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The entrepreneurial ecosystem clock keeps on ticking – A replication and extension of Coad and Srhoj (2023)

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ABSTRACT

A key hypothesis in the entrepreneurial ecosystem (EE) literature is that a positive relation exists between the quality of EEs and the prevalence of productive entrepreneurship. Recently, Coad and Srhoj (2023) argued that the quality of EEs should also be positively related to the persistence of productive entrepreneurship. However, using two different measures for high-growth firms in regions in Croatia and Slovenia, they found no consistent evidence for the persistence of productive entrepreneurship. This led them to conclude that the EE framework is not valuable for policymakers. We contend that their generalization is incorrect and that their findings are consistent with a further articulation of the EE approach.

We build our argument in two empirical studies. In Study 1, we replicate the approach by Coad and Srhoj (2023) in the Netherlands, where we find strong evidence for the persistence of productive entrepreneurship. We argue that the differences found in the replication study can be explained by accounting for the quality and size of EEs. In Study 2, we follow up on this notion by formulating two new hypotheses about the effect of quality and size of EEs on the persistence of productive entrepreneurship but argue that this effect decreases in strength as the quality and size of entrepreneurial ecosystems increase. Our hypotheses are supported by data on EEs and innovative start-ups in Europe. Accordingly, our results reconcile the different findings in the literature regarding the persistence of productive entrepreneurship. Theoretically, our work provides a further articulation of the EE approach by explaining the persistence of productive entrepreneurship, in addition to the more commonly studied prevalence of productive entrepreneurship. We conclude with policy implications of our findings.

1. Introduction

Productive entrepreneurship refers to any entrepreneurial activity "that contributes directly or indirectly to the net output of the economy or to the capacity to produce additional output" (Baumol, 1993, p. 30). It is an important driver of economic growth (e.g. Bisztray et al., 2023; Bos and Stam, 2014; Henrekson and Johansson, 2010) and is thus key for many (regional) economic strategies. In these strategies and in empirical studies, productive entrepreneurship is often measured using indicators such as innovative start-up activity or the presence of high-growth firms (HGFs) (Fotopoulos, 2023; Henrekson and Johansson, 2010; Leendertse et al., 2022; Stam and Van de Ven, 2021).

The entrepreneurial ecosystem (EE) approach (Leendertse et al., 2022; Spigel, 2017; Stam, 2015; Stam and Van de Ven, 2021; Wurth et al., 2022) is increasingly being used to explain productive entrepreneurship. An EE is defined as a set of interdependent actors and factors governed in such a way that they enable productive entrepreneurship within a particular territory (Stam, 2015; Stam and Spigel, 2018). A key hypothesis of the EE approach is that a positive relation exists between the quality of EEs and the prevalence of productive entrepreneurship in a region (Leendertse et al., 2022; Spigel, 2017; Stam, 2015). Multiple qualitative (Mack and Mayer, 2016; Spigel, 2017) and quantitative studies (Leendertse et al., 2022; Schrijvers et al., 2023; Stam and Van de Ven, 2021) have provided empirical evidence for this hypothesis. As a result, the EE framework has helped to identify, categorize, and organize the actors and factors deemed most relevant to understanding and

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improving EEs (see Wurth et al., 2023).

EE research shows that the prevalence of productive entrepreneurship is highly uneven across regions (Leendertse et al., 2022; Schrijvers et al., 2023), but we know little about whether this effect also holds over time. Numerous studies have shown the long-term regional persistence of self-employment and new firm formation in, for example, the UK (Fotopoulos, 2014; Fotopoulos and Storey, 2017), Germany (Fritsch and Wyrwich, 2014), and Sweden (Andersson and Koster, 2011). However, persistency in the prevalence of productive entrepreneurship in regions has received limited scholarly attention.[2] This is unfortunate, as the persistence of productive entrepreneurship demonstrates that development strategies for EEs indeed lead to long-term benefits, rather than a short-term boost in productive entrepreneurship in a region. Notable exceptions are Friesenbichler and Hölzl (2020) who find moderate regional persistence of HGFs in Austria, and the recent study by Coad and Srhoj (2023), who find no evidence of regional persistence of productive entrepreneurship (proxied with HGFs) in Croatia (2004–2019) and Slovenia (2007–2019). On the basis of their findings, Coad and Srhoj (2023) formulate a "broken clock" critique. They argue that, just as a broken clock shows the correct time twice a day, EE recommendations may sometimes be correct but are fundamentally flawed. Specifically, they state that "the relationship between inputs and outputs is so noisy that we conclude that the EE approach, according to its most recent formulations (Leendertse et al., 2022) is not a useful approach for policymakers with regards to generating the main outputs of ecosystems, i.e. High-Growth Firms" (Coad and Srhoj, 2023, p. 17). In the present paper, we argue that this generalization is incorrect and context-dependent. We show that their findings are consistent with a further articulation of the EE approach. Coad and Srhoj (2023) do not relate the persistency of HGFs over time empirically to the characteristics of EEs. In this paper, we do measure the quality of EEs and show that taking their quality and size into account can reconcile the apparent differences between empirical work on persistency in the prevalence of productive entrepreneurship and the predictions that come from the EE approach. To this end, we will present the results of two studies.

In Study 1, we replicate the empirical approach used by Coad and Srhoj (2023) at two regional levels in a larger country with, on average, higher-quality EEs: The Netherlands. In all replications, our results show regional persistence over time. We identify EE quality and size in terms of population as two prime factors that explain the differences in results between studies.

In Study 2, we use these insights to formulate two hypotheses about the relationship between respectively EE quality, EE population size, and the persistence of productive entrepreneurship. Taking a social network perspective (Uzzi and Spiro, 2005; Van Rijnsoever, 2020), we argue that in both cases, the EE needs to reach critical mass (Ball, 2004; Martin, 2010; Marwell et al., 1988) to yield productive entrepreneurship persistently, after which the relationship shows a decreasing positive slope. We test our hypotheses on European regions by using data on innovative start-ups (see Leendertse et al., 2022). We find more persistence in regions with higher-quality EEs and in EEs with a larger population size. This result reconciles the differences in findings obtained in Study 1. Accordingly, we answer the following research question:

What is the influence of the quality and size of entrepreneurial ecosystems on the persistence of productive entrepreneurship in regions?

Our work is a *further articulation* of the EE approach, which reconciles differences in findings between Coad and Srhoj (2023), Friesenbichler and Hölzl (2020), and Study 1 in this paper. Our focus on persistent productive entrepreneurship is an important addition to earlier studies that focused predominantly on the relationship between the quality of EEs and the prevalence of productive entrepreneurship (Audretsch and Belitski, 2017; Leendertse et al., 2022; Stam and Van de Ven, 2021; Vedula and Kim, 2019). Our further articulation of the EE approach is the first to explain the relationship between EE quality, EE size, and the persistence of productive entrepreneurship at the regional level. We present empirical evidence that Coad and Srhoj's (2023) conclusion about the EE approach being a broken clock is not supported by other data sources and is, at best, context-dependent.

In the remainder of this paper, we present our two empirical studies. Study 1 is a replication of Coad and Srhoj (2023) for The Netherlands, and Study 2 is an extension that enables us to achieve a further articulation of the EE approach, thereby reconciling the differences between the empirical studies. Finally, we draw conclusions and discuss the implications of our findings for future research and policy.

2. Study 1: a replication of Coad and Srhoj (2023) for The Netherlands

In Study 1, we first replicate the analyses of Coad and Srhoj (2023) for The Netherlands. Specifically, we compare the prevalence of HGFs in regions at the NUTS-2 and NUTS-3 level between different time periods via scatter plots and univariate regression analyses.

2.1. Theory: Study 1

We first provide a short theoretical background to the concept of persistent productive entrepreneurship. Coad and Srhoj (2023) argue that finding a positive relationship on a regional level between productive entrepreneurship and EE quality is not enough. They claim that, since the EE quality of regions is relatively stable over time, the regional levels of productive entrepreneurship should also be relatively stable—or as we call it in this paper, persistent. Empirically, this implies the level of productive entrepreneurship in one period should be similar to the level of productive entrepreneurship in the next with minimal fluctuation, if no external circumstance intervenes, such as the Covid-19 pandemic. Productive entrepreneurship is most often measured as the prevalence of HGFs, which are responsible for significant employment and economic growth. However, individual HGFs are unlikely to sustain high growth consistently and may decline (Coad et al., 2013; Mason et al., 2015; Raby et al., 2022). Thus, it is crucial to maintain the levels of persistent productive entrepreneurship in a region (with a continuous in- and outflow of HGFs within the population of firms). For that reason, innovative start-ups are also often used as indicators.

Innovative start-ups can be considered potential HGFs that can help replenish the diminishing population of HGFs. However, their growth trajectories are surrounded by uncertainty, and many will not survive (McMullen and Shepherd, 2006). Having more innovative start-ups in a region can increase the chances that some will become HGFs. Both the prevalence of HGFs and innovative start-ups are argued to be dependent on the quality of the EE (Leendertse et al., 2022; Stam and Van de Ven, 2021). Hence, we can theoretically expect that both measures are strongly correlated and relevant to EE research.

Finally, as regions vary greatly in size, these indicators are measured relative to the size of the economy in terms of either firm (Coad and Srhoj, 2023) or human population (Leendertse et al., 2022). This relative measure is called the prevalence of productive entrepreneurship. Both our study and that of Coad and Srhoj (2023) analyse the persistence in prevalence of productive entrepreneurship at the regional level. For brevity, we refer to this concept as the persistence of productive entrepreneurship. It takes place at the regional level and differs from persistence in the growth of individual firms, which is a separate area of study (Moschella et al., 2019).

[2] Extensive literature is available on the persistence of HGFs at the firm level. These studies suggest that HGFs are often "one-hit wonders" (Daunfeldt et al., 2015; Hölzl, 2014). This idea leads Coad and Srhoj (2023, p. 1) to note that "HGFs are rare events at the firm-level, but not at the regional level. While HGFs lack persistence at the firm level, there might be persistence at the regional level." Therefore, persistence of growth at the micro (firm) level differs from persistence in the prevalence of HGFs at the macro (region) level, which is our level of analysis, similar to that of Coad and Srhoj (2023).

2.2. Data and methods: Study 1

We use three proxies of productive entrepreneurship: employment HGFs, sales HGFs, and innovative start-ups (potential HGFs). Coad and Srhoj (2023) use the first two proxies, while the third is a variable commonly used in EE research (Leendertse et al., 2022; Schrijvers et al., 2023). By using three proxies, we can connect the work on HGFs in a region to that of EEs.

2.2.1. Employment HGFs

We operationalize the employment HGF variable using data from Statistics Netherlands (the Dutch Census Bureau). This dataset includes firms that employed at least 10 full-time equivalents (FTEs) at the start of the three-year period and have at least an average employment growth of 20 % per year in the following three years. This definition is the same as the HGF definition of the OECD used by Coad and Srhoj (2023) and Friesenbichler and Hölzl (2020) and matches the HGF employment variable of Coad and Srhoj (2023). The dataset covers the period between 2013 and 2018 and is only reliably available at the NUTS-2 level.

2.2.2. Sales HGFs

We operationalize the sales HGF variable using the dataset from the Dutch newspaper *Het Financieele Dagblad*, constructed in collaboration with the Dutch Chambers of Commerce (Het Financieele Dagblad, 2020). This dataset includes firms with a minimum revenue of 250,000 EUR at the start of a three-year period and a turnover growth of at least 20 % per year over three years. In addition, the firms had to be profitable for at least two of the last three years. The dataset excludes branches that are part of a larger corporation, such as franchises. The definition of sales HGFs is similar to the sales-based HGF definition of Coad and Srhoj (2023). The main differences are that our definition includes profitability criteria and the initial size is based on revenue not employment size. This measure is available at both the NUTS-2 and NUTS-3 level for The Netherlands, and the dataset covers the period 2013–2020.

2.2.3. Innovative start-ups

For the innovative start-ups variable, we follow Leendertse et al. (2022), who use firms registered in Crunchbase (Crunchbase, 2019; Dalle et al., 2017). Given that Crunchbase predominantly captures venture capital-oriented innovative start-ups and largely ignores companies without a growth ambition, it is a good source for data on potential HGFs (Dalle et al., 2017; El-Dardiry and Vogt, 2023; Leendertse et al., 2022). Therefore, Crunchbase is increasingly being used for academic research (Dalle et al., 2017; Nylund and Cohen, 2017). El-Dardiry and Vogt (2023) show that there is substantial overlap between data from a commercial start-up registry (e.g., Crunchbase) and HGFs listed in a business register. However, they also identify distinct differences. Crunchbase data largely come from two sources: a community of contributors and an extensive investor network. These data are then validated with other data sources using AI and machine-learning algorithms (Leendertse et al., 2022). We find that 26 % of the innovative start-ups in our Crunchbase data have attracted venture capital. To only include start-ups (and not long-established firms), we select firms founded between 2015 and 2020 and assigned them to the NUTS-2 and NUTS-3 levels.

2.2.4. Data preparation and analyses

Appendix Table A1 shows the average absolute values (presence) for all three productive entrepreneurship variables over time per region. This gives an impression of the differences per region. Large regions, such as Noord-Holland and Zuid-Holland, have by far the highest levels of productive entrepreneurship in absolute terms, while smaller regions, such as Zeeland, score relatively low. The correlations between the presence for these three variables are over 0.95, which confirms our arguments in Section 2.1 that the three proxies of productive entrepreneurship are highly correlated.

However, as part of the replication, we follow Coad and Srhoj (2023) and study the number of HGFs of innovative start-ups per 10,000 firms. Leendertse et al. (2022) operationalize the prevalence of innovative start-ups through the number of start-up firms per 10,000 inhabitants rather than per 10,000 firms owing to the uneven availability of the latter data across Europe. However, for The Netherlands, these two measures are strongly correlated with correlations between 0.929 and 0.997 for different years. Hence, this measure stays close to its original conception in EE research.

Table 1 presents the descriptive statistics and correlations between the variables, based on the years for which we have data for all three variables. Despite the small sample size, we present the Pearson correlations because the univariate regressions we replicate are based on these. As expected, all three productive entrepreneurship variables are still highly correlated.

Next, we follow the steps taken by Coad and Srhoj (2023) to replicate their analyses. This means that we first show the regional persistence for the two prevalence measures of HGFs and the measure for innovative start-ups in The Netherlands (at the NUTS-2 and NUTS-3 levels). To this end, we normalize the variables by year, such that each year has a mean of 0. We then categorize the data for employment HGFs into three time periods: 2010–2012, 2013–2015, and 2016–2018. The sales HGFs variable was categorized into two time periods: 2013–2015 and 2016–2018. Innovative start-ups were categorized into the time periods 2015–2017 and 2018–2020. Next, we visualize the correlations between time periods per variable via a series of scatterplots.

As a final part of the replication, we statistically relate the prevalence variables for the different time periods to one another through a series of univariate regression analyses. In the models, the most recent time periods ($t - t + 3$) serve as the dependent variable, while the lagged time periods serve as independent variables. Accordingly, we can estimate to what extent the level of productive entrepreneurship in the previous time period predicts the subsequent time period. An estimator of 1 means the level of productive entrepreneurship stayed equal. An estimator <1 means the level of productive entrepreneurship decreased across regions, while an estimator >1 means growth. An estimator <0 means there is no relationship between the two time periods or a fluctuating relationship. In this replication study, we deem productive entrepreneurship to be persistent when the estimator is close to 1.

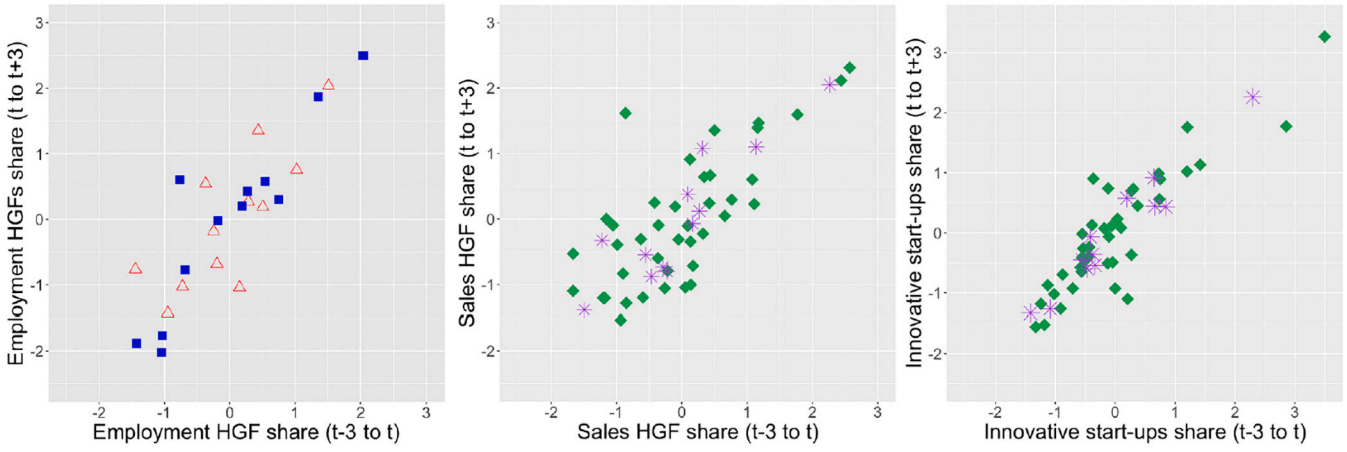
2.3. Results: Study 1

Fig. 1 displays the scatterplots between time periods for the three prevalence variables at the NUTS-2 and NUTS-3 levels. For all three productive entrepreneurship variables and both regional levels, a positive relationship exists between subsequent time periods across regions. Moreover, we consistently find persistence in the univariate regressions (Table 2), as evidenced by the estimators that are close to 1 for all HGF variables. For the innovative start-up variable, the estimator is slightly lower than 1, indicating a decrease. Possible explanations for this result are that Crunchbase includes a delay between the founding of a firm and inclusion on its website and that the 2018–2020 period covers a portion of the COVID-19 pandemic, which may have hampered the founding of new innovative start-up firms. For the employment HGFs variable, we can regress multiple time periods. The results show that the coefficient and significance of regional persistence decrease when the time between the two variables increases but remains close to 1. For the sales HGFs variable (2013−2020) and innovative start-ups variable (2015–2020), our data cover a shorter time period; hence, we could only compare two time periods. For the sales HGFs and innovative start-ups variables we find that the relation is stronger at the NUTS-2 than at the NUTS-3 level.

The correlation tables (Appendix Table A2) support our findings with both Pearson and Spearman rank order correlations, showing that persistence between time periods decreases as the interval between them increases. This outcome suggests that the prevalence HGFs change

Table 1
Descriptive statistics and Pearson correlations (based on 2015–2018 averages).

#			n	Mean	S.D.	1	2	4
1	NUTS-2	Prevalence of employment HGFs	12	313.421	52.269			
2		Prevalence of sales HGFs	12	75.115	35.030	0.651		
3		Prevalence of innovative start-ups	12	352.584	110.948	0.816	0.661	
4	NUTS-3	Prevalence of sales HGFs	40	67.176	34.295			
5		Prevalence of innovative start-ups	40	332.390	124.768			0.619



A. Employment HGFs (NUTS-2 level, 12 regions). *Note: Triangles represent when t-3 to t covers 2010–2012 and t – t+3 covers 2013–2015; squares represent when t-3 to t covers 2013–2015 and t to t+3 covers 2016–2018.*

B. Sales HGFs *Note: Diamonds represent 40 NUTS-3 regions and stars represent 12 NUTS-2 regions. t-3 to t covers 2013–2015; t to t+3 covers 2016–2018.*

C. Innovative start-ups (potential HGFs). *Note: Diamonds represent 40 NUTS-3 regions and stars represent 12 NUTS-2 regions. t-3 to t covers 2015–2017; t to t+3 covers 2018–2020.*

Fig. 1. Scatterplots between time periods for the standardized regional persistence of three productive entrepreneurship proxies.

Table 2
Regression results for the regional persistence of three productive entrepreneurship proxies in The Netherlands at NUTS-2 and NUTS-3 levels.

	Dependent variable						
	Employment HGF			Sales HGF		Innovative start-ups	
	NUTS-2			NUTS-2	NUTS-3	NUTS-2	NUTS-3
	2016–2018		2013–2015	2016–2018		2018–2020	
	1	2	3	4	5	6	7
Employment HGFs 2013–2015	1.234***(0.175)						
Employment HGFs 2010–2012		0.898[a](0.457)	0.989**(0.246)				
Sales HGFs 2013–2015				1.533***(0.241)	1.298***(0.192)		
Innovative start-ups 2015–2017						0.733***(0.058)	0.669***(0.058)
Constant	50.201 (40.931)	108.186 (115.870)	−18.716 (62.311)	9.970 (12.530)	18.223 (9.163)	−17.687 (21.322)	1.113 (20.423)
Observations	12	12	12	12	40	12	40
Adjusted R^2	0.815	0.207	0.580	0.782	0.534	0.935	0.775

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

gradually over time. As a further robustness test, we also use the absolute numbers (presence) in our regressions instead of the prevalence of productive entrepreneurship, which leads to the same results (Appendix Table A3). For the final robustness test, we used two-year periods instead of three years at the NUTS-3 level, this yields similar results (Appendix Table A4). This robustness test also allows us to use a slightly longer time period (8 years instead of 6 years) for our sales HGF dependent variable. Overall, our replication study for The Netherlands shows strong persistence in the regional prevalence and presence of the three proxies for productive entrepreneurship over time.

2.4. Discussion: Study 1

Our results demonstrate a high level of persistent productive

entrepreneurship for all three indicators. Table 3 compares our results and those by Coad and Srhoj (2023), who found no persistence for HGFs in Slovenia and Croatia, and those of Friesenbichler and Hölzl (2020), who found moderate regional persistence of HGFs in Austria. Based on the data, we identify two possible explanations for the differences in findings between the studies.

First, regions in The Netherlands have higher EE quality than other countries. To illustrate this, we use the operationalization of EE quality for European NUTS-2 regions by Leendertse et al. (2022). According to the EE index, the EE quality of NUTS-2 regions in The Netherlands ranges from 10.86 to 25.18. By contrast, the EE index for regions in Slovenia ranges from 3.47 to 7.34, and for Croatia, it ranges from 1.82 to 2.08. These EE scores are below the European average of 8.93, with Croatian regions ranking in the bottom 10 %. Austria, which has moderate persistent productive entrepreneurship, also falls in the middle range with regard to EE quality, with scores ranging between 7.85 and 22.26. These differences indicate that persistent productive entrepreneurship could be related to the quality of the EE.

Second, the regions in our Netherlands replication study differ substantially in population size, which is an indicator for the size of an EE, from the regions in Croatia and Slovenia (see Table 3). In 2020, the average number of inhabitants in Dutch NUTS-3 regions is over twice as high as in Croatian and Slovenian regions, while the size of Austrian regions is in the middle (Eurostat, 2023). This indicates that persistent productive entrepreneurship could be related to the population size of the EE. The occurrence of HGFs is a rare event (Coad and Srhoj, 2023), and in smaller regions, it may even be less frequent as they do not have enough talent to start and grow such firms. We also find a higher persistence in NUTS-2 than in NUTS-3 regions which is in line with this explanation.

Based on these data, we identify EE quality and EE size as possible explanations for the difference in findings between the three studies. We will explore these factors further in Study 2.

3. Study 2: an extension to reconcile earlier findings

In Study 2, we test the two explanations we identified in Study 1 by expanding the analysis to a larger European context. In particular, we include the regions from Coad and Srhoj (2023), Friesenbichler and Hölzl (2020), and Study 1. In the theory, we develop two hypotheses about the effect of EE quality and size on persistent productive entrepreneurship in a region. We test these hypotheses on innovative start-ups in NUTS-2 regions. Our results help us to reconcile the differences discussed in Study 1.

3.1. Theory: Study 2

3.1.1. The effect of EE quality on the persistence of productive entrepreneurship

As innovative and high-growth entrepreneurship is surrounded by uncertainty (McMullen and Shepherd, 2006), one can view the emergence and growth of HGFs that contribute to productive entrepreneurship in a region as rare and probabilistic events (Coad and Srhoj, 2023). Nevertheless, research has shown that the quality of an EE has a consistent positive effect on the probability that HGFs emerge and grow in a region (Leendertse et al., 2022; Stam and Van de Ven, 2021). Consequently, the quality of an EE is expected to be related to persistent productive entrepreneurship over time (Spigel, 2017). HGFs can still emerge in lower-quality EEs, albeit less often and less persistent than in higher-quality EEs.

We define EE quality, along the line of Leendertse et al. (2022), as the combined strength of the elements of the EE, which can be categorized in two layers (Leendertse et al., 2022; Stam and Van de Ven, 2021). The first layer comprises fundamental institutional arrangements, including formal and informal institutions, that subsequently influence the governance and allocation of resources in the second layer. The second layer includes actors and resources (e.g., talent, knowledge, and finance) that enable entrepreneurs to develop HGFs.

We expect that the relationship between EE quality and persistent productive entrepreneurship is positive but that the positive effect decreases as EE quality increases. This is because EEs can be seen as a network of actors that interact with one another (EE layer 2) under an institutional regime (EE layer 1) (Van Rijnsoever, 2020; Van Weele et al., 2018). In EEs, HGFs rely strongly on this network of peers and benefactors for the exchange of knowledge and resources that are critical for survival (Neck et al., 2004; Van Weele et al., 2018). Hence, a network is a critical asset to the quality of the EE (Wurth et al., 2022). In line with the critical mass concept of networks (Marwell et al., 1988), simulations showed that EEs need a critical mass of networked start-ups to become stable over time (Van Rijnsoever, 2020). This is because firms go bankrupt (Hyytinen et al., 2015) or ties decay over time (Burt, 2002). This critical network mass is dependent on the level of development of the EE (Van Rijnsoever, 2022, 2020). The more developed the EE is, for example with the help of intermediating support services, the more likely it is that the network has sufficient critical mass to be stable (ibid). After stabilizing, the effect of EE quality remains positive, but with a decreasing positive slope (Van Rijnsoever, 2020). This is because each additional tie in the EE network has associated diminishing returns (Uzzi and Spiro, 2005). Each tie has relatively less added value when it comes to exchanging resources between actors than a previously added tie. A second reason for the relationship is inherent to the definition of persistence, which is theoretically bound by a maximum value. This means that the positive relationship will also decrease as the value of persistent productive entrepreneurship approaches its maximum. This leads to hypothesis 1.

Hypothesis 1. *There is (a) a positive relationship between EE quality and the persistence of productive entrepreneurship that (b) decreases as EE quality increases.*

3.1.2. The effect of EE size on the persistence of productive entrepreneurship

We expect EE size to influence the persistence in prevalence of productive entrepreneurship through similar mechanisms as EE quality. Akin to EE quality, EE size influences the likelihood that HGFs are continuously created. In larger regions, this probabilistic event is more

Table 3
Persistence in the prevalence of HGFs and innovative start-ups in countries with different levels of EE quality.

	Number of NUTS-2 regions	Number of NUTS-3 regions	Start-ups per NUTS-2 region per year	Start-ups per NUTS-3 region per year	Range of EE index	Population per NUTS-3 region (in 2020)	Persistent productive entrepreneurship	Source
Croatia	2	21	17.25	1.64	1.82–2.08	193,246	Low	Coad and Srhoj (2023)
Slovenia	2	12	15.92	2.65	3.47–7.34	175,748	Some	Coad and Srhoj (2023)
Austria	9	35	14.67	3.77	7.85–22.26	254,317	Moderate	Friesenbichler and Hölzl (2020)
The Netherlands	12	40	181.04	54.31	10.86–25.18	435,190	High	Study 1, this paper

likely to occur regularly. In this case, ecosystem size is largely a function of the population size because entrepreneurs and the employees from firms largely come from the same region (Dahl and Sorenson, 2012; Stam, 2007). For persistence of productive entrepreneurship, there need to be sufficient prospective entrepreneurs and employees in a region.

We expect that the relationship between EE size and regional persistence is positive but that the positive effect decreases as the EE size increases. The critical mass arguments (Ball, 2004; Martin, 2010; Marwell et al., 1988) described in the previous section apply in a related matter to EE size. However, instead of the quality of the networks of actors, this mechanism now influences the regional persistence of HGFs through the sheer volume of actors. A larger size means more people and actors that HGFs can connect to in the network. This facilitates the exchange of knowledge and resources. As a result, larger EEs are more likely to reach a critical network mass (Van Rijnsoever, 2020). In smaller EEs, HGFs will still emerge but with less frequency and less persistence. However, once critical mass is reached, the marginal returns of each additional tie diminish (Uzzi and Spiro, 2005). The effect of EE size on persistence is thus positive with a decreasing trend. A second reason for this decreasing trend is again inherent to the fact that persistence is theoretically bound by a maximum value. As such, we also expect a positive relationship with a decreasing slope.

Hypothesis 2. *There is (a) a positive relationship between EE size and the persistence of productive entrepreneurship that (b) decreases as EE size increases.*

3.2. Data and methods: Study 2

Following (Leendertse et al., 2022), we test our hypotheses at the European level using data on innovative start-ups in NUTS-2 regions between 2015 and 2020. We choose this dataset because it encompasses all regions discussed in Study 1 and has sufficient variation in EE quality and size to make differences visible.

3.2.1. Persistence in the prevalence of productive entrepreneurship

As Study 1 focused on replicating the work by Coad and Srhoj (2023), we did not develop a formal measure for persistent productive entrepreneurship yet. However, such a measure is needed if we are to test our hypotheses. For data, we base our studies on innovative start-ups from Crunchbase, which is the only data source for productive entrepreneurship available for all European NUTS-2 regions. In Study 1, we found that this measure is highly correlated with the two HGF variables in The Netherlands. We calculate persistent productive entrepreneurship as the negative of the coefficient of variation of the prevalence of innovative start-ups over time. The coefficient of variation is a common statistical measure to express dispersion over a series of values, in line with our definition that these values should be stable over time. It is calculated as the standard deviation divided by the mean of a series of variables. The standard deviation σ_i expresses the variation of the prevalence of innovative start-ups in region i over time. However, with variables that have an absolute zero (as is the case here), a high mean also leads to a high standard deviation. The coefficient of variation corrects for this by dividing the standard deviation σ_i by the mean prevalence of innovative start-ups μ_i during the time period. Given that a higher standard deviation indicates more variation, and thus less persistence, we multiply the coefficient of variation with -1. This adjustment means that a higher value signifies more persistence. This leads to formula (1).

$$Persistence_i = -\frac{\sigma_i}{\mu_i} \quad (1)$$

As a robustness check, we also calculate persistence using the absolute number of start-ups in a region, rather than the prevalence of start-ups. Both measures are virtually identical with a correlation of 1.000. Hence, we only report the prevalence-based measure, which is in line with earlier studies.

3.2.2. EE quality

We operationalize EE quality using the EE index from Leendertse et al. (2022), who developed a set of indicators to measure the 10 elements of EEs, as defined by Stam (2015), for European NUTS-2 regions. Leendertse et al. (2022) combined these metrics into an EE quality index. First, they standardized and normalized the indicators of each element and set the maximum score for any single element to 5 to prevent a disproportionate influence of strong performing ecosystem elements on the overall index. They then calculated the index by summing the scores for all elements (E1 + E2 + … + E10). We refer to Leendertse et al. (2022) for details about the index.

3.2.3. EE size

To measure the size of an EE, we use the number of inhabitants (population) for each region Eurostat (2023). We use the average population between 2010 and 2014 to ensure a time lag between our independent and dependent variables.

3.2.4. Data preparation and analyses

Table 4 presents the descriptive statistics and correlation matrix of Study 2. For one region, data are insufficient to calculate the persistence measure as it recorded zero start-ups over the time period. For another region, we cannot calculate the EE index due to missing data. To test the decrease in slope (hypotheses 1b and 2b), we also calculate the natural logarithm of EE quality and EE size variables.

We test our hypotheses via a series of linear regression models, with persistent productive entrepreneurship as the dependent variable and EE quality and EE size as independent variables. We test the linear and natural log of the independent variables in separate models to test hypotheses 1a and 2a separately from hypotheses 1b and 2b.

3.3. Results Study 2

Table 5 presents the results of our regression analyses. As can be seen in model 1, a positive relationship exists between EE quality and persistent productive entrepreneurship. Moreover, the adjusted R^2 for the model with the log of EE quality is approximately 5 % points higher than the model with the linear term. This result lends support to hypothesis 1a and b and our argument for diminishing returns of the EE network. A similar result is obtained for EE size, where the model with the natural log of EE size has an adjusted R^2 that is about 14.5 % points higher than the model with the linear term. In model 5 and 6 we estimate the effect of the EE quality and EE size variables in one model. We find that in both models, the variables are still significant, and that the logged variables (model 6) perform better than the linear terms (model 5). This provides evidence that the two variables are complementary to each other.

We perform a series of robustness tests on our analyses. First, we construct two sets of dummy variables, with each variable either representing a 10 % increment in EE quality or a 10 % increment in EE size. We run regressions with these dummies as categorical predictors and the bottom 10 % as the reference category (Appendix Table A5). The results show that in both models, all other increments have significantly more persistence than the bottom 10 %, after which there is an overall gradually increasing trend. This finding is in line with the critical mass argument that serves as the basis of hypotheses 1b and 2b. Some estimators are lower than the previous increment, but these differences among increments are not significant. Second, we run a model with random effects for country effects. The results remain the same (Appendix Table A6). Third, as an additional robustness test for hypotheses 1b and 2b, we add a quadratic term as an alternative to model the positive decreasing relationship (Appendix Table A7). Additionally, the quadratic term is highly significant in these models. The inflection points fall at the right end of the observed range of the independent

Table 4
Descriptive statistics and Pearson correlations (based on 2015–2020 averages).

#		n	Mean	S.D.	1	2	3
1	Prevalence of innovative start-ups	273	0.220	0.443			
2	Persistent productive entrepreneurship	272	−0.595	0.360	0.218		
3	EE quality	272	8.935	6.462	0.565	0.329	
4	EE size (per 10,000 inhabitants)	273	186.540	152.552	0.094	0.314	0.101

Table 5
The influence of EE quality and EE size on the persistence of productive entrepreneurship in European NUTS-2 regions.

Dependent variable: Persistence of productive entrepreneurship						
	1	2	3	4	5	6
EE quality	0.017*** (0.003)				0.016*** (0.003)	
Log EE quality		0.178*** (0.025)				0.163*** (0.022)
EE size			0.001*** (0.000)		0.001*** (0.000)	
Log EE size				0.227*** (0.025)		0.187*** (0.023)
Constant	−0.744*** (0.034)	−0.929*** (0.051)	−0.732*** (0.033)	−1.719*** (0.124)	−0.853*** (0.039)	−1.828*** (0.122)
Observations	271	271	272	272	272	272
Adjusted R^2	0.104	0.158	0.091	0.236	0.179	0.317

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

variables (EE quality at 21.35, EE size at 629.02). This indicates that the model mostly captures the left side of the quadratic curve, which is again in line with hypotheses 1b and 2b. However, the R^2 of the logarithmic model is higher than the quadratic model, indicating that the logged model is a better fit than the quadratic robustness model. This is in line with our hypotheses as the logarithmic transformation best matches the critical mass arguments used in our hypotheses.

3.4. Discussion: Study 2

The results of Study 2 show that persistent productive entrepreneurship in a region is dependent on EE quality and size via a positive relationship with a decreasing slope. Theoretically, this finding can be explained by the need for networks in the EE to first build critical mass (Ball, 2004; Martin, 2010; Marwell et al., 1988) after which each additional actor or tie in the network has diminishing returns (Uzzi and Spiro, 2005). Our findings reconcile the different results between the studies by Coad and Srhoj (2023), Friesenbichler and Hölzl (2020), and Study 1, as the countries have levels of EE quality and EE size that correspond to the expected levels of persistent productive entrepreneurship.

4. Conclusion and discussion

Coad and Srhoj (2023) found no or little persistence in the regional prevalence of productive entrepreneurship in Croatia and Slovenia. By doing so, they validly pointed scholarly attention toward the persistence of productive entrepreneurship as an output of EEs. In Study 1, we replicated their approach for The Netherlands, where we found persistence of productive entrepreneurship. Thereby, we demonstrated that their findings are contextual; specifically, the lack of persistence of productive entrepreneurship seemed mostly true for EEs of a lower quality or a smaller size.

In Study 2, we explored this idea further. Drawing on insights from social networks in the context of EEs (Van Rijnsoever, 2022, 2020), we developed two formal hypotheses on the influence of EE quality and EE size on persistent productive entrepreneurship. We tested these hypotheses using innovative start-up data at NUTS-2 level regions in Europe, in combination with data about EE quality and EE size (see Leendertse et al., 2022), and found robust support for our hypotheses.

Our hypotheses predicted that regions in Croatia and Slovenia have lower persistence of productive entrepreneurship because they have a relatively low EE quality. By contrast, regions with high-quality EEs, such as the regions in The Netherlands in our analyses and the Austrian regions studied by Friesenbichler and Hölzl (2020), show higher persistence of productive entrepreneurship. The regions in Croatia and Slovenia are also smaller in size (with a low number of inhabitants). This finding suggests that the spatial scale of NUTS-3 level regions in Europe may sometimes be too small to identify the persistence of productive entrepreneurship, especially in the case of sparsely populated regions.

Coad and Srhoj (2023) concluded their paper with a “broken clock” critique of the EE approach. A broken clock tells the correct time twice a day but is not useful for telling time. Based on the results of our two studies, we conclude that the clock continues ticking but is perhaps less accurate in the context of lower-quality or smaller EEs.

4.1. Theoretical implications

In this paper, we further articulated the EE approach by showing that the quality of an EE is not just positively related to the subsequent prevalence of productive entrepreneurship (Leendertse et al., 2022) but also to the persistence of productive entrepreneurship in a region. Our approach is theoretically grounded in ideas about critical mass in social networks (Ball, 2004; Martin, 2010; Marwell et al., 1988) and decreasing marginal returns in social networks (Uzzi and Spiro, 2005), as well as on empirically grounded simulations on EEs (Van Rijnsoever, 2020). It allowed us to reconcile different empirical findings about the persistence of productive entrepreneurship across Europe. The persistence of productive entrepreneurship was always implied in the EE approach, but was never studied as a function of the EE. However, doing so is quite crucial, as it gives insights into the long-term benefits of having a high-quality or large EE. Therefore, we recommend that EE scholars add persistence explicitly to the concept of productive entrepreneurship.

4.2. Limitations and further research

While our articulation reconciles the results from earlier studies, it also raises many new questions for future research. First, our paper answers calls for more replication studies in economics (Hamermesh, 2007), management (Bettis et al., 2016), and entrepreneurship (Davidsson, 2016). In Study 1, we investigate persistent productive entrepreneurship using six- or nine-year time periods in The Netherlands. In Study 2, we focus on European NUTS-2 regions using data on innovative start-ups between 2015 and 2020. Further replication studies can use different indicators, longer time periods, or different

contexts (e.g., Africa, North or South America). This can help to enhance or contextualize the generalizability of our findings.

More research is needed to explore how long the benefits of a strong EE remain persistent over time and when its effects start to decay. For this, more longitudinal data are needed. Additional insights are also needed to understand what happens to the prevalence and persistence of productive entrepreneurship if the EE quality or size falls below the critical mass to properly function. Finally, more research is needed to understand how external shocks, such as a global pandemic, impact persistent productive entrepreneurship.

By comparing the results from Study 1 with those of Coad and Srhoj (2023) and Friesenbichler and Hölzl (2020), we identify two mechanisms that influence the persistence of productive entrepreneurship in regions. However, more research is needed to test and address additional mechanisms such as the density of the population, sectoral diversity, or the digital dimensions of entrepreneurial ecosystems (Bejjani et al., 2023).

An analytical implication is that scholars need to think carefully about the spatial level of analysis they use. Most empirical studies in Europe use either the NUTS-2 or NUTS-3 level. However, in some instances, the former spatial level might be too coarse while the other too fine-grained. A large problem is that EEs consist of dynamic networks of actors, who are not necessarily constrained by administrative borders (Fischer et al., 2022; Schäfer, 2021; Schäfer et al., 2024). Hence, further research is needed to identify where the actual boundaries of EEs are and how inter-ecosystem links either reinforce the strengths or complement the weaknesses of EEs (Wurth et al., 2022). EEs do not operate in isolation; they can complement or compete with another. For example, on a daily basis, human capital crosses borders from one region to another, which effectively means that resources are transferred between EEs. We need more insights into the interregional dependencies of EEs to understand to what extent these influence the prevalence and persistence of productive entrepreneurship.

4.3. Policy implications

Coad and Srhoj (2023, p. 17) argue that the recently formulated EE approach by Leendertse et al. (2022) is similar to a broken clock, and as such "is not a useful approach for policymakers with regards to generating the main outputs of ecosystems, i.e. High-Growth Firms." We provide evidence that this is not a correct interpretation and generalization based on their findings. Our most crucial implication for policymakers is to not overreact to the findings of Coad and Srhoj (2023), as we show that these findings only apply to the specific contexts of low quality and small EEs.

We offer two avenues of policy recommendations. First, for EEs that have reached critical mass, improving the quality of EEs is a viable policy approach. In doing so, policymakers can capitalize on the positive relationship between EE quality and the prevalence of productive entrepreneurship (see Leendertse et al., 2022) while increasing the persistence of productive entrepreneurship, albeit at a decreasing rate. Policymakers need to carefully examine which elements require strengthening. For EEs of insufficient quality or size, it is important to assess whether achieving critical mass is feasible. Scaling the administrative size may contribute to building a more coherent EE across regions, but this approach may pose challenges in sparsely populated areas where establishing interactions between EE elements is difficult. This brings us to the harder and more relevant question, which is how to improve each EE in a meaningful, effective, and efficient way.

CRediT authorship contribution statement

Jasper van Dijk: Writing – review & editing, Writing – original draft, Methodology, Data curation. **Jip Leendertse:** Writing – review & editing, Writing – original draft, Methodology, Data curation, Conceptualization. **Erik Stam:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Frank van Rijnsoever:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Erik Stam and Jasper van Dijk report financial support was provided by Netherlands Organisation for Health Research and Development grant number 10430 03201 0028.

Appendix A

Table A1
Average absolute number of HGFs per NUTS-2 region over the available time period.

NUTS code	Name region	Employment HGFs (2010–2018)	Sales HGFs (2013–2020)	Innovative start-ups (2015–2020)
NL11	Groningen	55.6	21.0	71.3
NL12	Friesland (NL)	53.3	13.9	62.5
NL13	Drenthe	44.4	4.1	47.3
NL21	Overijssel	125.6	42.6	130.8
NL22	Gelderland	233.9	49.0	216.5
NL23	Flevoland	43.9	8.8	58.7
NL31	Utrecht	187.8	86.4	211.5
NL32	Noord-Holland	444.4	138.8	698.7
NL33	Zuid-Holland	455.6	106.9	514.3
NL34	Zeeland	39.4	8.3	26.7
NL41	Noord-Brabant	327.2	95.5	285.7
NL42	Limburg (NL)	105.0	18.6	82.5

Table A2
Regional persistence of employment HGFs, sales HGFs, and innovative start-ups in The Netherlands.

	Pearson correlation [p-value]	Spearman's rank correlation [p-value]
Employment HGFs per 10,000 firms (NUTS-2 level, 12 regions)		
Pooled (2010–2018)	0.743 [0.000]	0.719 [0.000]
Period: 2010–2012 and 2013–2015	0.786 [0.002]	0.762 [0.006]
Period: 2010–2012 and 2016–2018	0.528 [0.078]	0.364 [0.246]
Period: 2013–2015 and 2016–2018	0.912 [0.000]	0.811 [0.002]
Sales HGFs per 10,000 firms (NUTS-2 level, 12 regions)		
Pooled (2013–2020)	0.918 [0.000]	0.889 [0.000]
Period: 2013–2015 and 2016–2018	0.895 [0.000]	0.860 [0.000]
Sales HGFs per 10,000 firms (NUTS-3 level, 40 regions)		
Pooled (2013−202,020)	0.799 [0.000]	0.771 [0.000]
Period: 2013–2015 and 2016–2018	0.739 [0.000]	0.691 [0.000]
Innovative start-ups per 10,000 firms (NUTS-2 level, 12 regions)		
Pooled (2015–2020)	0.674 [0.000]	0.671 [0.000]
Period: 2015–2017 and 2018–2020	0.998 [0.000]	0.993 [0.000]
Innovative start-ups per 10,000 firms (NUTS-3 level, 40 regions)		
Pooled (2015–2020)	0.608 [0.000]	0.527 [0.000]
Period: 2015–2017 and 2018–2020	0.884 [0.000]	0.821 [0.000]

Table A3
Regression results for three productive entrepreneurship proxies in The Netherlands at NUTS-2 and NUTS-3 levels using regional presence.

	Dependent variable						
	Employment HGF			Sales HGF		Innovative start-ups	
	NUTS-2			NUTS-2	NUTS-3	NUTS-2	NUTS-3
	2016–2018		2013–2015	2016–2018		2018–2020	
	1	2	3	4	5	6	7
Employment HGF 2013–2015	1.465*** (0.028)						
Employment HGF 2010–2012		1.404*** (0.072)	0.963*** (0.035)				
Sales HGF 2013–2015				1.756*** (0.064)	1.797*** (0.045)		
Innovative start-ups 2015–2017						0.752*** (0.014)	0.744*** (0.008)
Constant	4.673 (5.559)	−2.354 (14.841)	−5.499 (7.158)	0.497 (2.768)	−0.245 (0.747)	−6.533 (4.601)	−1.384 (1.003)
Observations	12	12	12	12	40	12	40
Adjusted R^2	0.996	0.972	0.986	0.986	0.976	0.996	0.995

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

Table A4
Regression results for two productive entrepreneurship proxies at the NUTS-3 level in The Netherlands using two-year averages.

	Dependent variable								
	Sales HGFs						Innovative start-ups		
	2019–2020			2017–2018		2015–2016	2019–2020		2017–2018
	1	2	3	4	5	6	7	8	9
Sales HGF 2017–2018	0.868*** (0.092)								
Sales HGF 2015–2016		0.952*** (0.167)		0.949*** (0.155)					
Sales HGF 2013–2014			1.236*** (0.266)		1.271*** (0.245)	0.834*** (0.195)			
Innovative start-ups 2017–2018							0.534*** (0.052)		
Innovative start-ups 2015–2016								0.489*** (0.058)	0.856*** (0.075)
Constant	15.871 (8.009)	25.181 (11.108)	32.183 (11.991)	19.482 (10.347)	24.840 (11.051)	25.760 (8.86)	−7.840 (18.508)	9.267 (20.547)	51.751 (26.572)
Observations	40	40	40	40	40	40	40	40	40
Adjusted R^2	0.690	0.449	0.346	0.483	0.399	0.307	0.730	0.643	0.769

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

Table A5
The influence of EE quality and region size (population) on the persistence of innovative start-ups in European NUTS-2 regions using quantile dummies. Dummies use bottom 10 % as reference category.

Dependent variable: Persistence of innovative start-ups		
Independent variable	EE quality dummies	Population size dummies
	1	2
Bottom 10 %		
10 %–20 %	0.301*** (0.085)	0.271** (0.088)
20 %–30 %	0.337*** (0.086)	0.369*** (0.088)
30 %–40 %	0.389*** (0.086)	0.415*** (0.088)
40 %–50 %	0.360*** (0.086)	0.439*** (0.088)
50 %–60 %	0.397*** (0.086)	0.527*** (0.088)
60 %–70 %	0.476*** (0.086)	0.480*** (0.088)
70 %–80 %	0.484*** (0.086)	0.500*** (0.088)
80 %–90 %	0.513*** (0.086)	0.510*** (0.088)
Top 10 %	0.544*** (0.086)	0.606*** (0.088)
Constant	−0.968*** (0.061)	−1.006*** (0.063)
Observations	271	272
Adjusted R^2	0.158	0.177

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

Table A6
The influence of EE quality and population size on the prevalence of innovative start-ups in European NUTS-2 regions, including random intercepts.

Dependent variable: Persistence of innovative start-up prevalence				
	1	2	3	4
Random effects (variance)				
Country (intercept)	0.032 (0.180)	0.030 (0.172)	0.037 (0.192)	0.036 (0.189)
Fixed effects				
EE quality	0.016*** (0.004)			
Log EE quality		0.198*** (0.037)		
EE size			0.001*** (0.000)	
Log EE size				0.218*** (0.024)
Constant	−0.735*** (0.053)	−0.960*** (0.078)	−0.728*** (0.049)	−1.66*** (0.122)
Observations	271	271	272	272
Conditional R^2	0.348	0.407	0.351	0.468

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

Table A7
The influence of EE quality and population size on the prevalence of innovative start-ups in European NUTS-2 regions using quadratic effects.

Dependent variable: Persistence of innovative start-up prevalence				
	1	2	3	4
EE quality	0.017*** (0.003)	0.044*** (0.009)		
EE quality squared		−0.001** (0.000)		
EE size			0.001*** (0.000)	0.002*** (0.000)
EE size squared				−0.000*** (0.000)
Constant	−0.744*** (0.034)	−0. 854*** (0.048)	−0.732*** (0.033)	−0.862*** (0.045)
Observations	271	271	272	272
Adjusted R^2	0.104	0.133	0.091	0.141

[a] $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Standard errors are reported in brackets.

Data availability

Data will be made available on request.

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