innovation ecosystems.

These limitations have already highlighted a range of potential directions for future research. Nevertheless, it is important to emphasize additional intriguing research questions at this juncture. For example, existing theoretical studies on the non-economic consequences of innovation have not thoroughly addressed the normative aspects and policy consequences of innovation's impact on inequality, nor have they conducted a

comprehensive social welfare analysis considering the aggregate implications of innovation in terms of efficiency, equity, and overall social welfare. Consequently, future research in this area must align more closely with mainstream theories of innovation and growth. This future research should mainly focus on the trade-offs between efficiency and equity in economies driven by R&D (see Castellacci, 2023).

Further, especially in addressing major societal challenges, the so-called mission-oriented approach to innovation policy, which emphasizes the entrepreneurial role of the state, gained momentum (Mazzucato, 2018). However, the concept has yet to prove its overall efficiency in addressing social needs, as the focus on a specific mission may lead to opportunity costs in other topics not covered by the respective mission. Further, this approach is centered around market-creating and market-shaping considerations to solve grand challenges (see Mazzucato, 2018). However, the social consequences of non-market failures may be significant and must be considered (Jaworski, 2013). The evaluation and advancement of emerging innovation concepts that address the call for more comprehensive innovation concepts is, thus, essential to ensure further development towards economic research that aims at improving people's quality of life (Phelps, 2013).

Overall, this dissertation addresses several aspects of the urgent calls for more comprehensive innovation research considerations, including social considerations (Giuliani, 2018; Wettstein et al., 2019). However, topics of non-economic consequences in the innovation literature are increasingly important, leading to a plurality of new research questions and policy implications that must be addressed (Castellacci, 2023). Therefore, innovation research that thinks beyond economic growth will continue to be characterized by growing dynamics and research questions of essential importance.

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Erklärung nach § 4 Abs. 1 PromO

Statement according to § 4 Abs. 1 PromO1

Hiermit erkläre ich,

I state that,

1. dass mir die geltende Promotionsordnung bekannt ist;

   I'm familiar with the current Course of Examination for Doctoral Applicants;

1. dass ich die Dissertation selbst angefertigt, keine Textabschnitte eines Dritten oder eigener Prüfungsarbeiten ohne Kennzeichnung übernommen und alle von mir benutzten Hilfsmittel, persönlichen Mitteilungen und Quellen in meiner Arbeit angegeben habe;

   I have composed and written the dissertation by myself, that no passages of text have been taken from third parties or own exam papers without having been identified as such and that all tools, personal notifications, and sources used have been indicated in the dissertation;

2. dass ich bei der Auswahl und Auswertung des Materials sowie bei der Herstellung des Manuskriptes keine unzulässige Hilfe in Anspruch genommen habe;

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I don't have enlisted the assistance of a commercial doctoral consulting agency and that no third parties have received either direct or indirect monetary benefits from me for work related to the contents of the submitted dissertation;

4. dass ich die Dissertation noch nicht als Prüfungsarbeit für eine staatliche oder andere wissenschaftliche Prüfung eingereicht habe;
   the dissertation has not already submitted as an examination paper for state or other academic examinations;
5. dass ich nicht die gleiche, eine in wesentlichen Teilen ähnliche oder eine andere Abhandlung bei einer anderen Hochschule bzw. anderen Fakultät als Dissertation eingereicht habe.
   I don't have submitted the same, a substantially similar or any different paper to another university or to another faculty as a dissertation.

Jena, 19.04.2023

ERKLÄRUNG ZU DEN CO-AUTORENSCHAFTEN

Tabelle 1: Darstellung des Anteils von Johannes Carl an den gemeinsam publizierten Artikeln gemäß der Skala „gering“, „proportional“, „federführend“

Artikel	Artikel 1: **The social impact of universities: assessing the effects of the three university missions on social engagement**	Artikel 3: **Technological innovation and objective well-being: Really such a harmonious relationship?**	Artikel 4: **Bridging the Gap: A Scalable Approach to Measuring Regional Social Innovation Capacities**
Ko-Autorenschaft	Ja	Ja	Ja
Autoren	Carl, J. & Menter, M.	Carl, J. & Grashof, N.	Carl, J. & Menter, M.
Idee	proportional	proportional	proportional
Literaturrecherche	federführend	federführend	federführend
Identifikation der Forschungslücke	proportional	proportional	proportional
Konzeption	federführend	proportional	federführend
Theorie	federführend	federführend	federführend
Forschungsdesign	federführend	proportional	proportional
Datenerheben und Datenaufbereitung	federführend	gering	federführend
Empirische Analyse	federführend	proportional	federführend
Interpretation der Ergebnisse	proportional	proportional	proportional
Diskussion Beitrag zu Theorie und Praxis	proportional	proportional	proportional