Research Policy 52 (2023) 104763

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

How does late-career entrepreneurship relate to innovation?

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ARTICLE INFO

Keywords:
Entrepreneurship
Career
Innovation
Aging
Age

ABSTRACT

In this paper, we present an explorative study that develops our understanding of the relationship between late-career entrepreneurship and innovation-driven business activity. Based on observations of 2903 solo founders of new ventures in Germany in 2008–2017, we offer first and robust evidence that late-career entrepreneurs (~50 years and above) are more likely than younger founders to introduce product/service innovations that are 'new to the market'. Our explorations specifically reveal that older founders who draw on personal financial resources and combine their innovation orientation with prior managerial experience are most likely to generate the types of innovations that bring new products or services to the market. We conclude by discussing how our study's insights contribute to the research agenda on innovations in late-career entrepreneurship.

1. Introduction

Entrepreneurship literature has long argued that new/small firm innovativeness is a key component in achieving a national competitive advantage and addressing global challenges by radically and systemically bringing novel solutions to the markets (Baumol, 2002, 2010; Boons et al., 2013; Schumpeter, 1934). However, the aging of the world's population, which is particularly acute in developed countries in Europe and North America, as well as Japan and South Korea (OECD, 2013; United Nations, 2017), can cause a serious decline in the number of new start-up enterprises and hamper job creation, economic growth, and the development of innovations (Kulik et al., 2014; Levesque and Minniti, 2011). The likelihood of engaging in entrepreneurship over the course of an individual's life follows an inverted U-shape, and especially decreases after the age of 45–50 (Kautonen et al., 2014; Levesque and Minniti, 2006). Similarly, research suggests that most innovations are created by individuals between the ages of 35 and 50 (Frosch, 2011).

Our specific aim in this paper is to provide initial insight into the creation of innovations in the context of 'late-career entrepreneurship', which refers to firm-founders with expansive life- and work-experience and who are around 50 years of age and above when they transition to entrepreneurial careers (Kautonen, 2008; OECD, 2012). The number of new ventures created by late-career entrepreneurs has grown faster than demographic change would suggest (Sternberg, 2020), and late-career entrepreneurship has been increasingly advocated as an important policy measure designed to tackle the grand challenge of population aging, chiefly through its capacity to support economic development by taking advantage of 'senior' individuals' human and social capital (Kautonen et al., 2017; United Nations, 2017). Nevertheless, the predominant investigative focus in prior research on late-career entrepreneurship has hitherto been on the motives and mechanisms that inform older people's transition to entrepreneurship, as well as in assessing the impact of late-career entrepreneurship on an individual's personal circumstances, such as well-being or income (Kautonen et al., 2014; Minola et al., 2016), and, to a far lesser degree, on the firm-level outcomes generated by older founders (Azoulay et al., 2020; Zhao et al., 2021).

To date only few studies have touched upon the capacity of late-career entrepreneurship to create innovations (Colovic and Lamotte, 2013; Sternberg, 2020), which are key to firms' success as well as the generation of broader economic and social changes (Bradley et al., 2021; Cefis and Marsili, 2006; Levesque and Minniti, 2011). These studies have investigated the aggregate innovation activity in late-career entrepreneurship and suggested that late-career entrepreneurs are "successful but in running businesses that are not particularly innovative" (Zhao et al., 2021, p. 3). At the same time, recent research has urged us to look beyond the quantity of innovation by addressing the types of innovations created

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https://doi.org/10.1016/j.respol.2023.104763
Received 23 December 2021; Received in revised form 27 February 2023; Accepted 27 February 2023
Available online 3 April 2023

across the span of an individual's career (Kaltenberg et al., 2023). For instance, studies have suggested that individuals holding senior positions in organizations are more likely to invest in the commercialization of 'radical' innovations than their younger counterparts (Ching et al., 2019; Wilden et al., 2022). This contradictory evidence in the prior research leaves us with a clear dearth in understanding whether, and how, late-career entrepreneurship relates to different *types of innovations* that either disrupt the market or enhance a firm's offering and processes (Rosenbusch et al., 2011), as well as how *older founders* as key decision-makers in their ventures influence their firms' innovation activities (Baron and Tang, 2011; Delmar and Shane, 2006; McGuirk et al., 2015).

Against this background, we find that the existing research has yet to achieve the sophistication necessary to formulate specific hypotheses on late-career entrepreneurship and innovations. We address this methodological challenge by presenting an explorative study, that is, an approach that offers valuable tools for addressing phenomena that can be observed in the real world (Helfat, 2007) yet are "new, scarcely documented, or ill understood" (Wennberg and Anderson, 2020, p. 2). Rather than focusing on testing theory, exploratory research approaches rely on abduction and call upon researchers to flesh out unforeseeable mechanisms that contribute to subsequent theory development (Heckman and Singer, 2017; King et al., 2021; Wennberg and Anderson, 2020).

Our study follows such an explorative approach to examine how late-career entrepreneurship is related to innovation. We use data on solo founders from the representative IAB/ZEW Start-up Panel database on newly founded German ventures between 2008 and 2017 to develop our understanding of late-career entrepreneurship as potentially innovation-driven business activity. In addressing this, we combine insights from lifespan theory (Bohlmann et al., 2017; Gielnik et al., 2018) and innovation research in entrepreneurship (Autio et al., 2014; Baron and Tang, 2011) to explore the creation by late-career entrepreneurs of 'new to the market' and 'new to the firm' innovations. We maintain that innovations 'new to the market' introduce novel products and services that precipitate changes in the markets, whilst innovations 'new to the firm' primarily improve a firm's offering and processes (Rosenbusch et al., 2011).

Our study's key insight is to demonstrate that the likelihood of firm founders introducing 'new to the market' innovations increases with age, whereas the likelihood of 'new to the firm' innovations, in particular those that relate to new processes, dwindles with firm founders' age. We show that late-career entrepreneurs are more likely to introduce 'new to the market' innovations than their younger counterparts; also, strikingly, our explorations reveal that older entrepreneurs who draw on personal financial resources and combine their innovation orientation with prior managerial experience are the group most likely to generate the types of innovations that bring new products or services to the market. On average, ten additional years of age increase a founder's probability of introducing a market novelty by a range of 19 % (conditional on our full set control variables) to 30 % (only including basic controls for firm age, year of observation, and industry). Highly innovation-oriented and managerially experienced late-career entrepreneurs (above the age of 50 years) are more than three times more likely to introduce market novelties than our sample average (8 % likelihood). Our results pointing to the age-effect on innovation remain robust when assessing a late-career entrepreneur's age at the time of both founding their venture and creating innovations, as well as when exploring the effects of a wide range of founder characteristics (such as education, professional experience, wages, or previous occupations) on the age-innovation relationship.

Taken together, our study significantly contributes to the extant research on innovations (Autio et al., 2014; Rosenbusch et al., 2011) in late-career entrepreneurship (Brieger et al., 2021; Kautonen et al., 2017; Levesque and Minniti, 2006; Zhao et al., 2021) by offering first and robust evidence that older entrepreneurs introduce overall fewer innovations than do younger entrepreneurs (Colovic and Lamotte, 2013; Sternberg, 2020), but that they are more likely to introduce innovations that can significantly change the markets. We conclude by discussing the main implications of our findings for theory and practice.

2. Theoretical background

2.1. Late-career entrepreneurship and innovations from a lifespan perspective

In the past two decades a growing number of late-career entrepreneurship studies have focused on understanding the various motives and mechanisms which inform older people's transitions to entrepreneurship (Curran and Blackburn, 2001; Kautonen, 2008; Kautonen et al., 2014; Singh and DeNoble, 2003). Recent late-career entrepreneurship research has begun to generate insights into the social barriers faced by older founders when developing their business (Kautonen et al., 2015; Kibler et al., 2015; Mallett and Wapshott, 2015); but also, how starting up businesses later in life can improve individuals' well-being (Kautonen et al., 2017; Minniti et al., 2017). Despite substantial advancements in this stream of research, there remains a significant lack of studies on the firm-level outcomes generated by older founders (Azoulay et al., 2020; Zhao et al., 2021) and, more generally, on the relationship between late-career entrepreneurship and innovations.

The limited number of studies at hand have investigated innovations and late-career entrepreneurship at an aggregate level and indicated that late-career entrepreneurs are only scantily involved in innovation-driven businesses (Sternberg, 2020), hence generating fewer innovations than their younger counterparts (Colovic and Lamotte, 2013). Nevertheless, studies examining entrepreneurial innovations in academic entrepreneurship and in established businesses suggest that senior individuals evaluate innovations from a broader perspective than their younger counterparts. This supports the creation of innovations that significantly change the market offering and practices, as well as those that require careful implementation (e.g., the acquisition of external resources or the protection of intellectual property rights) (Ching et al., 2019; Wilden et al., 2022). In light of this, extant research offers contradictory evidence on the creation of innovations in the context of late-career entrepreneurship, and we still know little about how older founders engage with different types of innovations. Overall, most new ventures focus on innovations that realize efficiency gains or service/product improvements and are 'new to the firm', and a minority of them create innovations that bring services and products which drastically differ from already available offerings, that is, which are 'new to the market' (Aldrich and Ruef, 2018; Autio et al., 2014; Rosenbusch et al., 2011). While 'new to the market' innovations entail more tangible economic and social benefits by changing/disrupting markets, in addition to having the tendency of emphasizing the commercialization of innovations, 'new to the firm' innovations typically focus more explicitly on improving a firm's market position by introducing efficiency gains (Rosenbusch et al., 2011). 'New to the market' innovations, therefore, have the potential to become radical innovations or 'breakthroughs' that introduce significant changes in the industry and contribute to societal well-being; whereas 'new to the firm' innovations represent a more incremental type of innovations that "improve existing systems or products to make them better, cheaper, or faster" (Wilden et al., 2022, p. 2).

To further our understanding of innovations in late-career entrepreneurship, we turn to the lifespan perspective (Baltes, 1987; Kanfer and Ackerman, 2004; Wohlwill, 1970) as it has been applied in entrepreneurship research (e.g., Bohlmann et al., 2017; Davis and Shaver, 2012). The lifespan perspective complements research on how entrepreneurs' orientation towards innovation contributes to new/small firm innovativeness (Baron and Tang, 2011) by incorporating lifespan- and age-related characteristics (e.g., life expectancy, cognitive and emotional skills, and work experience) to explain (ways of) entrepreneurial engagement (Bohlmann et al., 2017; Brieger et al., 2021; Gielnik et al., 2018; Zacher, 2015). Here, lifespan theory resonates with the idea of viewing entrepreneurship as a career choice that stems from, and is influenced by, an individual's personal and social history (Burton et al., 2016). It follows that the lifespan of new venture founders—the

individuals who make decisions on resource allocation and strategy—influences their entry into entrepreneurship and shapes the innovation activities of their businesses (Ching et al., 2019; Delmar and Shane, 2006; McGuirk et al., 2015) due to age-related differences in risk propensity, subjective value of time, human, social and financial capital, and family obligations (Zhao et al., 2021).

More specifically, the lifespan perspective suggests that late-career entrepreneurship is associated with a shorter future time horizon and higher opportunity costs when starting up a business (Gielnik et al., 2018; Singh and DeNoble, 2003). Hence, while an entrepreneur's image of their own age may vary (Kautonen et al., 2015; Weber and Schaper, 2004), older individuals have less time 'left' (before their retirement) during which they can personally contribute to venture development (Rudolph et al., 2018; Zacher and Frese, 2009), therefore possibly making them more reluctant to engage in start-up activities (Singh and DeNoble, 2003). Late-career entrepreneurs have also typically 'found their place' and achieved the social and financial equilibrium they desire (Brieger et al., 2021), hence experiencing higher opportunity costs when establishing new ventures as compared to younger counterparts still in the process of building their careers (Levesque and Minniti, 2006; Rogoff, 2007). These factors have been argued to explain why entrepreneurship at an older age is less attractive (Kautonen et al., 2015; Levesque and Minniti, 2006), and that older individuals tend to use the 'short(er)' time remaining in their work life on activities that improve personal well-being rather than taking risks in the pursuit of (increasing) personal financial gains (Gielnik et al., 2018; Kautonen et al., 2017).

Concomitantly, the lifespan perspective maintains that older age is typically associated with a longer working career and a related increase in an entrepreneur's human, social, and financial capital (Curran and Blackburn, 2001; Singh and DeNoble, 2003). Although certain cognitive skills might decline with age, thereby making it more challenging for older people to adopt new technologies and information (Colovic et al., 2020), longer life experience generates 'crystallized knowledge' that enables an individual to control emotions and better utilize the skills they have acquired (Horn and Cattell, 1967). Older individuals' human capital may, therefore, be applicable to a broader set of situations than, for instance, the possession of specific task-related skills (Becker, 1993).

Research has long addressed the role of human capital—such as knowledge, ideas, and skills—in enhancing firms' innovation activities (Becker, 2002; Ganotakis, 2012; Fonseca et al., 2019; McGuirk et al., 2015). For instance, level of self-confidence, versatile labor market histories, and experience from different industries—all of which accumulate with age—support entrepreneurs' innovation capacity (Koellinger, 2008; Åstebro and Thompson, 2011; Åstebro and Yong, 2016). The accumulation of immaterial resources helps late-career entrepreneurs translate their entrepreneurial intentions into action and thereby achieve their goals (Gielnik et al., 2018). With increasing age, profound life goals (e.g., happiness and a meaningful life) gain in importance (Carstensen et al., 1999; Lang and Carstensen, 2002), and older individuals are found to be motivated in businesses where they can 'give back' to the community, leave a legacy, and, ultimately, create social value (rather than economic value) (Brieger et al., 2021; Zacher and Kooij, 2017).

With this in mind, we suggest that because older entrepreneurs have 'less' time to implement and benefit from entrepreneurship, they find fewer opportunities worth pursuing (Gielnik et al., 2018), and they may be likely to refrain from business ideas that require long-term gains stemming from process innovations within the firm (Carstensen et al., 1999; Lang and Carstensen, 2002). As a result they may focus their capacities more on achieving results that generate the potential for either significant financial returns (Choi and Shepherd, 2004; Rosenbusch et al., 2011) and/or for a greater social impact (Brieger et al., 2021). Also, the introduction of innovations that are 'new to the market' is a potentially costly endeavor and necessitates aptitude in both evading errors and bringing together unknown components (Fleming, 2001). Possessing higher levels of human, social, and financial capital—acquired across a lifespan in both professional and educational contexts, as well as in social and family life—late-career entrepreneurs may be better equipped to pursue 'new to the market' innovations than their younger counterparts.

Against this backdrop, we proceed to examine the question of whether *late-career entrepreneurs are more likely to create 'new to the market' innovations than their younger counterparts.*

3. Research design

3.1. Data and sample

Our dataset combines primary survey data on startups with individual-level register data on the founders and employees. The survey data are drawn from the IAB/ZEW Start-up Panel, a representative panel dataset of new German ventures that is based on a stratified random sample of legally independent new ventures in all industries other than the primary, energy, and public sectors. The IAB/ZEW Start-up Panel is a joint project of the Institute for Employment Research (IAB) of the German Federal Employment Agency, the Leibniz Centre for European Economic Research (ZEW) Mannheim, and Creditreform, Germany's largest credit rating agency. The sampling frame of the IAB/ZEW Start-up Panel is the Mannheim Enterprise Panel, which contains basic information (postal addresses, year of establishment, sector of activity, and legal form) for almost all German firms. This population database is fed by firm and address data assembled by Creditreform, who automatically scan new firm registries in Germany. Moreover, regional units of Creditreform thoroughly search for otherwise undetected, newly entering firms and assemble their basic firm and address data (for a detailed description, see Bersch et al., 2014).

The IAB/ZEW Start-up Panel data are collected via computer-supported telephone interviews with the companies' founders and provide information on founders' essential characteristics (educational background, experience in managerial and entrepreneurial leadership) and venture characteristics (details on employment, innovation and R&D activities). In preparation of the interviews, the firms' major owners (and therefore usually the managing founders) are identified as contact persons for the interviews in the data of the Mannheim Enterprise Panel. At the beginning of each interview, interviewers confirm that the respondent is a founder actively working in the company, asking to be redirected should this not be the case. Once a new venture participates in the survey it is subsequently followed for up to seven years. The sample of the IAB/ZEW Start-up Panel is stratified by industry[1] and year of foundation.[2] We control for stratification by including dummy variables for the stratification cells in all regressions and by using sampling weights in (unconditional) graphs, i.e., when we do not include control variables. We refer to Fryges et al. (2010) for a detailed description of the sampling design of the panel dataset, and to Vaznyte and Andries (2019) for a recent application of the survey data that includes a discussion of the survey's sample response, which they rate as sufficiently good.[3] To exclude the possibility that team composition—including members of different ages—drives our results, we excluded all startups founded by teams from our main analyses. We include data on team founders in the online appendix for robustness-

[1] The sample is targeted at an over-representation of high-tech firms in order to be able to analyze such new firms in greater detail despite their lower total frequencies in the population of firms.

[2] From 2008 to 2012, KfW Bank, Germany's state-owned investment and development bank, was a foundational project partner of the start-up panel. For cohorts until 2012, funding by the KfW Bank was therefore an additional stratification criterion of the sample. As for the other stratification criteria, we control for this stratification in any statistical analyses.

[3] Detailed information on response rates of the individual survey waves of the panel dataset, including the reasons for non-response, are provided in technical reports to each wave on www.gruendungspanel.de.

check purposes; and we find that our results remain consistent.

The survey data are enriched by additional, individual-level data on the founder(s) and employees drawn from employment statistics provided by the German Federal Employment Agency, which contain details on individuals' characteristics, such as age, gender, and work history (wages, qualification levels, start and end dates of employment in a given firm, professions, and occupational status in terms of full or part-time employment). In Germany it is mandatory for establishments that employ individuals who are subject to social security contributions to report these data on their employees. Information on all spells of both employment and unemployment is collected by the federal employment agency and merged into an employment biography that allows an individual to be tracked on a day-by-day level. The founders' employment biographies are matched to firm-level data via the founders' names and dates of birth. The employees' employment biographies are matched via their employing establishments' names and addresses.[4]

Through the combination of firm-level and individual-level data sources, our data allow us to link information on founder characteristics, founder motives and entrepreneurial orientation, firm strategy, and firm outcomes which are unavailable in either plain registry or survey data, thereby enabling in-depth analyses of the firms' innovation outcomes and their individual-level determinants.

3.2. Measures

3.2.1. Dependent and independent variables

Our *dependent variables* are binary indicators of whether a specific type of innovation was introduced by a given startup during the past year. Following Rosenbusch et al. (2011) and the OECD's Oslo Manual (OECD, 2005), we distinguish between whether a start-up company innovated (1) within the company, by introducing a new or improved process—*new to the firm innovation*—or, (2) on the market, by introducing a novel product to the national or world market—*new to the market innovation*. Specifically, we capture 'new to the firm' innovation based on the survey question of whether the founder *had introduced any new—not used previously by the firm in question—processes in the production and provision of services* in a given year. We capture 'new to the market' innovation based on a two-stage question: in the first stage, founders were asked whether, in a given year, *they had introduced any products or services on the market which were new for their firm or which were significantly improved*. If this was the case, founders were then further asked whether *for any of these newly introduced products or services, they had been the first to introduce them on the global, the German, or their regional market*. Our study requires for a product or service to have been new to the national or international market so as to qualify as a 'new to the market' innovation. Following the OECD's Oslo Manual (OECD, 2005), new products or services can also qualify as innovations when they are only new for a firm yet not 'new to the market' (i.e., similar products or services have already been offered by other firms yet not by the firm in question). We address the relationship between founder age and 'new to the firm' product innovation and perform further sensitivity and robustness checks for the chosen innovation measures in Section 4.3. Most prominently, a potential caveat concerning our innovation measures is that they are self-reported and, therefore, might be subject to a degree of social desirability bias. If such a bias is more pronounced for older than for young individuals, this might confound our results. To address this problem, we use sales arising from 'new to the market' innovations from previous years as an additional indicator for checking the robustness of capturing innovation quality based on founders' subjective assessments.

The main *independent variable* in our models is (a), the *age of the founder*, measured in years. We use age in the year of innovation as a measure; and we include repeated innovations of entrepreneurs (available due to the panel dimension of our dataset) in order to include all information available and correlate it with the founder age that lies closest to the innovative activity. In robustness checks, we use the founder's age in the year of foundation as the main explanatory variable and analyze the relationship between the founder's age in the year of foundation and whether firms innovated at least once during our observation window. In addition to this main independent variable, we draw on (b), survey questions that capture a founder's self-assessed entrepreneurial orientation, in particular their *orientation to innovation*. The entrepreneurial orientation measures were previously applied and tested in the context of the IAB/ZEW Start-up Panel by Vaznyte and Andries (2019). Each of these questions consisted of two statements, the accuracy of which was to be rated against each other by the founders on a five-point scale ranging from "completely A" (e.g., low innovation orientation) to "completely B" (e.g., high orientation to innovation).[5] We transformed the items into ordinal variables reaching from 1 (completely A) to 5 (completely B), and constructed our measure as the maximum value of the two ordinal assessments. We decided on using the maximum values in order not to balance extremes in the founders' entrepreneurial orientations that might explain decision-making

[4] We were able to match labor market histories of about 80 % of the founders from the IAB/ZEW Start-up Panel. Since we do not expect all founders to have been previously employed in reportable employment, i.e., employment subject to social insurance in Germany (because, for example, they have always been self-employed or have immigrated), we consider this to be a very high ratio of matched individuals. In addition, we were able to match establishments to about 90 % of those firms that reported any employees subject to social insurance contributions in one of the interviews via a text-search algorithm. To exclude the possibility that selection effects induced by the data-matching affect our results, we double-checked our results with plain survey data where possible (see section on robustness checks and the online appendix). The results derived from the plain survey data and the matched sample are fully consistent.

[5] The questions are taken from a series of survey questions assessing founders' entrepreneurial orientation (for details, see Vaznyte and Andries, 2019). In the two questions on innovation orientation and the two questions on proactive behavior, founders had to rate two statements against each other on a five-point scale that included "completely A", "rather A", "undecided", "rather B", and "completely B". The first question on innovation orientation translates as: "*My company focuses on (A) marketing proven products or services, or (B) innovation, technology leadership, and research and development.*" The second question on innovation orientation translates as: "*I pursue a strategy to make (A) small, incremental changes, or (B) the most far-reaching, fundamental changes possible to my products or services.*" The first question on proactiveness translates as: "*In dealing with competition, my company pursues the strategy (A) to react to initiatives of the competition, or (B) to take the initiative itself, to which the competition must then respond.*" The second question on proactiveness translates as: "*When introducing new products or services, business processes or technologies, I want my company (A) to be not necessarily one of the first, or (B) to be one of the first.*" The first question on orientation to competitive aggressiveness translates as: "*My company (A) makes no special effort to steal sales from the competition, or (B) is very aggressive and competitive.*" The second question on orientation to competitive aggressiveness translates as: "*My company (A) avoids conflicts with competitors wherever possible and tends to follow the motto 'live and let live', or (B) does not shy away from conflict in order to dispute the market position of the competition.*" The first question on risk orientation translates as: "*In order to achieve corporate goals even in uncertain situations, my company acts (A) rather cautiously and takes a wait-and-see approach in order to avoid wrong decisions, or (B) acts rather courageously and offensively in order to avoid missing business opportunities.*" The second question on risk orientation translates as: "*My company has a strong tendency towards projects with (A) low risk and thus normal but safe returns, or (B) high risk and thus opportunities for very high returns.*" The first question on orientation to centralized decision-making translates as: "*I fundamentally believe that the best results occur when (A) employees have a say in deciding which business ideas and projects are pursued, or (B) I alone, as managing director, decide which business ideas and projects are pursued.*" The second question on orientation to centralized decision-making translates as: "*In my company (A) employees make decisions on their own without constantly checking back with me, or (B) employees must always check with me before making any decisions.*"

regarding innovation. We present fully consistent robustness checks when we construct measures as mean values of the ordinal assessments. Depending on the model specification, we condense the information in our five-point Likert-scales into binary indicators, set to '0' for innovation orientation below the median, and to '1' for median-or-above innovation orientation.

3.2.2. Control variables

Some of our analyses (see section on Method below) require *founder-level* and *firm-level/workforce-level* control variables. At the founder level, we control for a founder's qualities and assets available in the survey data, which include *gender*, whether the founder is of *non-German origin*, *educational level*, *managerial and entrepreneurial experience*, and whether the firm was *started with an opportunity motive* (e.g., because of a concrete business idea). By including measures for entrepreneurial orientation, we control for founders' self-assessed *orientation towards innovation*, *proactiveness*, *risk orientation*, *competitive behavior*, and *orientation towards centralization of decision-making*. In addition, we include details from a founder's *employment history* to proxy for founders' labor market success and breadth of experience. Measures include founders' *average wage before foundation*, *number of occupations before foundation*, *average number of employers per year before foundation*, and *average number of years in unemployment before foundation*.[6] When balancing our sample for robustness-check purposes (see sections on Method and Results), we add information on founders' employment history until the age of 35 and on the exact type of tertiary degree held. When exploring the mechanisms behind the effects of age, we add information on a founder's *private (net) wealth*, available for some waves of the survey.

At the firm and workforce level, we control for several attributes related to the size and strategy of the startup in order to understand the mechanisms through which founder age relates to innovation. Measures include *employment size*, *research and development spending relative to sales*, *firm age*, and *industry*. At the workforce level, we use survey information to account for the *share of employees with tertiary education* and *the share of full-time employees*. We add information from employees' employment histories to account for employees' *average wages within five years before working for the startup*, *share of female employees*, *share of non-German employees*, *share of employees with tertiary education*, and *average age of employees*.[7] In general, all values measured in euros (founder wages, employee wages, and innovation sales) are adjusted to 2015 prices by using a GDP deflator time-series for Germany.

3.3. Sample statistics

Our main regression sample consists of 8056 observations of 2903 solo founders between 2008 and 2017, for all of whom the included control variables are available. The panel is unbalanced, with an average of 2.78 observations per founder, and observation frequencies ranging from one to six observations.[8] We demonstrate the robustness of our results over different specifications of the sample in the Results section below. There exist no suspiciously high correlations between the explanatory variables of our models (see Table 1 for an illustration of pairwise correlations in our baseline sample). The mean VIF of our baseline model is 3.42.

Next, Table 2 reports summary statistics for the baseline sample at the firm-year level. In the online appendix we show aggregated summary statistics at the firm level (see Appendix Table A.1). Entrepreneurs' average likelihood of introducing a product that is new to the market in any given year is 0.08; their likelihood of introducing a process that is new to the firm in a year is 0.17. This suggests that, compared to successfully introducing 'new to the firm' process innovations, successfully introducing 'new to the market' innovations might require significantly more effort and/or be subject to higher uncertainty. Introducing both a 'new to the firm' product and a 'new to the firm' service in the same year occurs with a likelihood of 0.03—hence, a relevant share of product innovators simultaneously adjust processes.

Founders were on average 40.90 years old when founding their firms, and are on average 44.03 years old when observed in the panel data. Founder age ranges from 18 to 99 years, and the median age of founders in the sample is 44.[9] Around 26 % of observations are from founders older than 50 years of age. On Likert-scales reaching from 1 to 5, the sample average of innovation orientation is 2.84, the average self-assessed proactiveness 4.51, the average orientation to risk 3.38, the average competitive aggressiveness 3.14, and the average orientation to centralized decision-making 3.24. Therefore, founders' self-assessments of their orientations to innovation, risk, competitiveness, and centralization of decision-making appear well balanced, while they tend to assess their proactiveness as comparatively high.[10] 11 % of founders are female. This reflects the overall low number of female entrepreneurs in Germany, and is further reinforced by the over-representation of high-tech startups (in which female entrepreneurs are under-represented) in the sample of the IAB/ZEW Start-up Panel. We address the gender-related heterogeneity of our results in the exploratory analyses. 26 % of founders stated that they founded their firm explicitly because they had a concrete business idea they wanted to pursue (and not primarily because of other motives, such as working independently or lacking other employment options). Of the founders, 36 % hold a tertiary degree and have gathered significant experience: 30 % of entrepreneurs had already launched their own firm before, and 43 % of entrepreneurs had gained managerial experience as an employee prior to founding their present firm. Regarding their employment histories, founders had an average daily wage of slightly >100 euros a day and had held 4.77 different occupations before foundation. They worked on average for 0.58 employers per year and spent on average 0.92 years in unemployment.

[6] We consider the entire work history of founders so as not to exclude founders arbitrarily who were self-employed before starting their current venture (and who hence were not employed subject to social insurance contributions in Germany). As the wage data only contain daily wages but not hours worked in the case of part-time employment, we consider only full-time working spells when deriving average wages.

[7] As our main interest lies in the relationship between founder age and innovation, we impute missing values in employee characteristics so as not to reduce our sample arbitrarily by accounting for workforce characteristics. In order to avoid excluding businesses without employees from our analyses, workforce characteristics measured in shares of employees are set to zero. We impute missing values stemming from unmatched employment biographies of employees by way of sample averages. We control for imputed values in any regressions. Our results remain fully robust if we exclude unmatched firms instead of imputing values. To minimize the need to impute wage data for employees, unlike in the case for founders, we also consider part-time working spells for employees. For comparability of wages across employees, and in order to account for a lack of information on the exact hours worked, we multiply daily wages during part-time employment by two, and daily wages during minor employment ('mini-jobs') by five. In no case do we impute any information on the founders themselves.

[8] The panel is unbalanced as firms might cease to exist or, when firms continue to exist, due to non-response and an end to their participation in the survey. We perform consistency checks to test for the possibility that older founders are more likely to participate in the survey for longer and, therefore, might be more likely to report certain types of innovations in the Results section.

[9] In the year of foundation, of the 2903 founders in our sample 388 are below 30 years of age, 954 are between 30 and under 40 years of age, 970 are between 40 and under 50 years of age, and 591 are 50 or more years of age.

[10] We ensured the robustness of our results by excluding the proactiveness item from our models and found no considerable differences.

Table 1
Pairwise correlations of main variables in baseline sample ($N = 8056$).

	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	'New to the market' product in year	1								
(2)	'New to the firm' process in year	0.1577*	1							
(3)	'New to market' prod. & 'new to firm' proc. i.y.	0.5937*	0.3826*	1						
(4)	Age of founder in years	0.1036*	−0.0294*	0.0336*	1					
(5)	Female founder	−0.0363*	−0.0285*	−0.0133	0.0197*	1				
(6)	Founder of non-German origin	−0.0046	−0.0017	0.0007	−0.0927*	−0.0188*	1			
(7)	Founder with tertiary education	0.1302*	0.0436*	0.0774*	0.2569*	0.0139	−0.0202*	1		
(8)	Entrepreneurial experience	0.0810*	0.0505*	0.0584*	0.2153*	−0.0790*	0.0352*	0.1441*	1	
(9)	Managerial experience as employee	0.0242*	0.0220*	−0.0012	0.1014*	−0.0433*	−0.0699*	0.0914*	−0.1595*	1
(10)	Firm founded to leverage opportunity	0.1302*	0.0505*	0.0903*	0.0694*	0.0044	0.0049	0.1036*	0.0876*	−0.0096
(11)	Innovation orientation ≥ Median	0.2000*	0.1442*	0.1309*	0.0544*	−0.0450*	0.0450*	0.1299*	0.1178*	−0.004
(12)	Proactiveness ≥ Median	0.1082*	0.0750*	0.0660*	0.0568*	−0.0272*	0.0392*	0.0747*	0.0867*	0.0463*
(13)	Risk orientation ≥ Median	0.1162*	0.0848*	0.0894*	0.0605*	−0.0568*	0.0419*	0.1224*	0.1259*	0.0081
(14)	Competitiveness ≥ Median	0.0785*	0.0582*	0.0454*	0.0266*	−0.0006	0.0288*	0.0843*	0.0207*	0.0572*
(15)	Centralization ≥ Median	−0.0489*	−0.0277*	−0.0480*	−0.0287*	−0.0022	0.0363*	−0.0881*	−0.005	0.0125
(16)	Founder daily wage bef. foundation (log)	0.1204*	0.0178	0.0540*	0.4085*	−0.1634*	−0.1003*	0.3464*	0.0384*	0.2926*
(17)	Founder yearly no. of employers bef. found.	0.0149	0.0155	0.0181	−0.1891*	0.0340*	0.1138*	0.0328*	0.1008*	−0.1722*
(18)	Founder no. of occupations bef. foundation	0.0267*	−0.0138	−0.0045	0.1102*	−0.0122	0.0015	−0.0087	0.0374*	0.0087
(19)	Founder yearly days in unempl. bef. found.	−0.0487*	−0.0337*	−0.0333*	0.0645*	0.0523*	0.0695*	−0.1672*	0.0438*	−0.1294*
(20)	R&D intensity (R&D expenses/sales)	0.2168*	0.0888*	0.1470*	0.0642*	−0.0422*	−0.0107	0.1254*	0.1041*	−0.0116
(21)	FTE number of employees (log)	0.0556*	0.0831*	0.0543*	−0.0379*	−0.0188*	0.0363*	−0.0728*	0.0166	0.1255*
(22)	Share of full-time employees	0.0046	0.0496*	−0.0058	−0.0237*	−0.0682*	0.0292*	−0.0513*	0.0196*	0.0834*
(23)	Share of employees with tertiary education	0.1449*	0.1003*	0.1015*	0.1089*	0.0188*	−0.0153	0.3231*	0.0953*	0.0675*
(24)	Employee daily wage bef. startup (log)	0.0420*	0.0262*	0.0410*	0.0667*	−0.0503*	−0.0441*	0.0761*	0.0091	−0.0026
(25)	Share of non-German employees	0.0260*	0.015	0.0240*	−0.0307*	−0.0082	0.2031*	0.0417*	0.0295*	−0.0022
(26)	Share of female employees	0.0129	0.0395*	0.0073	0.0576*	0.0752*	−0.0074	0.0364*	−0.0104	0.1097*
(27)	Average age of employees	0.0182	−0.0237*	−0.0019	0.1948*	0.0143	−0.0486*	0.0647*	0.0028	0.0204*
(28)	Firm age in years	−0.0035	−0.0457*	0.0114	0.1729*	−0.0004	−0.0513*	0.0054	−0.0208*	0.0205*

	Variable	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
(10)	Firm founded to leverage opportunity	1								
(11)	Innovation orientation ≥ Median	0.1513*	1							
(12)	Proactiveness ≥ Median	0.0786*	0.1830*	1						
(13)	Risk orientation ≥ Median	0.0905*	0.2358*	0.2179*	1					
(14)	Competitiveness ≥ Median	0.0663*	0.1718*	0.1973*	0.1773*	1				
(15)	Centralization ≥ Median	−0.0227*	−0.0199*	−0.0119	−0.0096	0.0290*	1			
(16)	Founder daily wage bef. foundation (log)	0.0654*	0.0865*	0.0491*	0.0835*	0.0526*	−0.0980*	1		
(17)	Founder yearly no. of employers bef. found.	0.0501*	0.0505*	0.0483*	0.0648*	0.0318*	0.0419*	−0.2853*	1	
(18)	Founder no. of occupations bef. foundation	0.0158	0.0436*	0.0650*	0.0948*	0.0590*	−0.0121	0.0346*	0.1834*	1
(19)	Founder yearly days in unempl. bef. found.	0.0033	−0.0439*	−0.003	−0.0201*	−0.0227*	0.0521*	−0.2564*	0.2204*	0.3953*
(20)	R&D intensity (R&D expenses/sales)	0.1517*	0.1534*	0.0658*	0.1049*	0.0417*	−0.0275*	0.0784*	0.0319*	0.008
(21)	FTE number of employees (log)	−0.0018	0.0437*	0.0808*	0.0326*	0.1267*	−0.0419*	0.0069	−0.0544*	−0.0606*
(22)	Share of full-time employees	−0.0002	0.0251*	0.0557*	0.0022	0.0746*	−0.0123	0.0098	−0.0400*	−0.0891*
(23)	Share of employees with tertiary education	0.0822*	0.1416*	0.0607*	0.1353*	0.0541*	−0.0532*	0.1731*	−0.0015	−0.0263*
(24)	Employee daily wage bef. startup (log)	0.0272*	0.0591*	0.0025	0.0301*	0.0051	−0.0348*	0.1303*	−0.0182	−0.0025
(25)	Share of non-German employees	0.0176	0.0352*	0.0261*	0.0605*	0.0301*	0.0203*	−0.0037	0.0282*	−0.0002
(26)	Share of female employees	−0.0083	−0.0287*	0.0316*	0.0119	0.0695*	−0.0255*	0.0884*	−0.0631*	−0.0229*
(27)	Average age of employees	0.0393*	0.0048	−0.0023	−0.0067	0.0019	0.012	0.0655*	−0.0367*	0.0114
(28)	Firm age in years	0.0095	−0.0542*	−0.0360*	−0.0329*	−0.0321*	−0.0137	0.0491*	−0.0378*	−0.0906*

	Variable	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
(19)	Founder yearly days in unempl. bef. found.	1								
(20)	R&D intensity (R&D expenses/sales)	−0.0366*	1							
(21)	FTE number of employees (log)	−0.0361*	−0.0472*	1						
(22)	Share of full-time employees	−0.0469*	−0.0219*	0.7018*	1					
(23)	Share of employees with tertiary education	−0.1074*	0.1020*	0.1748*	0.1225*	1				
(24)	Employee daily wage bef. startup (log)	−0.0407*	0.0414*	−0.0572*	0.0072	0.0273*	1			
(25)	Share of non-German employees	0.0082	0.0024	0.1686*	0.1234*	0.0839*	−0.0487*	1		
(26)	Share of female employees	−0.0695*	−0.0295*	0.2645*	0.1300*	0.1836*	−0.1567*	0.1051*	1	
(27)	Average age of employees	0.0205*	0.0071	−0.0716*	−0.0307*	0.0063	0.1867*	−0.0362*	0.1180*	1
(28)	Firm age in years	−0.0315*	−0.0625*	0.0929*	0.0524*	0.0173	−0.0148	−0.0006	0.0419*	0.0148

Notes: Significance levels: * 10 %; Additional control variables in all regressions industry and year dummies, funding by KfW Bank, control variables for missing values in employee characteristics, control variables for zero values in employee characteristics measured in shares of employees. Source: IAB/ZEW Start-up Panel.

The included startups were on average 3.79 years old when observed. Founders invest an average of 4 % of their sales in R&D. In 64 % of cases founders employ (dependent) employees, while the average full-time equivalent (FTE) employment size is 2.37 employees. Of the employees, on average 24 % are regular full-time employees, 16 % hold a tertiary degree, 4 % are non-German, and 24 % female. Employees are on average 39.41 years old. Hence, on average, employees are 4–5 years younger than the firms' founders, and more than twice as likely to be

Table 2
Summary statistics of baseline sample (N = 8056).

Variable	Scale	Mean	SD	Min	Max
'New to the market' product in year	y/n	0.08	0.27	0.00	1.00
'New to the firm' process in year	y/n	0.17	0.37	0.00	1.00
'New to the market' and 'new to the firm' innov.	y/n	0.03	0.17	0.00	1.00
Age of founder in years	Years	44.03	9.79	18.00	99.00
Female founder	y/n	0.11	0.31	0.00	1.00
Founder of non-German origin	y/n	0.07	0.25	0.00	1.00
Founder with tertiary education	y/n	0.38	0.48	0.00	1.00
Entrepreneurial experience	y/n	0.29	0.45	0.00	1.00
Managerial experience as employee	y/n	0.45	0.50	0.00	1.00
Firm founded to leverage opportunity	y/n	0.26	0.44	0.00	1.00
Orientation to innovation	Likert scale	2.84	1.66	1.00	5.00
Innovation orientation $\geq$ Median	y/n	0.52	0.50	0.00	1.00
Proactiveness	Likert scale	4.51	1.00	1.00	5.00
Proactiveness $\geq$ Median	y/n	0.75	0.43	0.00	1.00
Orientation to risk	Likert scale	3.38	1.58	1.00	5.00
Risk orientation $\geq$ Median	y/n	0.51	0.50	0.00	1.00
Competitiveness	Likert scale	3.14	1.69	1.00	5.00
Competitiveness $\geq$ Median	y/n	0.59	0.49	0.00	1.00
Centralization	Likert scale	3.24	1.63	1.00	5.00
Centralization $\geq$ Median	y/n	0.63	0.48	0.00	1.00
Founder daily wage bef. foundation	Euros	104.40	39.93	5.58	194.84
Founder daily wage bef. found. (log)	Logged euros	4.56	0.45	1.72	5.27
Founder yearly no. of employers bef. found.	Count/years	0.54	0.62	0.03	17.39
Founder no. of occupations bef. found.	Count	4.61	2.39	1.00	19.00
Founder years in unemployment bef. found.	Count/years	0.84	1.46	0.00	15.81
R&D intensity (R&D expenses/sales)	R&D expenses/sales	0.04	0.21	0.00	2.67
FTE number of employees	Weighted count	2.37	6.03	0.00	175.50
FTE number of employees (log)	Logged weighted count	−0.10	1.36	−1.50	5.17
Share of full-time employees	Share	0.24	0.34	0.00	1.00
Share of employees with tertiary education	Share	0.16	0.32	0.00	1.00
Employee daily wage bef. startup	Euros	74.59	22.52	0.00	196.57
Employee daily wage bef. startup (log)	Logged euros	4.26	0.39	0.00	5.29
Share of non-German employees	Share	0.04	0.12	0.00	1.00
Share of female employees	Share	0.24	0.31	0.00	1.00
Average age of employees	Years	39.41	6.38	15.98	75.29
Firm age in years	Years	3.79	1.55	2.00	7.00
High-technology manufacturing	y/n	0.12	0.32	0.00	1.00
Technology-intensive services	y/n	0.24	0.43	0.00	1.00
Software supply and consultancy	y/n	0.05	0.22	0.00	1.00
Non-high-tech manufacturing	y/n	0.14	0.35	0.00	1.00
Skill-intensive services	y/n	0.10	0.29	0.00	1.00
Other business-oriented services	y/n	0.08	0.27	0.00	1.00
Cons.-or. services in creative sect.	y/n	0.04	0.20	0.00	1.00
Consumer-oriented services	y/n	0.03	0.17	0.00	1.00
Construction	y/n	0.14	0.35	0.00	1.00
Retail & wholesale	y/n	0.06	0.24	0.00	1.00

Notes: Additional control variables in all regressions: year dummies, funding by KfW Bank, control variables for missing values in employee characteristics, control variables for zero values in employee characteristics measured in shares of employees. Source: IAB/ZEW Start-up Panel.

female. The employees' average daily wage in the last five years prior to working for the startup is 74.59 euros.[11]

Observations are split relatively equally between firms in high-tech sectors (overall 41 %; 12 % in manufacturing, 29 % in services) and firms in more traditional industries (overall 59 %; 14 % in manufacturing, 45 % in services). We exploit this equal split of startups to explore effect heterogeneity across industries.

3.4. Method

We estimate models of the stylized form

$$Innovation_{it} = \alpha + \beta^{*}FounderAge_{it} + \boldsymbol{X_{it}}^{*}\boldsymbol{\gamma} + \epsilon_{it}$$

where $Innovation_{it}$ refers to firm i's innovation outcome in period t, either with respect to 'new to the market' product innovation, 'new to the firm' process innovation, 'new to the firm' product innovation, or innovation sales. $FounderAge_{it}$ denotes a founder's age in period t, X_{it} is a specification-dependent vector of time-constant and time-varying covariates. α, β, and the vector γ are parameters to be estimated and ϵ_{it} denotes an idiosyncratic error term.

As our main observed dependent variables are binary indicators of whether a specific type of innovation (i.e., 'new to the market' product innovation, 'new to the firm' process innovation, and 'new to the firm' product innovation) is introduced by a firm in any given year, we use probit estimates as baseline models. In the probit models, the dependent variable is the unobserved latent probability of innovation $Innovation_{it}^{*}$, our observed binary indicators of the introductions of innovations take a value of 1 when the latent variable is larger than 0, and a value of 0 otherwise. As our panel dimension is too short (on average under three observations per entrepreneur) to be able to exploit meaningful age differences from variation within founders, we estimate pooled models with standard errors that are robust to clustering at the level of the firm. Finally, we estimate ordinary least squares models with standard errors that are robust to clustering at the firm level whenever we use innovation sales as dependent variable.

[11] Due to differences in construction of the wage measures with respect to the covered time frame and the inclusion of part-time employment spells, employees' and founders' wages are not directly comparable (see footnote above).

We interpret the 'effect' of age as a correlate of a variety of factors, such as education, experience, financial means, or social capital, but also personal incentives and motives that might change the probability to select moving into entrepreneurship over the course of a lifetime. By its nature, the age 'effect' is therefore a mix of 'treatment effects' of age (e.g., abilities that grow or decline with age) and 'selection effects due to age' (e.g., incentives to engage in (innovative) entrepreneurship that change over the course of a life). Whether any of these effects should be controlled for in an empirical model therefore depends on the intended statement. For instance, when aiming to understand whether older entrepreneurs are more or less able to generate innovation from a given set of resources, we would want to control for the resources employed in a firm (e.g., investment into R&D). If we aim to understand whether older founders are more or less innovative overall, we would not want to control for intermediate, strategy-related outcomes (e.g., investment in R&D or choice of employees), which themselves might depend on founder age. Therefore, our empirical strategy relies on first analyzing the unconditional 'overall' relationship between founder age and different types of innovation (i.e., the 'raw' correlation between founder age and innovation measures, without the inclusion of control variables), before consecutively adding control variables for industry and age of firm, founders' gender, education, and experience, firm strategy and workforce, and founders' private financial resources in order to explore the mechanisms behind the overall effects.

To assess the influence of non-randomness of the selection of moving into entrepreneurship/self-employment at a different age (if, for example, more or less competent individuals become founders at a higher age, this might explain differences in innovation outcomes), we simulate a quasi-experimental setting by using entropy balancing to balance two groups of founders over a wide range of observable characteristics (Hainmueller, 2011; Hainmueller and Xu, 2013). This permits us statistically to generate a synthetic control group to an otherwise comparable treatment group of individuals based on observable characteristics of the founders. Specifically, we compare the innovations created by start-up companies established by founders who are between 36 and 49 years of age, to startups of founders who are between 50 and 63 years of age, and we balance the two samples over characteristics of the founders at the age of 35. We choose the age of 35 as a cut-off because education (even when pursuing a PhD) is usually accomplished by 35 and individuals have entered the labor market. This allows us to generate meaningful measures from individuals' employment biographies that do not further change endogenously with the founder's age. As such, we make the groups of young and old founders statistically comparable—according to the specified characteristics at the age of 35—and evaluate a treatment effect of 15 years of further aging before the focal firm is founded. While this setting does not exclude the influence of additional unobserved factors that force selection into entrepreneurship or cohort effects, we consider this to be a very rigorous control method to grasp the mechanisms behind our results. We describe details below.

4. Results

4.1. Descriptive analysis: relationship between founder age and innovations

We start with a descriptive analysis of the unconditional relationship between age and innovation (i.e., without the inclusion of control variables). In Fig. 1, we depict the unconditional relationship between founder age and 'new to the market' product innovation (upper panel) and 'new to the firm' process innovation (lower panel) by using sampling weights to correct for the stratification criteria of our panel data. The plotted values are predicted from linear probability models of 'new to the market' product and 'new to the firm' process innovations on both a linear and a squared term of age. The squared term is not significant in either of the models.

We find that there exists a positive relationship between founder age and 'new to the market' product innovation; and a negative relationship between founder age and 'new to the firm' process innovation. Both relationships show continuous trends (upward-sloping for 'new to the market' product innovations, and downward-sloping for 'new to the firm' process innovations). In the online appendix (Appendix Fig. A.1; upper panel for 'new to the market' innovations), we split the sample into 10-year bins of age to analyze the evolution of the age effect in the various age groups and provide non-parametric evidence of the relationship between founder age and innovation in our sample through binned scatterplots. Consistent with the previous analysis and the insignificance of the squared term of age in the multivariate models, we find a steady evolution of the effect of age on 'new to the market' innovations, with a slightly stronger age effect for age groups between 45 and 65. This provides some evidence that the likelihood of late-career entrepreneurs bringing new product/service innovations to the market continues to increase. However, the variance of the likelihood of introducing 'new to the market' innovations also appears to increase for older founders. We further explore this heterogeneity in the following.

4.2. Multivariate analysis: founder age and innovations across specifications

In order to understand the robustness of the relationships (graphically identified above) and the mechanisms that underlie them, we turn to multivariate analyses and subsequently add sets of control variables to our models. In the 'A' columns of Table 3 (for 'new to the market' product innovation) and Table 4 (for 'new to the firm' process innovation), we show estimates for founder age when we control only for firm age, as well as year and industry fixed effects, to correct for stratification and the most basic market entry decisions. In the 'B' columns we add squared founder age as an additional explanatory variable so as to allow for a non-linear relationship between founder age and innovation outcomes. In the 'C' columns we add controls for the founders' human capital and their labor market histories and entrepreneurial orientation. In the 'D' columns we add controls for firm-level outcomes and strategies which might directly influence innovation outcomes (R&D intensity, the number of employees, and details on the workforce structure). Finally, in the online appendix in Table A.2 (columns C and E), we repeat the estimates with the full set of controls, but lag measures for R&D intensity and workforce characteristics by one period as a robustness check of the potentially endogenous nature of both variables.

Importantly, across all specifications, we find a significant positive relationship between age and 'new to the market' product innovation, and a significant negative relationship between founder age and 'new to the firm' process innovation. Depending on the model specification, one additional year of age corresponds to an 0.24 (only controlling for firm age, year, and industry) to 0.15 (controlling for the full set of controls) percentage point increase in the likelihood of introducing a 'new to the market' innovation ($p < 0.01$). Hence, a founder who is ten years older than the sample average of 44 years has, on average, a 30.0 % to 18.8 % higher likelihood to introduce a 'new to the market' innovation successfully (from the sample average of 0.08). In contrast, one additional year of age corresponds to an 0.13 to 0.17 percentage point decrease (7.6 to 10.0 % decrease over ten years from the sample average of 17 %) in the likelihood of introducing a 'new to the firm' process ($p <$ 0.01–0.05). For both innovation outcomes, we detect no evidence for a significant non-linearity of the relationship with founder age.

Turning to the control variables, as companies become older, their likelihood of pursuing innovative activities decreases. In line with the idea that innovation results from a recombination of knowledge, skills, and experience—and is therefore primarily a human capital exercise—measures for founders' tertiary education, pre-foundation wages, and variety of experiences relate positively and significantly to 'new to the market' innovations. In contrast, the founders' average years in unemployment relate significantly and negatively to innovation.

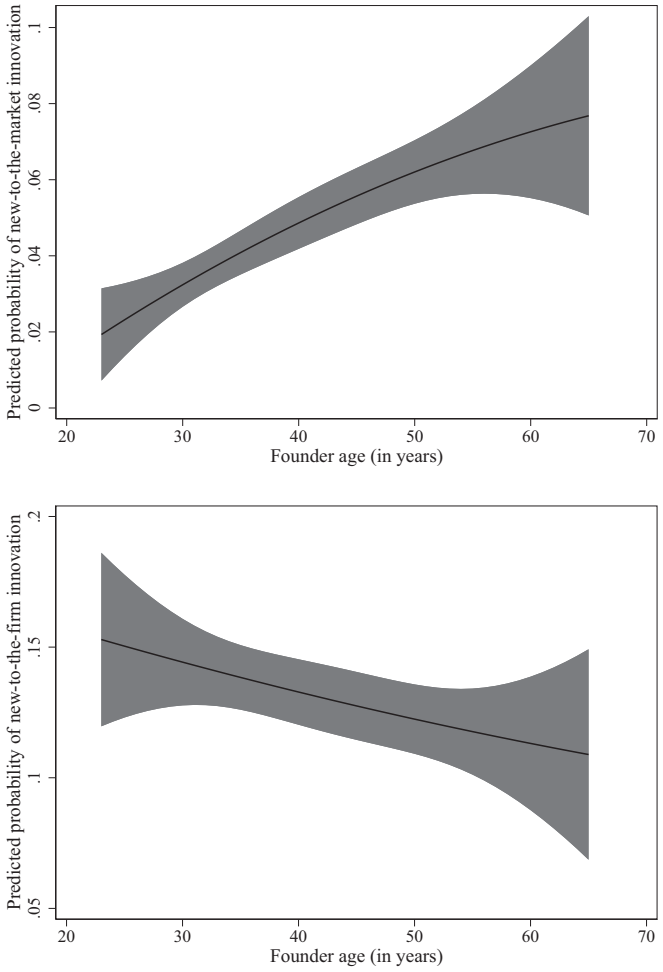

Fig. 1. Unconditional relationship between founder age and different types of innovation

Notes: The graph shows the relationship between founder age and the probabilities of introducing any 'new to the market' product innovation (upper panel) and 'new to the firm' process innovation (lower panel) in a year in the full data of the IAB/ZEW Start-up Panel ($N = 29{,}308$ for 'new to the market' product innovations and $N = 21{,}297$ for 'new to the firm' process innovations). Probabilities are predicted from unconditional weighted linear probability models, i.e., regressing innovation outcomes of solo founders on a linear and a squared term of founder age without further control variables. The sampling weights are chosen in order to correct for the stratification criteria of the IAB/ZEW Start-up Panel. Source: IAB/ZEW Start-up Panel.

Turning to the founders' entrepreneurial orientations and motivations, ranking median or above in terms of innovation orientation stands out as explanatory factor for 'new to the market' innovation in both economic and statistical terms. We note that while opportunity motivation and median or higher proactiveness and risk orientation are also significantly and positively related to introducing 'new to the market' innovations, orientation to centralized decision-making relates significantly and negatively to this type of innovation. Firm-level measures for R&D intensity, as well as the firm size measured in logarithmic full-time equivalent employment, are positively and significantly related to 'new to the market' innovation. Again, consistent with the view of innovation as a (re-)combinative human capital exercise, the share of employees with tertiary education also relates significantly and positively to 'new to the market' innovation. In contrast, the relationship with the share of full-time employees is negative and significant, which might be explained by more full-time employees indicating a loss of flexibility in resource allocation or a shift of the founder's' priorities from innovation to scaling.

In contrast, founders' human capital seems rather less relevant in explaining 'new to the firm' process innovation, which is mainly explained by positive relationships with median or higher innovation orientation, proactiveness, and risk orientation, as well as higher R&D intensity and larger and more educated workforces. Moreover, more diverse workforces, with a higher share of female employees, relate positively and significantly to the introduction of 'new to the firm' processes, while the opposite holds true for workforces that are on average older.

4.3. Sensitivity and robustness checks

In the following, we assess the sensitivity of our results with respect to our measures for innovation, selection into entrepreneurship, and empirical choices regarding methods, measures, and sample definitions.

4.3.1. Measures

First, we assess the robustness of our results in regard to contrasting 'new to the market' product innovation and 'new to the firm' process innovation by also analyzing 'new to the firm' product innovation (see online Appendix, columns A-C in Table A.3). As discussed in the theoretical section above, in our study we contrast process improvement within the firm and product improvements on the market as distinct types of innovations. We understand product innovations that are only novel at the firm level as a middle ground.[12] Our results are consistent with the notion that 'new to the firm' product innovations are an intermediate type of innovation, with a theoretically less clear relationship to founder age. When we include new products in the measure for 'new to the firm' innovation, the relationship to founder age remains negative yet turns insignificant. If we estimate the relationship between founder age and product innovations that are new to the firm (but not to the market), we detect a positive but insignificant relationship to founder age. Finally, if we construct a measure for product innovations that need to be at least new to the firm (but include 'new to the market' innovations), the relationship to founder age is positive and significant yet statistically weaker than the relationship between founder age and (only) 'new to the market' innovations.[13]

Second, we use sales arising from innovations from previous years as an additional innovation indicator for the purpose of checking robustness (see online Appendix: columns D and E of Table A.3). This helps us abstract from founders' subjective assessments of their introductions of 'new to the market' innovations, thereby reducing a possible social

[12] Similarly to 'new to the market' innovations, 'new to the firm' product innovations are directed to the outside by offering a new or improved product on the market. However, they increase product variety on the market only to a limited extent since similar products are already offered by other firms. Therefore, we expect product innovations that are only novel at the firm level to be of lower societal value and to promise lower margins than 'new to the market' innovations.

[13] Due to the design of the questionnaire, we also face a number of restrictions regarding the availability of the different innovation measures in the data. First, as firms are assumed to introduce processes and products that are new to the firm usually in their year of foundation, items on 'new to the firm' services and products are only included in the survey from the second year onward. This might lead to an underreporting of innovation activities, e.g., when the risk involved in innovative companies leads to a higher likelihood of early failure. Importantly, questions on 'new to the market' products———our main variable of interest———are also available for the year of foundation (thus reducing the two-step question described above into a single step). To allow for the comparability of the presented marginal effects across the different innovation measures, we consolidate our samples and do not include the year of foundation in our main multivariate models. We include 'new to the market' innovations in the year of foundation in our initial unconditional results, and we have checked robustness in multivariate models. The results for 'new to the market' product innovations remain fully consistent once the year of foundation is included.

Table 3
Conditional effects of founder age on 'New to the market' product innovations.

	A	B	C	D	E
Dependent variable:	'New to the market' product	'New to the market' product	'New to the market' product	'New to the market' product	'New to the market' product
Method:	Probit	Probit	Probit	Probit	Probit
	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)
Age of founder in years	0.0024 (0.0004)***	0.0060 (0.0024)**	0.0014 (0.0004)***	0.0015 (0.0004)***	0.0015 (0.0004)***
Age of founder in years squared		−0.0000 (0.0000)			
Innovation orientation ≥ Median			0.0810 (0.0086)***	0.0717 (0.0081)***	0.0656 (0.0066)***
Age * Innovation orientation ≥ Median					0.0019 (0.0007)***
Female founder			−0.0172 (0.0125)	−0.0181 (0.0123)	−0.0177 (0.0123)
Founder of non-German origin			0.0036 (0.0133)	0.0071 (0.0130)	0.0078 (0.0130)
Founder with tertiary education			0.0271 (0.0080)***	0.0173 (0.0079)**	0.0176 (0.0079)**
Entrepreneurial experience			0.0089 (0.0077)	0.0045 (0.0074)	0.0046 (0.0074)
Managerial experience as employee			0.0010 (0.0074)	0.0002 (0.0072)	0.0002 (0.0072)
Firm founded to leverage opportunity			0.0328 (0.0075)***	0.0269 (0.0072)***	0.0268 (0.0072)***
Proactiveness ≥ Median			0.0458 (0.0111)***	0.0429 (0.0105)***	0.0429 (0.0105)***
Competitiveness ≥ Median			0.0105 (0.0077)	0.0084 (0.0074)	0.0085 (0.0074)
Risk orientation ≥ Median			0.0231 (0.0079)***	0.0157 (0.0075)**	0.0157 (0.0075)**
Centralization ≥ Median			−0.0153 (0.0073)**	−0.0128 (0.0070)*	−0.0126 (0.0070)*
Founder daily wage before foundation (log)			0.0323 (0.0110)***	0.0302 (0.0103)***	0.0304 (0.0103)***
Founder yearly no. of employers bef. found.			0.0106 (0.0049)**	0.0104 (0.0047)**	0.0105 (0.0047)**
Founder no. of occupations bef. found.			0.0031 (0.0015)**	0.0028 (0.0015)*	0.0030 (0.0015)**
Founder years in unemployment bef. foundation			−0.0079 (0.0032)**	−0.0069 (0.0029)**	−0.0070 (0.0029)**
R&D intensity (R&D expenses/sales)				0.0597 (0.0100)***	0.0593 (0.0099)***
FTE number of employees (log)				0.0161 (0.0042)***	0.0160 (0.0042)***
Share of full-time employees				−0.0612 (0.0139)***	−0.0611 (0.0139)***
Share of employees with tertiary education				0.0433 (0.0094)***	0.0430 (0.0094)***
Employee daily wage bef. startup (log)				0.0048 (0.0077)	0.0048 (0.0078)
Share of non-German employees				0.0051 (0.0261)	0.0047 (0.0260)
Share of female employees				−0.0209 (0.0142)	−0.0213 (0.0142)
Average age of employees				0.0001 (0.0005)	0.0001 (0.0005)
Firm age in years	−0.0065 (0.0024)***	−0.0067 (0.0024)***	−0.0011 (0.0023)	−0.0006 (0.0022)	−0.0005 (0.0022)
Industry & year fixed effects	Yes	Yes	Yes	Yes	Yes
N / Pseudo R-sq.	8056 / 0.0766	8056 / 0.0773	8056 / 0.1848	8056 / 0.2129	8056 / 0.2136

Notes: Significance levels: *** 1 %, ** 5 %, * 10 %; marginal effects from pooled probit models; cluster-robust standard errors in parentheses; additional control variables in all regressions: funding by KfW Bank and control variables for missing and zero values in employee characteristics. Source: IAB/ZEW Start-up Panel.

desirability bias in answering survey items on the introductions of such novelties. Ten additional years of age are associated with approximately 35,200 euros' worth of higher sales of innovations (an increase of about 26 % from the sample average of 134,064 euros). Consistent with our previous results, older entrepreneurs not only bring more innovations with high degrees of novelty to the market but also those that sell better—which is additional evidence for the economic relevance of late-career entrepreneurs' innovative activity.[14]

4.3.2. *Selecting into entrepreneurship at an older age*

We understand the 'effect' of founder age to be a correlate of various factors, such as social, human, or financial capital, and selection effects that might motivate individuals to become entrepreneurs at different ages. Therefore, we gradually increase the level of control to understand the mechanisms behind the age 'effect' and, at its most extreme, we simulate an experimental setting using entropy balancing. As described above, we condition on founders' characteristics, education, and employment history until the age of 35 by balancing our sample, and compare 'younger' founders, who launch their firms between the ages of 36 and 49, to 'older' founders launching their firms between 50 and 63 years of age. Explicitly, we balance over the means of being female, being of non-German origin, holding a tertiary degree from a university of applied sciences, holding a tertiary degree from a university, holding a PhD, whether founders had reached a managerial position by the age of 35, their average daily wage before the age of 35, their average number of employers per year before the age of 35, their accumulated years in employment before the age of 35, and their accumulated years in unemployment before the age of 35. Comparing older and younger founders before balancing reveals that those who found a firm at an older age are distinctly more likely to be female and hold a university degree or PhD, and to have spent distinctly less time in unemployment before the age of 35. Moreover, they were paid slightly higher wages and were slightly more likely to have reached a managerial position by the age of 35. After balancing these differences vanish. In this strongly controlled setting, which, in addition to the balancing, includes all prior control variables, we still find positive and significant relationships between being an older entrepreneur and 'new to the market' innovations as well as innovation sales (columns A and C of Table 5). In contrast, the negative relationship between founder age and 'new to the firm' process innovation vanishes (column B of Table 5). The latter result should be qualified by the results on age effects over the age distribution (see Appendix Fig. A.1). In the experimental setting, only founders who enter entrepreneurship above the age of 35 and below the age of 64 remain within the sample. Hence, we omit age cohorts with

[14] A further argument against a strong impact of social desirability bias on the presented results arises from the presented opposite directions of the relationships between age and 'new to the firm' innovation and age and 'new to the market' innovation. If differences in social desirability bias over the founder age distribution drive our results, such differences would have to work in opposite ways for the two different types of innovations to explain our results. We regard this as unlikely.Information on innovation sales is only available if a company reports any new products—either 'new to the firm' or 'new to the market'—in one year and subsequently takes part in the survey again in the following year (i.e., only founders who reported innovations are subsequently asked questions on innovation sales). As this increases concerns regarding sample attrition, we only use the information on innovation sales for robustness-check purposes.

Table 4
Conditional effects of founder age: 'New to the firm' process innovations.

	A	B	C	D	E
Dependent variable:	'New to the firm' process	'New to the firm' process	'New to the firm' process	'New to the firm' process	'New to the firm' process
Method:	Probit	Probit	Probit	Probit	Probit
	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)
Age of founder in years	−0.0013 (0.0005)**	0.0007 (0.0034)	−0.0019 (0.0006)***	−0.0017 (0.0006)***	−0.0017 (0.0006)***
Age of founder in years squared		−0.0000 (0.0000)			
Innovation orientation ≥ Median			0.0775 (0.0110)***	0.0699 (0.0108)***	0.0697 (0.0107)***
Age * Innovation orientation ≥ Median					0.0009 (0.0010)
Female founder			−0.0147 (0.0186)	−0.0164 (0.0186)	−0.0161 (0.0186)
Founder of non-German origin			−0.0182 (0.0202)	−0.0204 (0.0199)	−0.0196 (0.0199)
Founder with tertiary education			0.0076 (0.0123)	−0.0007 (0.0124)	−0.0003 (0.0125)
Entrepreneurial experience			0.0281 (0.0121)**	0.0213 (0.0120)*	0.0210 (0.0121)*
Managerial experience as employee			0.0200 (0.0109)*	0.0145 (0.0109)	0.0150 (0.0109)
Firm founded to leverage opportunity			0.0094 (0.0117)	0.0068 (0.0116)	0.0066 (0.0116)
Proactiveness ≥ Median			0.0376 (0.0134)***	0.0343 (0.0131)***	0.0341 (0.0131)***
Competitiveness ≥ Median			0.0198 (0.0112)*	0.0132 (0.0111)	0.0134 (0.0111)
Risk orientation ≥ Median			0.0307 (0.0111)***	0.0240 (0.0109)**	0.0242 (0.0109)**
Centralization ≥ Median			−0.0141 (0.0107)	−0.0094 (0.0106)	−0.0092 (0.0106)
Founder daily wage bef. foundation (log)			−0.0091 (0.0152)	−0.0145 (0.0150)	−0.0134 (0.0151)
Founder yearly no. of employers bef. found.			0.0004 (0.0072)	0.0011 (0.0073)	0.0015 (0.0073)
Founder number of occupations bef. found.			−0.0017 (0.0023)	−0.0014 (0.0023)	−0.0013 (0.0023)
Founder years in unemployment bef. foundation			−0.0029 (0.0041)	−0.0015 (0.0040)	−0.0015 (0.0040)
R&D intensity (R&D expenses/sales)				0.0490 (0.0185)***	0.0479 (0.0184)***
FTE number of employees (log)				0.0184 (0.0061)***	0.0182 (0.0061)***
Share of full-time employees				−0.0140 (0.0181)	−0.0146 (0.0181)
Share of employees with tertiary education				0.0482 (0.0152)***	0.0475 (0.0152)***
Employee daily wage bef. startup (log)				0.0182 (0.0157)	0.0181 (0.0158)
Share of non-German employees				−0.0187 (0.0363)	−0.0193 (0.0362)
Share of female employees				0.0371 (0.0204)*	0.0365 (0.0205)*
Average age of employees				−0.0013 (0.0008)*	−0.0013 (0.0008)*
Firm age in years	−0.0138 (0.0034)***	−0.0139 (0.0034)***	−0.0083 (0.0034)**	−0.0095 (0.0034)***	−0.0094 (0.0034)***
Industry & year fixed effects	Yes	Yes	Yes	Yes	Yes
N / Pseudo R-sq.	8056 / 0.032	8056 / 0.0321	8056 / 0.0588	8056 / 0.0711	8056 / 0.0715

Notes: Significance levels: *** 1 %, ** 5 %, * 10 %; marginal effects from pooled probit models; cluster-robust standard errors in parentheses; additional control variables in all regressions: funding by KfW Bank and control variables for missing and zero values in employee characteristics. Source: IAB/ZEW Start-up Panel.

comparably strong reductions in the likelihood of introducing 'new to the firm' process innovation in this setting.

In a nutshell, despite an increasing level of statistical control—and concomitant increase in the comparability of founders and their strategies—we do not find evidence that the effect of founder age on 'new to the market' innovations is mainly driven by selection effects that arise from individuals with higher capabilities selecting to move into entrepreneurship at an older age. It is important to note that while, on the one hand, such a high level of statistical control might even be unwanted depending on the 'effect' of age of interest (see Method section for a discussion), on the other hand, we cannot exclude that further unobservable factors explain founders' selection into entrepreneurship. Nevertheless, based on the presented evidence we consider changes in individual ability and incentives over the course of a life as the most influential drivers of the relationship between founder age and innovation. This is corroborated by the highly stable statistical relevance of the coefficient of founder age across all presented models (independently of the included control variables).

4.3.3. Further sensitivity and robustness checks

In the following, we assess the robustness of our results regarding various changes in model specifications and sample specifications (see online Appendix Tables A.2, A.4, and A.5). Our results remain fully robust if we simultaneously estimate 'new to the firm' and 'new to the market' innovations by seemingly unrelated bivariate probit regressions to account for potential interdependencies between the introduction of new processes and new products (columns A and B in online Appendix Table A.2); lift sample restrictions by only including control variables that are regularly contained in the survey panel data to diminish the probability that selection effects stemming from reductions in sample size due to missing values or matching data from different sources affect our results (columns D and F in online Appendix Table A.2); derive the entrepreneurial orientation measures as mean values of the two survey items instead of maximum values to exclude the possibility that our choice of constructions affects the results (columns A and D in online Appendix Table A.4); and not only control for year and industry-fixed effects but also for their interactions to capture industry-variant time-varying economic trends (columns B and E in online Appendix Table A.4).

Furthermore, we assess the sensitivity of our results across five broad industries (high-tech manufacturing, high-tech services and software, conventional manufacturing, construction, and conventional services and retail). We find no significant industry-dependent differences in the relationship between founder age and 'new to the market' innovations, while the relationship between age and 'new to the firm' process innovations is not stable in either construction or low-tech services/retail (columns C and F in online Appendix Table A.4). Finally, we find that all results remain robust when we do not consider firms repeatedly but consolidate our sample to one observation per firm and assess the relationship between founder age in the year of foundation and whether the firm ever introduces an innovation (columns A and D in online Appendix Table A.5). Similarly, we find that our results are robust if we include teams of founders in our analysis and measure founder age either by the average age of the founders (columns B and E in online Appendix Table A.5) or the age of the oldest founder in the team (columns C and F in online Appendix Table A.5). While including teams demonstrates the generalizability of our results beyond the context of solo founders, the former robustness check is chosen to exclude the

Table 5
Synthetic control approach: Results after entropy balancing.

	A	B	C
Dependent variable:	'New to the market' product	'New to the firm' process	Innovation sales
Method:	Probit	Probit	Probit
	M.E. (S.E.)	M.E. (S.E.)	M.E. (S.E.)
Late-career entrepreneur (≥ 50 years at startup)	0.029 (0.013)**	0.003 (0.015)	82,960.022 (32,171.696)**
Female founder	−0.017 (0.020)	0.009 (0.026)	−73,753.436 (33,672.523)**
Founder of non-German origin	0.005 (0.029)	0.005 (0.035)	2476.347 (38,946.880)
Founder with tertiary education	0.013 (0.015)	−0.024 (0.018)	21,270.685 (42,006.493)
Entrepreneurial experience	0.012 (0.012)	0.021 (0.016)	−8394.410 (20,036.233)
Managerial experience as employee	−0.001 (0.012)	0.012 (0.015)	17,262.388 (18,376.373)
Firm founded to leverage opportunity	0.025 (0.013)*	−0.003 (0.016)	−17,625.158 (22,020.535)
Innovation orientation ≥ Median	0.096 (0.013)***	0.079 (0.016)***	25,334.398 (31,828.504)
Proactiveness ≥ Median	0.034 (0.017)**	0.047 (0.018)**	13,911.199 (31,148.151)
Competitiveness ≥ Median	0.028 (0.012)**	0.023 (0.016)	−9391.840 (38,393.998)
Risk orientation ≥ Median	0.002 (0.013)	0.019 (0.016)	−6738.735 (25,448.679)
Centralization ≥ Median	−0.015 (0.012)	0.011 (0.015)	−11,737.806 (27,992.419)
Founder daily wage bef. found. (log)	0.035 (0.019)*	0.001 (0.023)	−30,009.383 (64,580.618)
Founder yearly no. of employers bef. found.	0.023 (0.011)**	0.010 (0.010)	25,063.236 (12,182.541)**
Founder no. of occupations bef. found.	0.001 (0.003)	−0.004 (0.003)	3545.278 (5249.980)
Founder number of years in unempl. bef. found.	−0.011 (0.005)**	−0.009 (0.007)	−11,465.804 (8766.819)
R&D intensity (R&D expenses/sales)	0.077 (0.017)***	0.069 (0.026)***	−32,326.457 (27,337.719)
FTE number of employees (log)	0.018 (0.008)**	0.018 (0.009)**	59,188.335 (14,557.860)***
Share of full-time employees	−0.076 (0.025)***	−0.016 (0.027)	16,813.636 (41,834.111)
Share of employees with tertiary education	0.068 (0.016)***	0.062 (0.020)***	64,508.336 (31,147.175)**
Employee daily wage bef. startup (log)	0.013 (0.016)	0.006 (0.020)	−40,087.379 (57,792.791)
Share of non-German employees	0.008 (0.048)	0.030 (0.054)	265,158.084 (187,307.074)
Share of female employees	−0.050 (0.025)**	0.028 (0.031)	−28,005.837 (41,119.344)
Average age of employees	0.001 (0.001)	−0.000 (0.001)	214.743 (1933.098)
Firm age in years	−0.001 (0.004)	−0.015 (0.004)***	8802.257 (8738.449)
Industry & year fixed effects	Yes	Yes	Yes
N / Pseudo R-sq.	5362 / 0.181	5362 / 0.081	947 / 0.169

Notes: Significance levels: *** 1 %, ** 5 %, * 10 %; marginal effects from pooled weighted models with weights retrieved by entropy balancing; only founders between 36 and 63 years of age remain in the sample; cluster-robust standard errors in parentheses; additional control variable in all regressions: funding by KfW Bank and control variables for missing and zero values in employee characteristics; mean value of 'new to the market' innovations: 0.09, mean value of 'new to the firm' process innovations: 0.16, mean value of innovation sales: EUR 131,431.70. Source: IAB/ZEW Start-up Panel.

possibility that our results are driven by a subset of older entrepreneurs who introduce 'new to the market' innovations at a high frequency. To reduce the risk that our results are driven by a higher likelihood of older entrepreneurs continuing to take part in the surveys and possibly report a successful innovation (age differences in panel attrition unrelated to firm survival), we also repeated the analysis by only considering innovations reported within three years of a firm's foundation and found no noticeable differences. We would regard survival differences in general—i.e., when older entrepreneurs' businesses survive longer, thus becoming more likely to complete an innovation project successfully and introduce an innovation—as the potential intermediate outcome of the effect of age on innovation.

Interestingly, the marginal effect of founder age only changes slightly throughout all robustness checks, hence suggesting that, after controlling for founder characteristics, additional controls only add minor explanatory value. We summarize our findings, and those of the additional explorations described below, in Table 6.

4.4. Explorations: founder age and 'new to the market' innovations

After establishing the overall relationship between founder age and both 'new to the market' innovation and 'new to the firm' innovation, we now seek to understand the mechanisms behind the relationships between age and innovation in more detail. We focus here on describing the relationship between age and 'new to the market' product innovations, a relationship which most robustly correlates with age across our empirical specifications and which, in our view, provides the most valuable contribution in terms of our research focus on late-career entrepreneurship. For this, we turn to investigate the contingency of the age effect on fundamental founder characteristics and workforce characteristics which might, in theory, overlap with the age effect: innovation orientation (as the driving force for founders' innovation strategy), founder experience and founder financial capital (which can be expected to increase with a founder's age and be important determinants of the ability to implement innovation successfully), gender (as age might affect outside career opportunities of female and male entrepreneurs differently), workforce characteristics (as older founders might be better able to attract and remunerate more highly skilled employees), and industry choice (which determines the opportunities available for innovation and the fixed cost of entry at a competitive scale, therefore possibly providing different advantages to younger and older founders, who may possess different future time perspectives and

Table 6
Summary of main findings and explorations.

Analyzed relationship	Key results	Details, see
Main results		
Unconditional relationship (including only basic control variables) between founder age and innovations	10 more years of founder age come with a 30.0 % higher probability of 'new to the market' product innovation. 10 more years of founder age come with an 7.6 % lower probability of 'new to the firm' process innovation.	Section 4.1.
Conditional relationship (including the full set of control variables) between founder age and innovations	10 more years of founder age come with a 18.8 % higher probability of 'new to the market' product innovation. 10 more years of founder age come with an 10.0 % lower probability of 'new to the firm' process innovation.	Section 4.1.
Sensitivity and robustness		
Non-linearity of the innovation-age relationships	No evidence for a significant non-linearity of the relationship with founder age for all tested innovation outcomes.	Section 4.2.
'New to the firm' products	Statistically insignificant or weaker relationships with founder age.	Section 4.3.1.
Sales arising from innovations from previous years	10 more years of founder age is associated with higher innovation sales worth appr. EUR 35,200 (increase of 26 % from the sample av. of EUR 134,064).	Section 4.3.1.
Analysis of selection effects due to the decision to become an entrepreneur at different ages	Relationships between founder age and 'new to the market' innovations and innovation sales seem not to be driven by (observable) selection effects. Relationship between founder age and 'new to the firm' process innovation is not robust when controlled for selection.	Section 4.3.2.
Selection of further sensitivity and robustness checks (see Section 4.3.3 for all robustness checks)	Results remain fully robust across numerous specifications, i.e., when • considering interdependencies between new product and new process introductions by estimating seemingly unrelated bivariate probit regressions; • excluding multiple innovations by the same firms and including only the first three years of each firm to limit influence of age-dependent non-response; • including teams of founders in our analysis and measuring founder age by their average age or the age of the oldest founder; • analyzing industry differences: relationship between founder-age and 'new to the market' innovation robust across industries. Founder-age-'new to the firm'-innovation relationship not stable in construction or low-tech services/retail.	Section 4.3.3.
Moderation and mediation	'New to the market' product innovation only	Section 4.4
Innovation orientation as moderator/mediator	Statistically and economically significant moderation of the relationship of founder age with 'new to the market' innovation by innovation orientation. No robust evidence for mediation of the age effect through innovation orientation.	Table 3, Col. E; Tables A.6/ A.7; Fig. 2
Founder-, firm-, and industry-level moderators/mediators		Table A.7
Founder education	Relationship between founders' age and innovation robustly partly mediated by tertiary education of the founder. No evidence of moderation by education.	
Founder managerial and entrepreneurial experience	No mediation of the age effect through managerial experience, but strong moderation of the age effect in combination with high innovation orientation. Limited evidence for partial mediation by entrepreneurial experience when only basic controls are included.	Fig. A.2
Founder financial resources	Founders' financial resources consistently mediate and moderate the age-innovation relationship. Strongest moderation in combination with high innovation orientation.	Fig. A.3
Share of full-time employees and employee education and age	Limited evidence for negative mediation of the age effect by the share of full-time employees, and positive mediation by the share of employees with tertiary education: older founders are more likely to hire full-time employees (and employees with tertiary education) who are negatively (positively) related to innovation. Evidence for significant moderation of founder age effect by older employees, strongest in combination with high innovation orientation.	
Manufacturing vs. service industries and high-tech vs. low-tech industries	'New to the market' innovations more likely in manufacturing than in services industries and in high-tech than in traditional industries. Likelihood of introducing 'new to the market' innovations increases more with age in manufacturing than in services industries.	

amounts of available financial capital).[15]

Methodologically we use graphical analyses after split sample and interacted models, as well as mediation analyses to understand how the relationship between age and 'new to the market innovation' varies across different scenarios. When an evaluated characteristic is a significantly positive (negative) moderator of the age-innovation relationship, we conclude that increasing the characteristic increases (decreases) the age-dependency of 'new to the market' innovation. When we find significant mediation, we conclude that a characteristic is affected by age itself and, hence, an intermediate outcome of the age-innovation relationship, i.e., a channel through which age affects innovation.

When testing for moderating effects in order to account for both the nature of our dependent variables and a correct derivation of marginal effects of interaction terms, we first present probit-estimates of baseline interaction models with innovation orientation measured as a binary indicator. For exploratory analyses that require the interpretation of continuous-by-continuous interactions, we derive average effect sizes and significance levels from linear probability models and plot the

[15] Consistent with the comparatively low power of the included control variables in explaining 'new to the firm' process innovation as compared to 'new to the market' product innovation, the role of these factors in explaining the founder-age-process innovation relationship, through mediation or moderation, likewise remains limited. Most notably, we detect some evidence for positive moderation between founder age and proactiveness: highly proactive older founders maintain higher levels of 'new to the firm' process innovation. Regarding mediation, we only find robust evidence for a negative mediating role of older employees for the founder-age-process innovation relationship. Older founders hire older employees who, just as older founders, are associated with lower likelihoods of introducing 'new to the firm' process innovations.

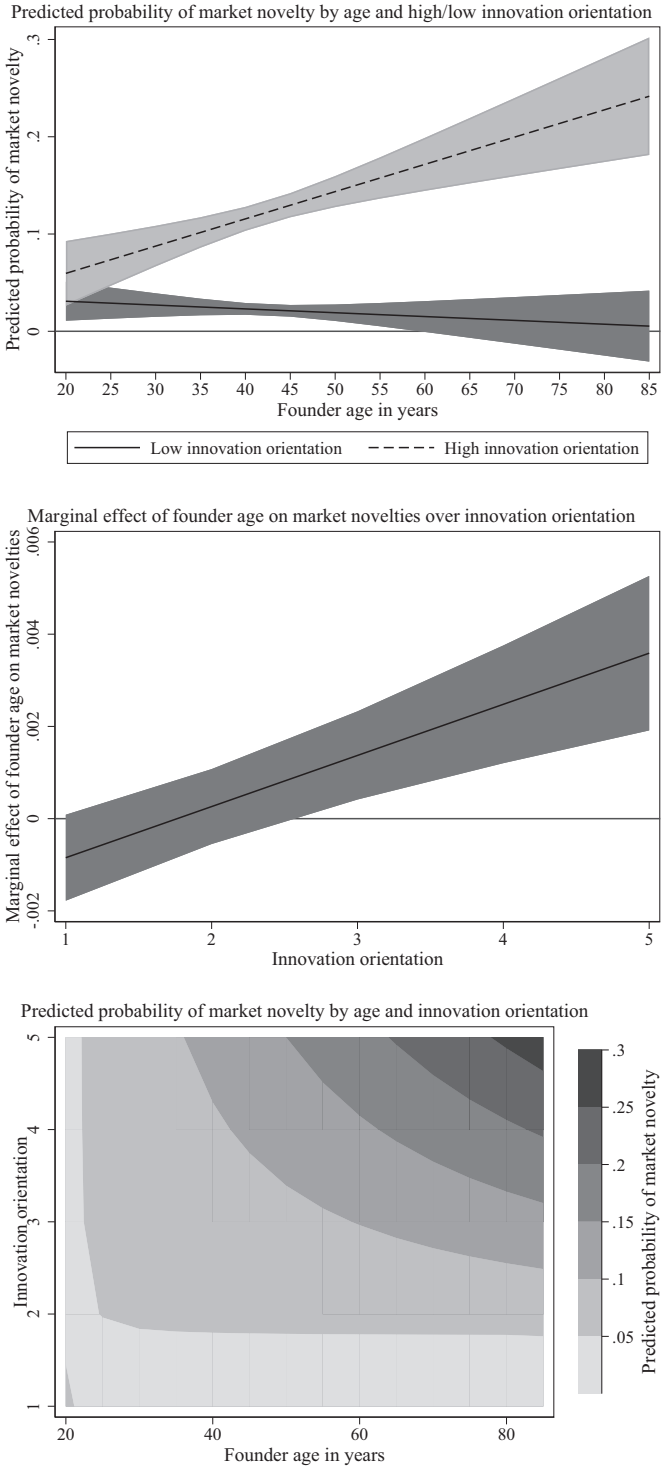

Fig. 2. 'New to the market' innovations: Interaction between founder age and innovation orientation

Notes: The graph illustrates the interaction effects between founder age and innovation orientation in linear probability models for the introduction of any 'new to the market' product innovations in a year. The upper panel illustrates the binary-by-continuous interactions between founder age and the dichotomous measure for low/high innovation orientation. The middle panel illustrates how the marginal effect of founder age on the probability to introduce a 'new to the market' product changes over the (full) five-tier measure of innovation orientation. The lower panel explores the full continuous-by-continuous interaction space between founder age and the (full) five-tier measure of innovation orientation. The lower panel shows that founders who rank below 2 on innovation orientation show annual probabilities to introduce 'new to the market' innovations of only 0–5 %, independent of their age. In contrast, for founders who rank highest on innovation orientation, the annual probabilities to introduce 'new to the market' innovations increase strongly with age, from 5 to 10 % (for young founders below 30 years of age) to 20–30 % (for old founders above 60 years of age). Alternatively, the graph can be interpreted in terms of changes in the marginal effect of innovation orientation over founder age, which reveals a consistent pattern. As we move from very low to very high innovation orientation, the annual probability to introduce a 'new to the market' innovation increases only moderately, from 0 to 5 % to 5–10 %, for young founders (below around 40 years of age), while the probability increases much more strongly in innovation orientation, from 0 to 5 % to 20–30 %, for old founders (above around 60 years of age). Source: IAB/ZEW Start-up Panel.

continuous-by-continuous interactions for interpretation.[16] We base our exploratory mediation analyses on the testing procedures suggested by Imai et al. (2010) and Hicks and Tingley (2011). We compare mediation effects when including only basic controls for firm age, industry, and years to mediation effects when including the full set of controls. We assess significant mediation based on the criteria that we find evidence that founder age affects the mediator and the mediation effect is significant at a 10 % significance level.

4.4.1. Moderation and mediation by innovation orientation

We delve more closely into the relationship between aging and founders' orientation towards innovation, as we expect the motivation for engaging in innovation to be a determinant of actual innovation outcomes and, potentially, to be affected by age. Consistent with this view, innovation orientation stands out as the explanatory factor for innovation success in our empirical analyses.

Overall, there appears to be a stable—and statistically and economically significant—complementarity between founder age and orientation towards innovation. When we interact founder age with a binary indicator for ranking at the median or above on innovation orientation, we find a positive and significant interaction ($p < 0.01$; see column E of Table 3). Graphical representations of the binary-by-continuous interactions illustrate this relationship (see Fig. 2, upper panel, for the interaction between founder age and low/high innovation orientation).

Comparing founders with low and high innovation orientation reveals that the positive relationship between age and the propensity to introduce 'new to the market' innovations is only evident for founders with median-or-above innovation orientation, while founders with lower innovation orientation in fact exhibit slightly (but insignificantly) decreasing propensities to innovate as they become older (see upper panel in Fig. 2). This is also visible when turning to continuous-by-continuous interactions, so as to explore the full interaction space in linear probability models (see middle and lower panels in Fig. 2, and in Table A.6 in the online Appendix). With increasing innovation orientation, the relationship between founder age and the introduction of 'new to the market' innovations moves from an (insignificantly) negative effect to a significant and positive effect ($p < 0.01$), for innovation orientation values above 2.5. Exploring the full continuous-by-continuous interaction space reveals that founders who rank below 2 on innovation orientation show yearly probabilities of introducing 'new to the market' innovations of only 0–5 %, regardless of their age. In contrast to this, for founders who rank highest on innovation orientation, yearly probabilities of introducing 'new to the market' innovations increase strongly with age, from 5 to 10 % (for young founders below 30 years of age) to 20–30 % (for old founders above approximately 60 years of age).[17]

When testing for a mediating role of innovation orientation, we find limited evidence for mediation of the age effect through innovation orientation (see Table A.7 in the online Appendix). When assessing mediation by only including basic controls for firm age, years, and industry, we find significant partial mediation of about 9 % of the age effect through higher self-assessed innovation orientation of those who found at a higher age. However, this mediation channel becomes insignificant as we include the full set of control variables. Therefore, while maintaining a high innovation orientation seems to be a prerequisite for founders to profit from higher age in terms of 'new to the market' innovation, changes in innovation orientation over a life's course do not seem to drive the age-innovation relationship.

4.4.2. Founder-level, firm-level, and industry-level moderation and mediation

For the remainder of our Results section, we further scrutinize how the relationship between 'new to the market' innovation and founder age changes across different groups of founders (see Table 6 for an overview; see Tables A.6 and A.7 in the online Appendix for details regarding the statistical significance of all further explorations of moderating and mediating effects on 'new to the market' innovation).

4.4.2.1. Founder-level moderation and mediation. According to our investigation, the economically and statistically most relevant moderating and mediating factors of the age-market-novelty relationship are founder education, managerial experience, previous wage, and private wealth. The founder-age-innovation relationship is robustly partially mediated (about 6 % of the age effect) by the tertiary education of the founders, even when the full set of control variables (that might overcontrol for intermediate outcomes of the education-innovation relationship) is included. We detect no significant moderation by founder education. Hence while the general educational level seems to be a channel through which age affects innovation, age seems similarly influential for innovation for employees with both higher and lower levels of education. In contrast, we do not detect robust mediation through founders' managerial or entrepreneurial experience but find a significant three-way interaction between managerial experience, innovation orientation, and age: the likelihood of introducing 'new to the market' innovations increases more for innovation-oriented founders as they become older in cases where they have also collected managerial experience. Hence, a strong complementarity appears to pertain between age, innovation orientation, and managerial experience, which leads to very high propensities of 'new to the market' innovations of 3–5 times the sample average (see Fig. A.2 in the online Appendix for an illustration of this relationship). Strikingly, entrepreneurial experience appears to matter for the founder-age-innovation relationship to a lesser extent than managerial experience.

The founders' financial resources, as measured in terms of pre-foundation wages and wealth, are the most significant mediators and moderators of the age-market-novelty relationship. The average wage before launching one's own firm partially mediates about 23 % of the age effect, even when the full set of controls is included; and we find a significant three-way interaction between founder age, innovation orientation, and pre-foundation wage. When we instead measure founders' financial resources in terms of private wealth, which we can derive from survey items for a subset of observations, results are fully consistent. Private wealth robustly partially mediates about 8 % of the age effect and significantly interacts with founder age and innovation orientation (see Fig. A.3 in the online Appendix for illustrations). Relatedly, we find robust partial mediation of about 3 % of the age effect through older founders' larger variety of pre-foundation occupations. Hence, older founders earn higher pre-foundation salaries and accumulate more wealth and experience before founding firms which—in particular in combination with maintaining high innovation orientation—turns out to be a driving force of successful 'new to the market' innovation.

[16] We calculate marginal effects for interactions of founder age with the binary indicator for innovation orientation after the estimation of probit models using the contrast operator in Stata's 'margins' command. Unlike in linear probability models, the derivation of marginal effects of interaction terms is not straightforward in (non-linear) probit models, in particular because there is no unambiguous representation of marginal effects of continuous-by-continuous interactions (Ai and Norton, 2003; Greene, 2010). We checked the consistency between probit and linear probability models where possible. In line with Angrist and Pischke's (2009) recommendations, we conclude that the linear probability models deliver very similar results to the probit models.

[17] An analysis of the marginal effect of innovation orientation over founder age reveals a consistent pattern. As we move from 'very low' to 'very high' innovation orientation, the annual probability of introducing a 'new to the market' innovation increases only moderately, from 0 to 5 % to 5–10 %, for young founders (below around 40 years of age), while the probability increases drastically, from 0 to 5 % to 20–30 %, for old founders (above around 60 years of age).

4.4.2.2. Firm-level and industry-level moderation and mediation. In contrast to founder-level factors, firm- and industry-level factors appear quantitatively less important in explaining the founder-age-innovation relationship. Most notably, at the firm level there seems to be significant moderation of the founder age effect by older employees (in particular for highly innovation-oriented older founders). At the industry level, we find that the likelihood of introducing 'new to the market' innovations is generally distinctly higher in manufacturing than in services industries, and in high-tech rather than traditional industries, and that the likelihood of introducing 'new to the market' innovations increases more with age in manufacturing than in services industries. In line with the explorations on private wealth above, this suggests that the positive effect of founder age on 'new to the market' product innovation pertains most strongly where market entry and innovation require most investment (i.e., in manufacturing rather than the services sector).

5. Discussion and implications

In this explorative study (Heckman and Singer, 2017; Wennberg and Anderson, 2020) our aim has been to advance understanding of late-career entrepreneurship (Curran and Blackburn, 2001; Kautonen et al., 2017; Levesque and Minniti, 2006; Minola et al., 2016) as a potentially innovation-driven business activity. Specifically, we examined how a variety of age-related characteristics influence the innovation outcomes created by late-career entrepreneurs with expansive life- and work-experience and who are around 50 years of age and above (Kautonen, 2008; OECD, 2012). The key finding of our study lies in demonstrating that the likelihood of solo founders introducing 'new to the market' product innovations—which significantly impact a firm's surroundings—increases with age, whereas the likelihood of 'new to the firm' process innovations—which primarily improve a company's operations—dwindles with firm founders' age.

5.1. Theoretical contributions

Our study contributes to the research on late-career entrepreneurship by shifting attention from the individual-level (dis-)advantages of late-career entrepreneurship (e.g., well-being and income) to the role of late-career entrepreneurs in creating new innovations. Concomitantly, we complement research which has predominantly examined the early stages of the (late-career) entrepreneurial process—the emergence of career choices (Feldman, 2007; Zissimopoulos and Karoly, 2007), entrepreneurial intentions (Kautonen et al., 2014), business goals (Brieger et al., 2021), and the launching of enterprises (Gielnik et al., 2018), amongst others—by scrutinizing firm-level outcomes of late-career entrepreneurship (Azoulay et al., 2020; Zhao et al., 2021). More precisely, our study adds to the rather limited number of studies addressing innovations in late-career entrepreneurship (Colovic and Lamotte, 2013; Sternberg, 2020), thereby allowing us to expand the characteristics of the economic and social potential inherent in late-career entrepreneurship, hitherto investigated only in terms of number of enterprises and their impact on economic growth (Levesque and Minniti, 2011; Zhao et al., 2021).

By offering initial and robust evidence that links late-career entrepreneurship with the creation of market novelties, our findings challenge the dominant understanding in late-career entrepreneurship research which has proposed that older founders are not particularly innovative (Colovic and Lamotte, 2013; Sternberg, 2020). We expand this debate by distinguishing between innovations that are 'new to the market' and 'new to the firm', thereby showing that older founders' businesses are, indeed, less focused on improving their operations and product offerings, yet more productive in creating and bringing to market entirely new products and services that result in increased sales. Our study indicates that entrepreneurs do not necessarily attain their peak performance at middle age (Azoulay et al., 2020); instead, the positive relationship between founder age and the introduction of 'new to the market' innovations remains constant for late-career entrepreneurs until (at least) the age of their retirement. Overall, our findings demonstrate that innovations which are 'new to the market' are a less typical outcome of entrepreneurial activities than 'new to the firm' innovations (8 % vs. 17 % yearly probability in our data). Hence, we confirm the notion held within entrepreneurship research that only a few companies grow exponentially and bring services and products to markets which differ drastically from existing offerings.

Finally, our findings add to research on entrepreneurial innovations (Aldrich and Ruef, 2018; Autio et al., 2014; Bosma et al., 2009) by examining how the lifespan of venture founders contributes to the firms' innovations (Baron and Tang, 2011; Ching et al., 2019; Delmar and Shane, 2006; McGuirk et al., 2015). Our findings provide evidence that, over the course of an entrepreneur's lifetime, higher education, personal financial resources, opportunity motivation, entrepreneurial orientation, and variety in pre-foundation job experiences increase a founder's capacity to generate 'new to the market' product innovations. Our findings indicate that these age-related characteristics change the motivations and ability to realize innovations through firms. It goes without saying that we acknowledge that founders who select entrepreneurial careers at an early (versus later) stage of their lives may also significantly differ from each other (Burton et al., 2016; Gielnik et al., 2017; Levesque and Minniti, 2011); however, our analyses find that age remains a significant predictor of innovation even when controlling for a wide range of observable founder characteristics. We encourage future research to pursue further explanations of how a founder's age affects innovations.

Building on these insights, our study concretely challenges predominant stereotypes related to late-career entrepreneurship, such as those which, in practice, may result in discrimination that inhibits the development of older entrepreneurs' firms (Ainsworth and Hardy, 2008; Kibler et al., 2015) even as bias is infused into research efforts that come to approach late-career entrepreneurship solely as a 'mundane' form of self-employment, or home-based entrepreneurship, amongst people who are retired or close to retirement (Wainwright and Kibler, 2014). By highlighting the potential of late-career entrepreneurship as an innovation-driven business activity, our work shows a need to redefine late-career entrepreneurship in such a way as to distinguish between new ventures that do involve 'entrepreneurial' characteristics—such as innovation capacity—and those that do not, representing entrepreneurship chiefly by way of their legal status. Our findings suggest that late-career entrepreneurs are productive in bringing about innovations that are 'new to the market', and that they benefit from their experience in different occupations and forms of employment, accruing economic benefits by translating their innovations into higher sales. These findings indicate that older entrepreneurs may also benefit from their age in terms of possessing high levels of legitimacy and trustworthiness in the eyes of their stakeholders. Our results on the age-effect are robust when assessing a late-career entrepreneur's age at the time of founding their venture and at the time of creating innovations; and they are robust in terms of controlling for a firm's original point of departure (i.e., whether the firm was founded based on an opportunity or concrete idea as opposed to a foundation born of necessity). This notwithstanding, we acknowledge that older founders vary in terms of their innovation outcomes, and that they operate a range of different types of ventures across industrial fields. For this reason we suggest exploring the plurality of forms to be found under the umbrella of late-career entrepreneurship.

5.2. Avenues for further research

Our explorations generate several implications for future research which acknowledges how the age and life stage of entrepreneurs affect their entrepreneurial activities.

As an initial step, we encourage future research to scrutinize how, and which, individual characteristics associated with an entrepreneur's lifespan shape entrepreneurial outcomes. In the explorative work at

hand, we have assessed how age—both on its own, as well as in combination with further individual characteristics, such as innovation orientation, prior work experience, gender, and personal financial resources—modifies the various types of innovations created by ventures. We encourage further research to build on these explorations and complement them with more nuanced analyses on the interrelations between age and innovations. For instance, do factors of health, specific skills, particular and idiosyncratic life-events, or social circumstances and groupings—both in the private domain as well as in business—support the development of entrepreneurial innovations at different stages of an entrepreneur's career? How do older, and younger, entrepreneurs cope with potential social discrimination (Kibler et al., 2015) and develop an age-based self-image (Kautonen et al., 2015) that supports achieving those innovation goals which are significant to them (Brieger et al., 2021)? Our study built on a panel dataset that predominantly consisted of male entrepreneurs; it follows that further research could analyze how different generations of people—and in particular women, who will come to be increasingly prevalent in an aging workforce—relate to the production of different types of innovations over the courses of their lives (Strohmeyer et al., 2017).

Our study has focused on addressing firm-level innovations in late-career entrepreneurship, yet we consider our findings to provide grounds for further research that assesses the implications of different types of innovations on individuals. Prior research has suggested that late-career entrepreneurship tends to yield benefits for individuals in terms of improved quality of life rather than generating higher income (Minniti et al., 2017). Our findings on the high propensity of 'new to the market' innovations amongst older founders—and of 'new to the firm' innovations amongst younger founders—calls for addressing in more detail the implications of such novelties on the entrepreneurs themselves. For instance, do older founders who succeed in creating market novelties postpone their retirement and continue in their careers for longer than those entrepreneurs who do not aspire to, or succeed in, achieving these types of innovations (Beehr, 2014; Feldman and Beehr, 2011)? Is the creation of innovations that are new to the firm a necessary step that helps younger entrepreneurs to foster their personal capacities and courage which, in turn, contributes to their career and entrepreneurial development later in life (Galenson, 2009)?

Our study has concentrated on the age-related characteristics of founders and refrained from assessing either team-level dynamics or those organizational attributes that are most advantageous for innovations (Fonseca et al., 2019). Further research could therefore continue our work and examine the broader role played by age in organizations (Frosch, 2011; Kulik et al., 2014; Li et al., 2021; Robyn et al., 2014). Our findings suggest that the number and educational level of employees contributes to the creation of 'new to the market' innovations. In light of this, how can organizations develop a balanced focus in terms of developing the efficiency of their own operations and introducing new products and services to the market? We also find some evidence that older founders tend to work better with older employees. This, then, calls for further investigation of how entrepreneurial teams—consisting of individuals from various age groups—can cultivate and support the creation of innovations.

Beyond this, our study identified a number of differences that pertain between industries in terms of late- and early-career entrepreneurs' likelihood of introducing innovations. This calls for further exploration of the dynamics across different industrial fields in order to examine how age serves as an asset, or a burden, for innovation activities. The (reporting of) innovations by entrepreneurs may vary greatly by industry; and entrepreneurs' education and prior experience might depreciate more rapidly in some industries. Thus, further research is needed to examine how founders' capacities to innovate—and benefit from innovations—change over the course of their lives and the degree to which they depend on an organization's industrial field.

At the country-level, prior research suggests that innovative entrepreneurs are more likely to come from developed countries with high income, whereas in developing countries entrepreneurs more often reproduce existing business models (Koellinger, 2008). Specifically, it has been found that innovative, high-growth enterprises are created in countries that have an abundance of knowledge and capital, both of which support the creation and utilization of entrepreneurial opportunities (Stenholm et al., 2013). The findings of our study are derived from data generated in a single country—Germany—which represents a large market area that invests in innovation by continuously increasing the country's gross domestic spending on R&D activities (OECD, 2022). It also has a historically high level of education, which means that the differences between generations are small; even amongst the 55–64 year-olds, 84 % have passed through upper secondary education (OECD, 2014). In countries with similar institutional and individual-level characteristics the innovation activities of older founders may follow similar patterns found in our study. In order to examine the innovation potential of late-career entrepreneurship in aging societies, further research is called for in multi-country settings that encompass a multitude of institutional contexts (Autio et al., 2014; Bradley et al., 2021).

5.3. Practical implications

For aging societies, our core finding accentuates the innovation potential of late-career entrepreneurship by showing that—contrary to the stereotypical view of older entrepreneurs as being less innovative—a founder's age continues to enhance their likelihood of introducing market novelties all the way to their retirement. We remain hopeful that this finding serves to inspire debate on how we can best take advantage of the skills and knowledge of (older) generations in societies undergoing significant demographic change (Kulik et al., 2014; Levesque and Minniti, 2011; Moulaert and Biggs, 2013; Sargent et al., 2013).

We maintain that our findings provide implications for states—in Europe and North America, Japan, and South Korea—which are experiencing an unprecedented and severe aging of their population (United Nations, 2017) and face the need to mitigate the financial challenges, for example rising pension expenses, which accompany such demographic shifts. We suggest that, in these states, benefiting from older entrepreneurs' capacity to develop truly novel innovations requires supporting a form of career mobility that enables them to transition to entrepreneurship later in life and to take full advantage of their (managerial) experience. With this goal in mind, states can consider making pension schemes (Wainwright and Kibler, 2014) more attractive to late-career entrepreneurship and provide information that demolishes the age norms surrounding entrepreneurship (Kautonen et al., 2011).

In contrast, numerous African and Middle Eastern countries have young populations, and the number of youths is expected to grow throughout the course of the current century (United Nations, 2015). Our findings show that young individuals are less likely to introduce market novelties. In order to accelerate the creation of such entrepreneurial innovations, these countries could introduce incentives that encourage older individuals with their industry experience and accumulated personal wealth to engage in new venture activities.

Across all societies, entrepreneurship—even later in life—could come to be seen as "a step along a career path as opposed to always a final destination" (Burton et al., 2016, p. 241), thus suggesting that a number of businesses as well as entrepreneurship support organizations should find ways to draw upon the core skills and qualities of older individuals, even after their actual engagement in entrepreneurship. Older founders could adopt roles as advisors, members of the boards of directors, or, in the case of greater private wealth, as investors and business angels, thereby using such positions to contribute to entrepreneurial innovation.

Research finds that employees who work for start-up companies tend to earn less (Sorenson et al., 2021); yet evidence also exists that being an entrepreneur at an early stage in one's career can result in earning higher wages later in life (Mérida and Rocha, 2021). This indicates that younger people should be encouraged and supported in becoming entrepreneurs,

and, as our study reveals, this could well be accomplished in partnership with older founders. Innovations tend to enhance a firm's chances of survival (Cefis and Marsili, 2006), and we find that firms established by older founders also translate innovations into higher sales. Collaboration with older founders could therefore provide younger individuals with a good basis for successful entrepreneurship. Age-diversity in a team's composition has been found to contribute to the creation of 'more important' innovations that spur further patented innovations (Kaltenberg et al., 2023).

For the institutions providing entrepreneurship education, our findings call for the type of training that supports career transitions to entrepreneurship (Burton et al., 2016) after managerial experience has been collected. Our results suggest that entrepreneurial experience as such is not crucial for the innovation activities of late-career entrepreneurs. This implies that entrepreneurship education should not be provided in isolation, but that it is advisable to offer some knowledge of entrepreneurship also to those (young) students who initially pursue a managerial career in paid employment. Moreover, we strongly believe that entrepreneurship training should not discriminate against older people who lack prior start-up experience, and, therefore, such training very clearly belongs in MBA or executive training programs.

CRediT authorship contribution statement

Martin Murmann: Conceptualization, Methodology, Formal analysis, Data curation, Visualization, Writing – original draft, Writing – review & editing. **Virva Salmivaara:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Ewald Kibler:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

Acknowledgements

We gratefully acknowledge the financial support received by Ewald Kibler from the Academy of Finland (grant number: 319951).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.respol.2023.104763.

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