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Measuring Entrepreneurial Ecosystems

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U.S.E. Discussion Paper Series nr: 17-11

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Measuring Entrepreneurial Ecosystems

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August 2017

Abstract
How can entrepreneurial ecosystems and productive entrepreneurship can be traced empirically and how is entrepreneurship related to entrepreneurial ecosystems. The analyses in this chapter show the value of taking a systems view on the context of entrepreneurship. We measure entrepreneurial ecosystem elements and use these to compose an entrepreneurial ecosystem index. Next, we measure the output of entrepreneurial ecosystems with different indicators of high-growth firms. We use the 12 provinces of the Netherlands as a test case for measuring the entrepreneurial ecosystem elements, composing an entrepreneurial ecosystem index and relate this to entrepreneurial outputs. The prevalence of high-growth firms relates to the overall value of the entrepreneurial ecosystem index, but not to individual elements of the entrepreneurial ecosystem. The model fit increases once we introduce a multiplicative index and a non-linear model. By measuring entrepreneurial ecosystems and their outputs in this way we move from the ecosystem metaphor to a complex system model of the entrepreneurial economy.

Keywords: Entrepreneurial ecosystems, complex systems, entrepreneurial ecosystem index, entrepreneurship, regional development

JEL classification: L26, M13, P51, R11, R58

Measuring Entrepreneurial Ecosystems

Forthcoming in: O'Connor, A., Stam, E., Sussan, F. & Audretsch, D.B. (2018)
Entrepreneurial Ecosystems. Place-Based Transformations and Transitions. New York: Springer.

1 Introduction

The entrepreneurial ecosystem approach has gained prominence amongst entrepreneurs, entrepreneurship supporters (Feld 2012), and in public policy (Isenberg 2010). Entrepreneurial ecosystems have revealed to be a mobilizing metaphor in the public and private sector, also bridging the boundary between the two. The popularity of the concept is however not a sign of its robustness: the approach is highly undertheorized, and not yet adequately measured (Stam 2015). This chapter offers measures and methods for analysing entrepreneurial ecosystems as a system, moving beyond the metaphorical use of the entrepreneurial ecosystem concept. We use complex systems - systems composed of many components which may interact with each other – reasoning to improve insight into how entrepreneurial ecosystems function as a whole system. Complexity economics (Arthur 2013) provides the conceptual basis for analysing the relation of entrepreneurial ecosystems with outputs (entrepreneurship) and outcomes (value creation and structural change).

Several studies (Stam 2015; Spigel 2017; Stam and Spigel 2018) have shown that the entrepreneurial ecosystem approach can be used to synthesize prior academic research on the geography of entrepreneurship (see e.g. Sternberg 2009; Stam 2010) and entrepreneurship and regional development (see e.g. Fritsch 2013). The synthesizing model (see Figure 10.1) includes insights from the academic literature (i.e. the aspects that have been deemed important elements of entrepreneurial ecosystems), but most importantly it provides more causal depth with four ontological layers (framework conditions, systemic conditions, outputs, and outcomes), including the upward and downward causation, and intra-layer causal relations. Upward causation reveals how the fundamental causes of new value creation are mediated by intermediate causes, while downward causation shows how outcomes and outputs of the system over time also feed back into the system conditions. Intra-layer causal relations refer to the interaction of the different elements within the ecosystem, and how the different outputs and outcomes of the ecosystem might interact. The model is distinctive of existing measurements of entrepreneurial (eco)systems that do not separate inputs and entrepreneurial outputs of the system (e.g. Acs et al. 2014; Bell-Masterson and Stangler 2015).

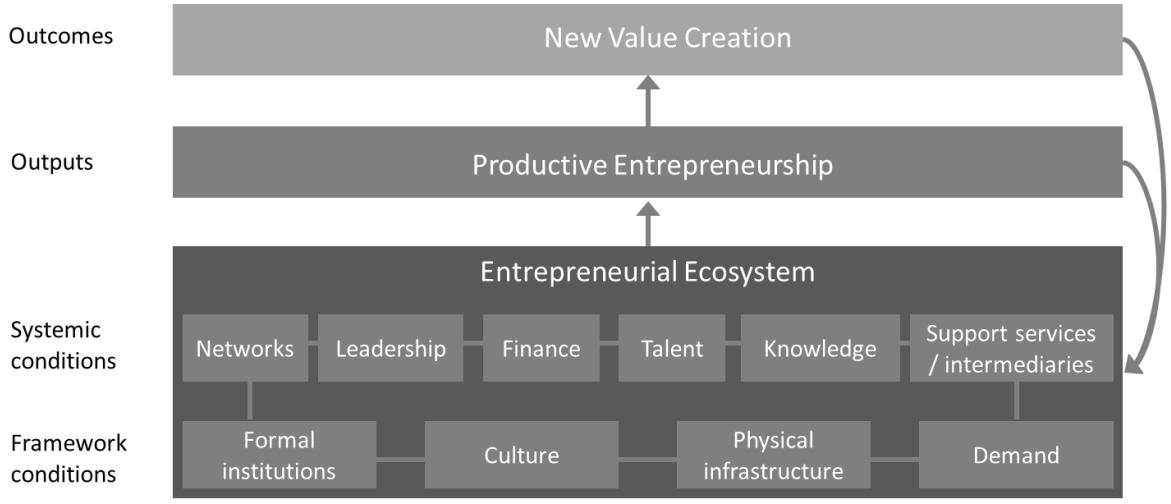

Fig. 1 Key elements, outputs and outcomes of the entrepreneurial ecosystem (based on: Stam 2015)

The entrepreneurial ecosystem approach can go beyond a metaphorical approach by constructing a complex systems approach to entrepreneurship and structural economic change. The economy is a constantly evolving system in which economic agents at the micro level experiment and interact with each other. Many of these experiments fail, but some succeed as innovations and create wealth for society (Beinhocker 2006). Economic development does not emerge automatically: entrepreneurs are needed to create new value (Fayolle 2007; Schumpeter 1934). This new value creation is an emerging property of a complex system of economic agents and their interactions: the entrepreneurial ecosystem. Entrepreneurs might structurally change the economy and society, as exemplified with new sets of technologies, institutions and organizational arrangements (Arthur 2013). An entrepreneurial ecosystem can be defined as a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship within a particular territory (Stam 2015; Stam and Spigel 2018). Entrepreneurship is both the result of and the mediator of evolution (Day 1987): entrepreneurial behaviour as an output is enabled by the system, while the new value created, and potential structural change as an outcome of the system is mediated by entrepreneurship. This outcome is an emergent property of the system, and redefines the nature of the system via feedback effects. Such feedback effects mean that the system and its outputs should not be interpreted as a one way relation, as the current state of the system might be affected by previous outcomes. This comes close to the statistics problem of simultaneity, which "arises when one or more of the explanatory variables is jointly determined with the dependent variable [...]" (Wooldridge 2013, p 530). However, in dynamic systems analysis this is not a problem to be evaded, but an inherent characteristic of system dynamics. In the next section, we discuss how we can empirically trace the elements of entrepreneurial ecosystems as a first step towards analysing the entrepreneurial economy (Thurik et al. 2013) as a complex system.

2 Elements of entrepreneurial ecosystems

Entrepreneurial ecosystems are constituted by framework conditions and systemic conditions. Both are summarized in Figure 1. The framework conditions include the social (formal institutions and culture) and physical conditions enabling or constraining human interaction. In addition, access to a more or less exogenous demand for new goods and services is also of great importance. This access to buyers of goods and services, however, is likely to be more related to the relative position of the ecosystem than its internal conditions (in contrast to for example the important role of 'home demand' in Porter's (1990) cluster approach). These conditions might be regarded as the fundamental causes of value creation in the entrepreneurial ecosystem (cf. Acemoglu et al. 2005). However, to fully understand how these fundamental causes lead to this outcome, we first need to gain insight into how systemic conditions lead to entrepreneurial activity (cf. Cooke 2001).
Systemic conditions are the heart of the ecosystem: networks of entrepreneurs, leadership, finance, talent, knowledge, and support services. The presence of these elements and the interaction between them are said to be of crucial relevance for the success of the ecosystem. Networks of entrepreneurs provide information flows, enabling an effective distribution of knowledge, labour and capital. Leadership provides direction and role models for the entrepreneurial ecosystem. This leadership has been said to be critical in building and maintaining a healthy ecosystem: this involves a set of 'visible' entrepreneurial leaders who are committed to the region (Feld 2012). Access to finance — preferably provided by investors with entrepreneurial knowledge — is crucial for investments in uncertain entrepreneurial projects with a long-term horizon (see e.g. Kerr and Nanda 2009). But perhaps the most important element of an effective entrepreneurial ecosystem is the presence of a diverse and skilled group of workers ('talent': see e.g. Acs and Armington 2004; Lee et al. 2004; Qian et al. 2013). An important source of opportunities for entrepreneurship can be found in knowledge, from both public and private organizations (see e.g. Audretsch and Lehmann, 2005). Finally, the supply of support services by a variety of intermediaries can substantially lower entry barriers for new entrepreneurial projects, reduce the time to market of innovations (see e.g. Zhang and Li 2010), and enhance the diffusion of innovations, as input to next generations of innovation

(Howells 2006). There is (quantitative) empirical evidence for the effects of all these elements[1] on entrepreneurship and economic growth, most often on the regional level. We thus build on previous studies for selecting empirical indicators of these elements. The challenge is to find empirical indicators that are comparable over time and space.

2.1 Formal Institutions

Formal and informal institutions (culture) reflect the rules of the game in society (North 1990). For entrepreneurship, the quality and efficiency of institutions matter: the level of perceived corruption and the general regulatory framework within countries. We use data from the Quality of Governance 2012 survey. It consists of data acquired for a large, European Commission-funded project on measuring quality of governance within the EU (Charron et al. 2012). The survey is the largest one ever undertaken to measure quality of governance at the sub-national level so far. It includes approximately 34,000 EU citizens for a total of 172 regions, either at the NUTS1 or NUTS2 level, within the EU Member States. Survey questions are focused on four aspects related to three public services (education, healthcare and law enforcement): corruption, rule of law, government effectiveness and voice & accountability. Four standardized indicators are provided with and used in the "formal institutions" element of the entrepreneurial ecosystem (for additional details refer to Charron et al. 2012).

2.2 Entrepreneurship Culture

Entrepreneurship culture (as an informal institution) reflects the degree to which entrepreneurship is valued in society. We measure entrepreneurship culture indirectly with the prevalence of new firms, which indicates how 'common' starting up a business is in a particular region.
Entrepreneurship culture could also be measured with the degree to which self-employment is seen as a viable career choice and the degree to which successful entrepreneurs are valued (both derived from the Global Entrepreneurship Monitor). However, this measure is not readily available for regions within the Netherlands.

2.3 Infrastructure

Physical infrastructure is a composite measure including indicators of motorway and railway potential accessibility and the number of passenger flights (see Anoni and Dijkstra 2013). Motorway accessibility includes the population living in surrounding regions weighted by travel time along motorways, while railway accessibility includes the population living in surrounding regions weighted by travel time along railways. Motorway and railway potential accessibility indicators take into account ferry networks allowing for correcting islands penalization. Potential accessibility is a construct of two functions, the activity function representing the activities or opportunities to be reached and the impedance function representing the effort, time, distance or cost needed to reach them (Spiekermann et al. 2002). For potential accessibility the two functions are combined multiplicatively, i.e. they are weights to each other and both are necessary elements of accessibility. The interpretation is that the greater the number of attractive destinations in areas j and the more accessible areas j are from area i, the greater the accessibility of area i. The accessibility model used is based on the work of Spiekermann and Wegener (1996) and uses centroids of NUTS 2 regions as origins and destinations. The accessibility model calculates the minimum paths for the road network, i.e. minimum travel times between the centroids of the NUTS 2 regions. For each region the value of the potential accessibility indicator is calculated by summing up the population in all other regions weighted by the travel time to go there. For access to the region to itself, the time to the centroid of the region is used, while for access to other regions: (i) travel time over the network between the

[1] Except on the role of leadership (see Beer and Clower 2014 for a recent discussion).

two centroids plus the (ii) access from the destination centroid to the destination region are used. The potential accessibility indicators use population and give the highest weight to the population that can be reached within four hours.
The indicator on passenger flights is from Eurostat/EuroGeographics/National Statistical Institutes and corresponds to the daily number of passenger flights accessible within a 90 minutes' drive from the region centre.

2.4 Demand

Demand is measured as a composite consisting of disposable income per capital and two measures of potential market demand. Disposable income is included as income per capita. The two indicators on potential market demand provide an estimate of the GDP and population available within a pre-defined neighbourhood. They are expressed respectively in purchasing power standards and population size (EU average set to 100). See Annoni and Kozovska (2010) for details on the computation of potential market demand indicators.

2.5 Networks

Networks indicate the connectedness of businesses for new value creation, which is measured as the percentage of businesses (with at least 10 employees) in a region that collaborate for innovation, based on data of the Community Innovation Survey 2010 (CIS; see Arundel and Smith 2013).

2.6 Leadership

Leadership provides guidance for and direction of collective action. Leadership is measured with the prevalence of innovation project leaders. We have constructed a database with information on all the innovation projects in the Netherlands that received (Dutch or European) public subsidies in the period 2010-2013 (see Stam et al. 2016). We selected projects with at least two participating organizations (2231 projects). The geographical origin of these projects is established by taking the province of the main applicant or principal firm. This allowed us to measure the prevalence of innovation project leaders per 1000 businesses in each region.

2.7 Talent

Talent can be indicated by the prevalence of individuals with high levels of human capital. This is measured with the share of the population aged 15-65 years with a higher education degree.
Talent could also be measured with the share of the labour force with at least secondary education, but we have chosen for the more general, population based indicator.

2.8 Finance

The supply and accessibility of finance for new and small firms is an important condition for their growth and survival. We use the percentage of SMEs that applied for bank finance and received it as an indicator for the finance element. This measure is based on a study amongst 3027 SMEs in the Netherlands on their need for bank finance and the success rate in acquiring bank finance (Snoei & Ichou 2010). High-growth SMEs in the Netherlands do not more often apply for bank finance than other SMEs, but are more successful in getting bank finance, and use more credit facilities at their bank (Braaksma et al. 2014).
Finance can be traced in many other ways: for example with the ease of access to loans (World Economic Forum), the prevalence of informal investors (Global Entrepreneurship Monitor), venture capital, and crowdfunding. Data for these measures is available at the national, but not at the regional level.

Table 1. Empirical measures of the Entrepreneurial Ecosystem Elements

Elements	Description	Empirical indicators	Data sources
Formal institutions	The rules of the game in society, in particular the quality of government.	Four components: corruption, rule of law, government effectiveness and voice & accountability.	Quality of Government Survey 2012 (Regional Competitiveness Index - RCI 2013)
Entrepreneurship culture	The degree to which entrepreneurship is valued in a region.	New firms registered per 1000 inhabitants	CBS (Statistics Netherlands) 2012
Physical infrastructure	Physical infrastructure and the position of a region	Three components: accessibility via road, accessibility via railroad, accessibility via airports (number of passenger flights within 90 minutes' drive)	RCI 2013
Demand	Potential market demand	Three components: purchasing power per capita, regional product, total human population	RCI 2013
Networks	The connectedness of businesses for new value creation	Percentage of firms in the business population that collaborate for innovation	Community Innovation Survey 2010
Leadership	Leadership that provides guidance for and direction of collective action	Leadership is measured with the prevalence of innovation project leaders per 1000 businesses, derived from a database with information on all the innovation projects in the Netherlands that received (Dutch or European) public subsidies in the period 2010-2013. The geographical origin of these project leaders is established by taking the province of the main applicant or principal firm.	Birch Consultants (see Stam et al. 2016)
Talent	The prevalence of individuals with high levels of human capital	Percentage of higher-educated in the adult population	CBS 2013
Finance	The supply and accessibility of finance for new and small firms	Percentage of SMEs that have applied for bank loans and also received this.	EIM 2009
New knowledge	Investments in new knowledge	Percentage of gross domestic product invested in R&D (by public and private organizations)	CBS 2009
Intermediate services	The supply and accessibility of intermediate business services	Percentage of business service firms in the business population	CBS 2013

2.9 New knowledge

Investments in new knowledge are an important source of entrepreneurial opportunities, and if they lead to (better) solutions, they are also a source of prosperity. New knowledge is created in many ways, but probably the best measured activity is investments in (public and private) research and development. Our indicator for the knowledge element is the percentage of gross domestic product invested in R&D (by public and private organizations).

2.10 Intermediate services

The supply and accessibility of intermediate business services can substantially lower the barriers and increase the speed of new value creation. Our indicator for intermediate services is the percentage of business service firms in the business population.

3 Entrepreneurship outputs

A 'healthy' entrepreneurial ecosystem is said to produce entrepreneurship as an output and ultimately aggregate value as outcome. There are no perfect measures of either entrepreneurship nor aggregate value creation. To capture both output and outcome we use the concept of productive entrepreneurship (see Stam 2015; Stam and Spigel 2018). Productive entrepreneurship refers to "any entrepreneurial activity that contributes directly or indirectly to net output of the economy or to the capacity to produce additional output" (Baumol 1993, p 30). We interpret this as entrepreneurial activity that creates aggregate welfare.

We have proxied productive entrepreneurship with the prevalence of high-growth firms (Henrekson and Johansson 2010; OECD 2011; Stam and Bosma 2015). These high-growth firms are rare, but not so rare as "unicorns" (start-ups valued over $1 billion). Taking "unicorns" as entrepreneurial output, would leave many regions with zero output. We could also start at the other side of the 'entrepreneurship funnel', and count the share of the population that has the intention to start a business, or has just started a business. But we regard this to be an indicator of entrepreneurial culture in a region, not as entrepreneurial output. However, one might take a more process view of entrepreneurial outputs, and differentiate the entrepreneurial ecosystem contexts per phase of the entrepreneurial process (see Stam and Bosma 2015). This is probably most relevant for the finance element, with nascent entrepreneurs, start-ups, moderately growing, high-growth and unicorn firms having substantially different finance needs.
We use three measures of high-growth firms: ambitious entrepreneurs, high-growth businesses, and gazelles. The academic literature also proposes other measures (see: Stam 2007; Bos and Stam 2013; Parker et al. 2010; Daunfeldt et al. 2014), but these are not readily available for regions within the Netherlands in recent years.

3.1 Ambitious entrepreneurs

To create a scale-up, entrepreneurs need to have the ambition to create a substantial new organization (Stam et al. 2011; 2012). The share of the adult population in a region that has the ambition to grow a new business to a size of 20 employees within 5 years, based on Global Entrepreneurship Monitor data, so-called ambitious entrepreneurs (see Stam et al. 2011; 2012). This is a measure of potential productive entrepreneurship, not of realized productive entrepreneurship. Having the ambition to grow a business is close to a necessary condition for subsequent growth, but it is far from a sufficient condition: only about 1 out of 5 entrepreneurs with a growth ambition realizes this within a two-year period (Stam et al. 2012, p 97).
This measure is better available on a global scale than most other proxies of productive entrepreneurship. We analysed the prevalence of individuals in the adult population that are

involved in setting up a business, or own a young business (less than 42 months old), who expect this new business to have at least 20 employees within 5 years (see Bosma et al. 2009; Stam et al. 2009; Stam and Van Stel 2011; Stam et al. 2011). Given the low frequency of this kind of activity we took a longer time frame (2006-2014) to compute the annual average per province over this period.

3.2 High-growth businesses

There is an emerging consensus on seeing high-growth businesses as business that grow substantially consistently: businesses that have grown with at least 20 % per year in turnover or employment over a three-year period (OECD 2011). Statistics Netherlands (CBS) annually composes a dataset of high-growth businesses in the Netherlands. The regionalized version of this dataset consists of businesses that have grown with at least 20 % per year in turnover or employment over a three-year period, with at least 10 employees at the start of this three-year period. The number of high-growth businesses has declined from 20,590 businesses in 2010 to 17,020 in 2015. As a share of the total business population, it has gone down from 16.7 % in 2010 to 12 % in 2015. There is some regional variation, ranging from 13.7 % in Zuid-Holland and Limburg to 9.7 % in Friesland (in 2014).

3.3 Gazelles

The Dutch Financial Times (Financieele Dagblad), in collaboration with the Chambers of Commerce, has developed a somewhat more selective measure of high-growth businesses in the Netherlands: the number of independent firms with a profitable growth in turnover of at least 20% per year over three years (i.e. at least 72.8 % over the full three-year period). The selection logic for the 2013 sample is as follows (FD Gazellen 2013):

1. There are about 2 million registered firms in the Netherlands
2. 825,000 of these firms are obliged to publish their annual financial details
3. 11,400 of these firms have published annual financial reports in time
4. Only 1750 of these firms had an average turnover growth of at least 20 % over the last three years
5. 784 of these also fulfilled the following requirements: profitable, financial position, payment behaviour.
6. After a quality check, 395 gazelles remained (in 2014: 332).

Table 2 shows the shares of the three measures of entrepreneurship in the Dutch provinces, and the rankings of the provinces based on their performance on these measures.

There is some convergence in the province rankings: the Northern peripheral provinces of Groningen, Friesland and Drenthe never rank higher than 6, and the southern provinces of Noord-Brabant and Limburg never rank lower than 6, just like the urbanized province Zuid-Holland. For the other provinces, there is quite some divergence over the rankings of the different entrepreneurship measures.

For our analyses, we take the most selective measure of productive entrepreneurship, the share of gazelles. In the next section, we will analyse the effects of the individual components on the shares of gazelles.

Table 2 Shares and rankings of the three measures of entrepreneurship in Dutch provinces.

Province	Share ambitious entrepreneurship, 2006-2014	ranking	Share high-growth businesses, 2014	ranking	Share gazelles, 2014	ranking
Groningen	0.399 %	9	11.2 %	11	0.020 %	6
Friesland	0.337 %	10	9.7 %	12	0.018 %	9
Drenthe	0.465 %	8	13.2 %	6	0.003 %	12
Overijssel	0.312 %	12	13.4 %	4	0.025 %	4
Gelderland	0.482 %	7	12.4 %	9	0.014 %	10
Flevoland	0.559 %	5	13.5 %	3	0.010 %	11
Utrecht	0.494 %	6	12.4 %	9	0.045 %	1
N-Holland	0.706 %	2	12.8 %	8	0.029 %	2
Z-Holland	0.847 %	1	13.7 %	1	0.024 %	5
Zeeland	0.331 %	11	13.0 %	7	0.020 %	6
N-Brabant	0.561 %	4	13.3 %	5	0.027 %	3
Limburg	0.631 %	3	13.7 %	1	0.020 %	6

4 Entrepreneurial ecosystem elements and entrepreneurship outputs

There is substantial variation in the values of the different entrepreneurial ecosystem elements, even within a small country like the Netherlands (see Table 3). Very often the highest ranked region has a value that is more than double the value of the lowest ranked region. There is also a 15-fold difference in the rate of gazelles between regions within the Netherlands. This regional heterogeneity in the prevalence of gazelles is much more substantial than the heterogeneity in the prevalence of start-ups, as captured with the entrepreneurship culture element (cf. Stam 2005).

Several entrepreneurial ecosystem elements are highly correlated in this Dutch dataset (see Table 3), as might be expected. The infrastructure index and demand index are strongly positively correlated. Education is highly positively correlated with new firm formation and the prevalence of intermediate services. There seems to be a cluster of knowledge economy variables, including Research and Development, education, and (knowledge-intensive) intermediate services. Remarkably, the quality of government index is strongly negatively correlated with the infrastructure and demand indices, pointing at the peculiarities of the value of this index in Dutch regions (especially the relatively low quality of government in Noord-Brabant and Limburg).

Table 3 Correlation table entrepreneurial ecosystem elements and output

	min	max	mean	SD	Gazelles	RCI_Ins	NewFiFo	RCI_Infra	RCI_Ma	FirmCol	ProjLd	SucFin	HiEdp	RD	ImServ
Gazelles	.0030	.0450	.0213	.0105	1										
RCI_Ins	1.12	1.59	1.3333	.1689	-.355	1									
NewFiFo	9.69	16.07	11.8555	1.9331	.622*	-.260	1								
RCI_Infra	-.16	1.99	1.1092	.7307	.468	-.922**	.386	1							
RCI_Ma	-.24	1.45	.7383	.5837	.503	-.846**	.488	.948**	1						
FirmCol	.0990	.1430	.1160	.0138	-.547	.276	-.291	-.456	-.458	1					
ProjLd	.33	2.45	1.3342	.7465	.449	-.384	.473	.476	.433	-.179	1				
SucFin	37	95	56.50	16.065	.130	.271	-.039	-.375	-.407	.146	.204	1			
HiEdp	.2000	.3700	.2674	.0477	.756**	-.135	.845**	.329	.398	-.267	.658*	.078	1		
RD	.40	2.40	1.5083	.6142	.501	-.615*	.466	.664*	.599*	-.068	.821**	.177	.613*	1	
ImServ	.131	.269	.1858	.0380	.713**	-.241	.871**	.472	.565	-.329	.552	-.156	.948**	.601*	1

**. Correlation is significant at the 0.01 level (2-tailed)

*. Correlation is significant at the 0.05 level (2-tailed)

These high correlations between predictor variables pose the statistics problem of 'multicollinearity'. One predictor variable (e.g. infrastructure) can be linearly predicted from the others (e.g. market access) with a substantial degree of accuracy. In a situation of multicollinearity, the coefficient estimates of the multiple regression may change erratically in response to small changes in the model or the data. Multicollinearity does not reduce the predictive power or reliability of the overall model, it only affects calculations regarding individual predictors. A multiple regression model with correlated predictors can indicate how well the entire bundle of predictors forecasts the outcome variable (i.e. a high R2), but it may not give valid results about any individual predictor, or about which predictors are redundant with respect to others. This multicollinearity is also a reason why an index value might better represent the 'quality' of the entrepreneurial ecosystem than a set of independent variables. Despite these collinearity problems, we are interested in how and to what extent the decomposable parts of the entrepreneurial ecosystem, statistically explain differences in entrepreneurship output measures. We first performed a correlation analysis to see whether there are bivariate relations between the individual elements on the one hand and the shares of gazelles on the other hand. The correlation table (Table 3) shows that only three variables are (positively) statistically related to the share of gazelles, namely entrepreneurship culture, talent and intermediate services.

The 'standard' methodological procedure in social science for tracing the effects of individual independent variables, controlling for the effects of the other independent variables, is a multivariate regression model. We executed a multivariate linear regression model with ten independent variables reflecting the ten elements of the entrepreneurial ecosystem, with the share of gazelles per province as dependent variable (see Table 4). Despite of the high R2 (0.940) of the model, none of the independent variables has a statistically significant effect on the dependent variable, and several even have negative coefficients. Even if we reduce the model from 10 to the 5 variables with positive coefficients (R2 0.703), there is only one independent variable (higher education) with a weak (p 0.096) statistically significant effect. The lack of statistical significant relations of 'predictor' variables with entrepreneurial output does not mean that the elements are unimportant. They may all be important, but are perhaps already at a value that is beyond a necessary threshold value (such as institutions and infrastructure, which are all at the top levels within Europe; see Anoni and Dijkstra 2013). The diagnostics question is whether a weakest link analysis (cf. Acs et al. 2014; Szerb and Acs 2011) is appropriate in this context, because a relatively low value of an element that is beyond the necessary minimum level (e.g. formal institutions) is not a substantial constraint. And on the other hand, the Netherlands performs rather bad on accessibility of SME loans (see Gomez and Stam 2017), which means that a relatively high score on the finance element might still be a substantial constraint in the ecosystem.

Table 4 Multivariate linear regression of ten entrepreneurial ecosystem elements on gazelles

	B	SE	Sign
(Constant)	,032	,097	,796
RCI_InsLN	,007	,029	,845
NewFiFo	,003	,010	,826
RCI_InfLN	-,007	,007	,481
RCI_MaLN	,016	,020	,559
FirmCol	-,654	,514	,424
ProjLd	-,024	,024	,500
SucFin	-,001	,001	,689
HiEdp	,973	,919	,482
RD	,041	,055	,590
ImServ	-1,431	1,953	,597

R2: 0.940

Decomposing the entrepreneurial ecosystem into a set of elements and then regressing these on the output of the entrepreneurial ecosystem, does not seem to be adequate both for substantive and statistical reasons. The substantive reason is that the entrepreneurial ecosystem should be treated as one system, not as set of independent elements. In an ecosystem there are no direct, one-to-one relationships. The statistical reason is that the individual elements do not reveal to be statistically significantly related to the prevalence of gazelles, despite the large explained variance of the model.

In the next section we will take a systems analytical strategy, and analyse how the entrepreneurial ecosystem index is related to the share of gazelles, as the entrepreneurial ecosystem output measure.

5 Entrepreneurial Ecosystem Index

For mapping the 'health' or 'quality' of the entrepreneurial ecosystem we have constructed an entrepreneurial ecosystem index. The index is created to compare different units (regions, countries) and a rank in terms of multiple features (elements). The unit may be regions or countries, depending on the (policy) audience to which it is targeted and/or which spatial unit of analysis most adequately covers the relevant mechanisms in the context of entrepreneurship. Since one unit is stronger in one particular feature and the other in another feature, it is necessary to find a universal way to compare and summarize them in one index. This results in the following transformation (Acs et al. 2011):

$$P = [y_{ij}] \text{ -> } I = [Ii] \quad (1)$$

P: is a matrix of the dataset containing n x k elements
n: is the number of units (country, region, etc.)
k: is the number of variables
y_{ij}: is the observed value of unit i with respect to feature j
I_i: is the index associated to the ith unit (i = 1,2,…n)

On the basis of existing geography of entrepreneurship studies (see Stam 2015; Stam and Spigel 2018), an entrepreneurial ecosystem index is proposed which includes ten elements. The elements included in the entrepreneurial ecosystem index are listed in Table 1. The index compresses a large amount of data: the Dutch entrepreneurial ecosystem index, with 12 regions (units), is based on ten thousands of datapoints (for example the value of the finance element is based on a survey of 3027 SMEs, and the value of the leadership element is based on 2231 innovation projects). To develop an entrepreneurial ecosystem index based on a set of elements (features) we have used insights from other related indices, such as the World Economic Forum Global Competitiveness index (Porter et al. 2004), the European Commission Regional Competitiveness Index (RCI) (Dijkstra et al. 2011), and the Global Entrepreneurship & Development Index (GEDI) (Szerb and Acs 2011).

The ten elements of the entrepreneurial ecosystem can be quantified (see section 2), and be given a comparable value. This is done by normalizing the average value of each element to 1 and then let all deviations be relative to one: with elements in regions performing less than the average having a value below 1, and elements in regions performing better than the average having a value above 1. The advantage is that this allows us to compose an index value, and compare the 'strength' or 'health' of different entrepreneurial ecosystems. This index value is computed in an additive way (see formula 2).

$$I_i = \sum [E_{ki}] \quad (2)$$

I_i: is the index value of unit *i*, computed as the sum of the normalized values of each element E_{ki}
E_{ki}: is the normalized value of element k, of unit i

The elements of the index all get the same weight. In a later research phase other weighting techniques than the equal weighting methodology may be applied, based on either the opinion of experts or based on statistical properties of the data. The elements are here summed into one index value, which moves around 10, with regions performing on the average for all elements scoring an index value of 10, while regions performing above the average for all elements scoring an index value higher than 10. This is shown in Figure 2 for provinces in the Netherlands, revealing variation from 6.66 (Drenthe) to 11.97 (Utrecht).

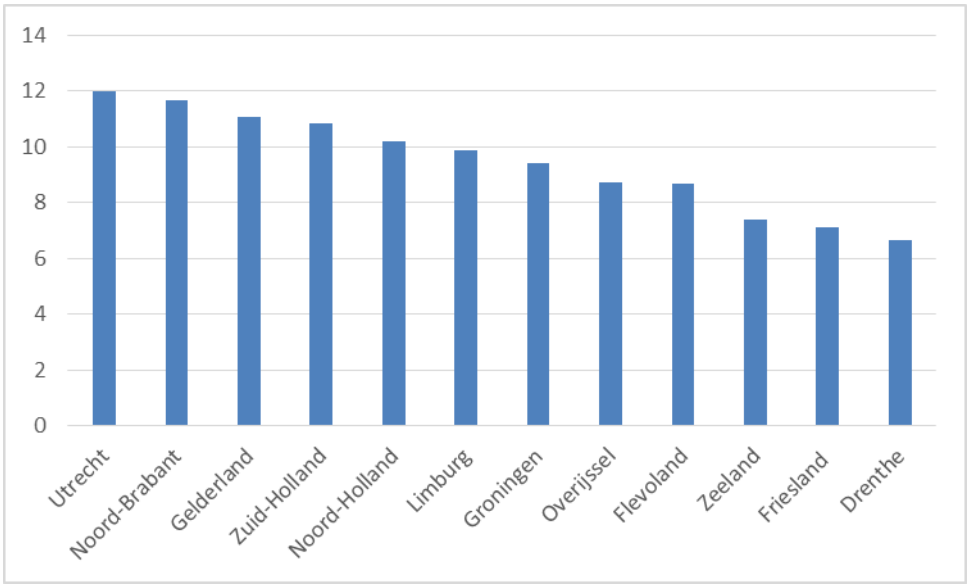

Fig. 2 Entrepreneurial Ecosystem index Netherlands provinces (additive)

The disadvantage of this index construction is that elements with above average value (ranging from 1 to infinity) can have a stronger effect on the index than elements with below average value (ranging from 0 to 1). To solve this we take the natural logarithm of the elements, so that these symmetrically oscillate around 0, with negative values for regions below average, and positive values for regions above average. This also means that the total index value oscillates around 0 and not around 10 (see Figure 3). The index values now vary between -2.52 (Drenthe) and 0.67 (Utrecht). The rank order of provinces remains largely the same, with Groningen moving from the 7th to the 8th place.

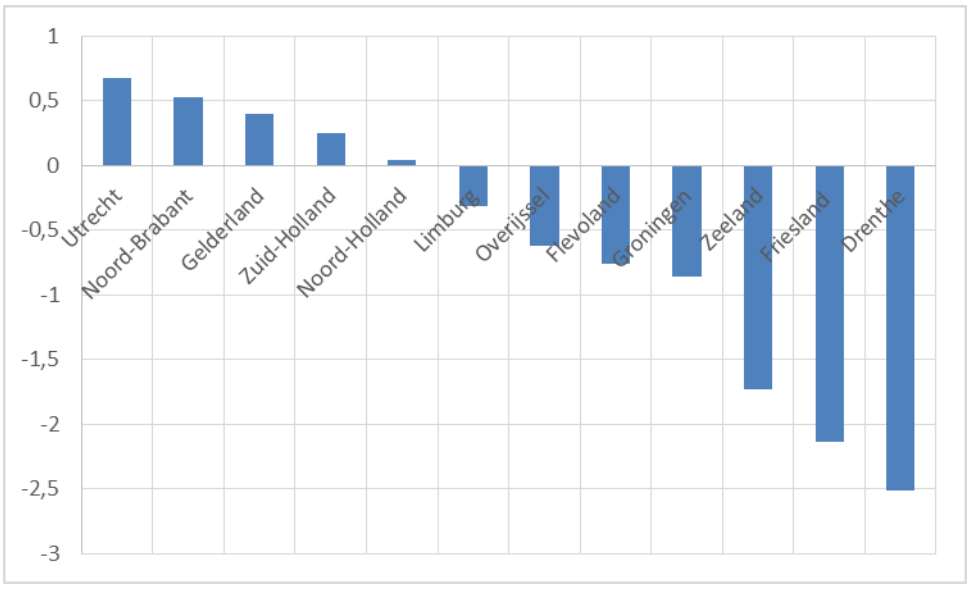

Fig. 3 Entrepreneurial Ecosystem index Netherlands provinces (natural logarithm values)

The essence of ecosystems is the interaction among its elements. This interaction is not adequately covered when an index is constructed as a sum of its elements. If we take the interactive nature of the system seriously, and the resulting non-linear relations, the index should be constructed differently. For this we compute an index that is not additive (the sum of the normalized values of each element E_k for unit i) but multiplicative (the product of the normalized value of each element Ek for unit i). This leads to index values with much larger variation, as the effect of deviations of the average is now much more substantial. The index values now vary between 0.003 (Drenthe) and 4.727 (Utrecht) (see Figure 4). This leads to substantially more variation in the index value, which might not be valid in a small country such as the Netherlands with relatively small regional differences in entrepreneurial activity (Stam 2005).

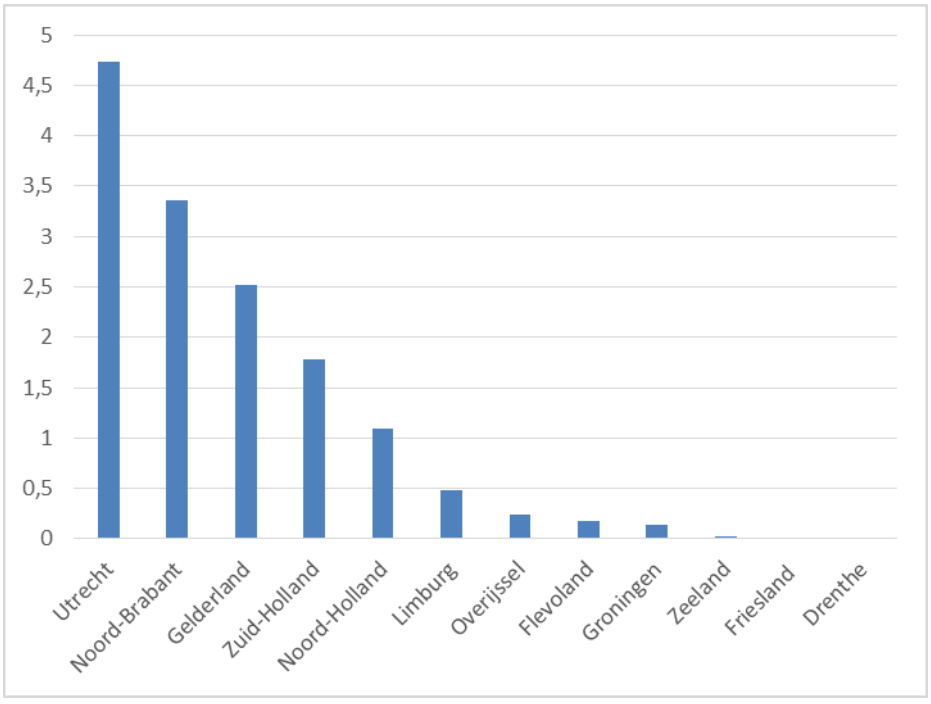

Fig. 4 Entrepreneurial Ecosystem index Netherlands provinces (multiplicative)

6 Entrepreneurial Ecosystem Index and its Output

To what extent is entrepreneurship related to the 'health' of entrepreneurial ecosystems? The three selected entrepreneurship measures do positively correlate with the entrepreneurial ecosystem values, but only the gazelles measure is strongly and statistically significantly correlated to the entrepreneurial ecosystem index.

	Share ambitious entrepreneurship, 2006-2014	Share of high-growth businesses, 2014	Share gazelles, 2014
Correlation with Entrepreneurial Ecosystem Index	0.448	0.234	0.629

Table 4 Relation of the entrepreneurial ecosystem index (EEI) values with entrepreneurship measures

As a robustness check and perhaps demarcation of the boundary conditions of an entrepreneurial ecosystem approach, we also used three other proxies of productive entrepreneurship, namely the internationalization of firms (based on Statistics Netherlands) and innovators (based on Community Innovation Survey 2010 data). Internationalization is a measure of success beyond national context – an indicator of the 'competitiveness' of regional firms. Innovators is measured as being an innovator or not (having introduced a new good or service) and the share of innovative sales. All measures are aggregated at the regional level, indicating the average prevalence of these proxies in the regions. There is hardly any correlation with the strength of the entrepreneurial ecosystem and international traders (0.082), somewhat stronger but not statistically significant with turnover share innovation (0.323) and even a negative (but not significant) correlation with the share of business innovators (-0.417).

To what extent is the prevalence of gazelles a function of the 'quality' of the entrepreneurial ecosystem? To trace this, we have constructed several statistical models based on different computations of the entrepreneurial ecosystem index values. First, we use the additive index to create a linear model, which has a R2 of 0.39 (see Figure 5). Second, we use the multiplicative index to create a linear model, which has an improved R2 of 0.47 (Figure 6). Third, we use the multiplicative index and create a non-linear (polynomial) model, which further improves the R2 to 0.52 (Figure 7).

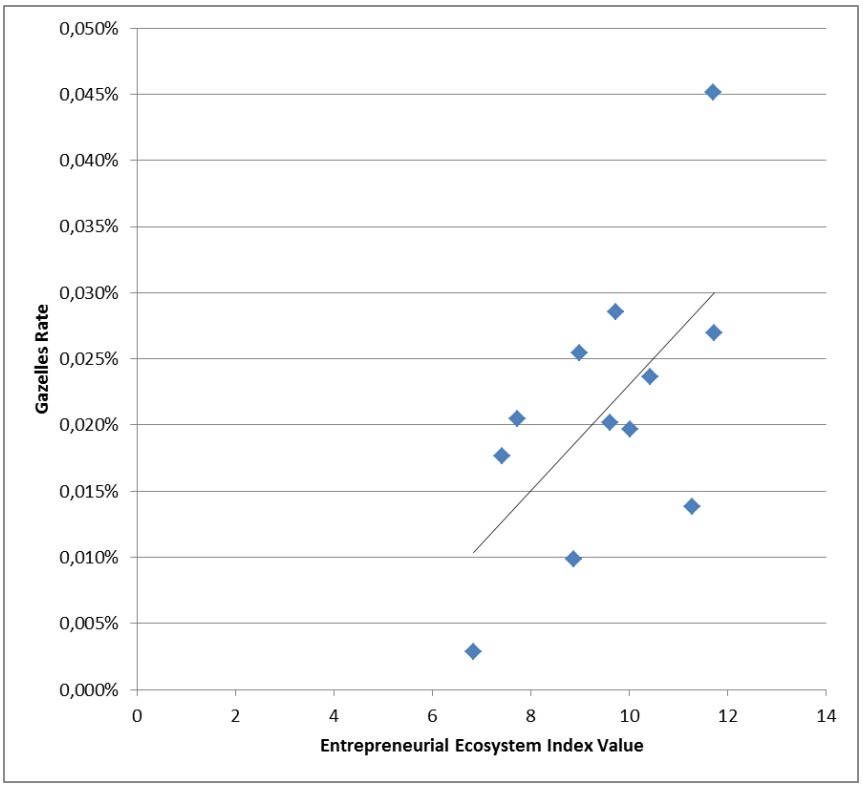

Fig. 5 Relation Entrepreneurial Ecosystem (additive) and Gazelles

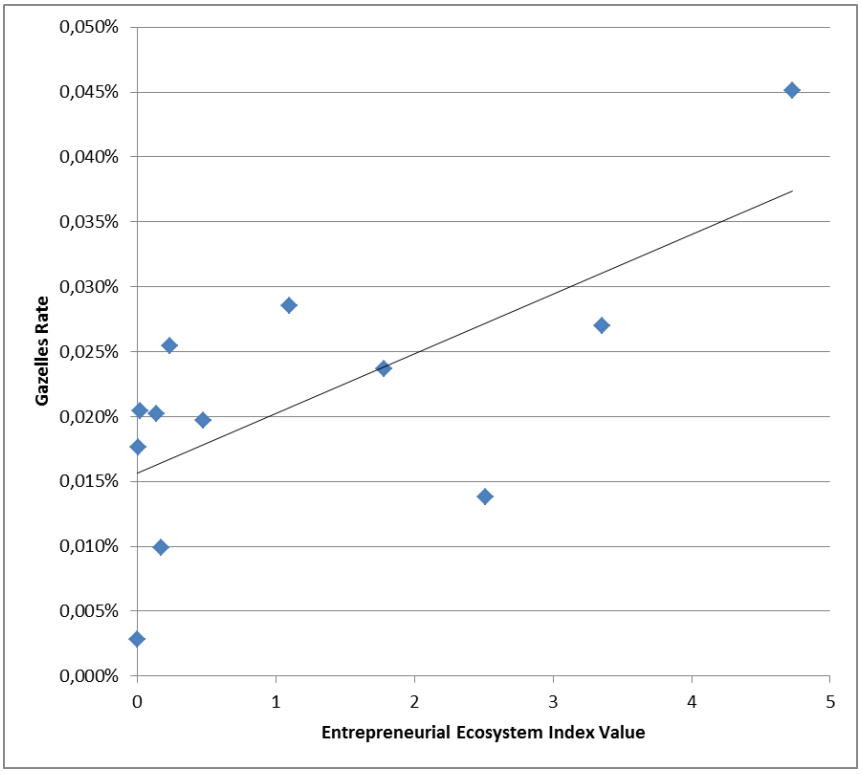

Fig. 6 Relation Entrepreneurial Ecosystem (multiplicative) and Gazelles

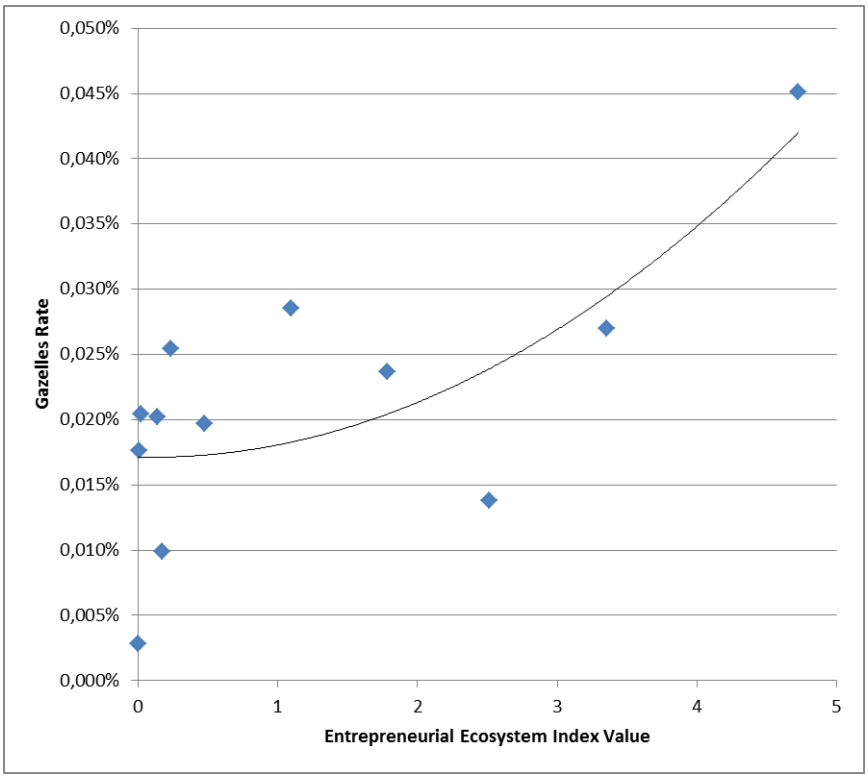

Fig. 7 Relation Entrepreneurial Ecosystem (multiplicative) and Gazelles (polynomial function)

Figure 5, 6 and 7 show that taking non-linearities into account increases the 'explanatory' power of the model. However, there might be a too limited number of data points available for creating systematic patterns, and for example tracing threshold values. Visual inspection of Figure 7 shows that even though there might be a threshold index value of around 1.5-2.0 beyond which the rate of gazelles substantially increases, the individual data points do not suggest such a threshold.

7 Discussion

The aim of the entrepreneurial ecosystem approach is not to predict, but to better understand how (entrepreneurial) economies function and in particular how they 'produce' entrepreneurship as an emerging property of the system. In this chapter we have explored how entrepreneurial ecosystems and productive entrepreneurship can be traced empirically and how entrepreneurship is related to entrepreneurial ecosystems. We have been looking for tendencies at one period in time. The analyses show that taking a systems view on the context of entrepreneurship necessitates measuring the quality of the context as a system. In this sense, we moved from the ecosystem metaphor to a complex system model of the entrepreneurial economy, at least from an epistemological point of view (Martin and Sunley 2007). Our analysis is based on a relatively small set of regions in one period in time. To arrive at more robust findings, this analysis should be repeated in multiple periods. This not only delivers more data points of entrepreneurial ecosystem index values and entrepreneurial outputs, but would also allow for feedback effects of the entrepreneurial output on the entrepreneurial ecosystem. The analyses should also be repeated in other contexts, potentially revealing different relations between the entrepreneurial ecosystem and its output.

Several other issues for further research remain. We discuss three of them: the boundary and openness of the system, functional decomposability of the system, and structural change as an emerging property of the system.

7.1 Boundary and openness of the system

We have been quite pragmatic in selecting the 'least worst', or most readily available measures of elements of entrepreneurial ecosystems in Dutch provinces. However, it may be debated whether the provincial border provides the most adequate boundary of entrepreneurial ecosystems. The boundaries are almost always arbitrary, most likely somewhere in between the municipality and the national level. Is the province the best unit of analysis, or should entrepreneurial ecosystems perhaps be analysed in a more nested or polycentric (Ostrom 2010) way, further problematizing the territorial view 'borrowed' from the ecological analogy? If we take the openness of the system serious this also opens 'explanatory power' of events and elements outside the current regional boundary, affecting the prevalence of entrepreneurship beyond regional boundaries.

7.2 Functional decomposability

The established empirical literature on the geography of entrepreneurship and economic development has revealed several factors to be of relevance in explaining the spatial heterogeneity in entrepreneurship. This suggests that there is a limited set of factors, or elements that affects the prevalence of entrepreneurship in a region. However, because of its inherent connectivity, nonlinearity and openness, a complex system affords limited functional decomposability (Martin and Sunley 2007), which suggests that the overall functioning of the entrepreneurial ecosystem cannot be deduced from knowledge of the function of its elements. We have seen this in the non-significance of the individual elements in explaining the rate of gazelles. By constructing an index value, also by multiplicating the composing elements, we have done more justice to the systemic nature of the ecosystem than can be done with traditional multivariate regressions. However, the connectivity, nonlinearity and openness can be taken into account in a more adequate fashion in future studies.

7.3 Structural change

Complex systems may be best applicable for gaining understanding in structural change of the system, e.g. radical changes in technology, institutions and organizational arrangements (Arthur 2013). Entrepreneurship is said to be a driving force of such structural change (Schumpeter 1934). Prior research has shown that ambitious entrepreneurship has stronger effects on economic growth than other types of entrepreneurship (Stam et al. 2011; Wong et al. 2005), and that young firms are a driver of job creation (Haltiwanger et al. 2013; Criscuolo et al. 2014), and that young high-growth firms accelerate the reallocation of jobs from old to new industries (Bos and Stam 2013). However, it may be the case that our – already very refined – measure of entrepreneurship does not sufficiently cover structural change, and is not an adequate indicator of emerging properties of the system.

Acknowledgements
I would like to thank Allan O'Connor and Niels Bosma for comments on previous versions of this chapter.

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