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The triple-helix model as foundation of innovative entrepreneurial ecosystems

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Abstract

Purpose – Recommend ways to increase the entrepreneurial performance score for city-centered entrepreneurial ecosystems (EES) and the possible role within the triplex helix concept. The former applies to lower-ranked EESs. For the latter, the authors hypothesize that the standard triple helix model of counting on some existing, well known multi-party interest in bringing together businesses and other stakeholders (especially universities and government) is insufficient. Including more players and alternative cooperation models may truly enable a long lasting productive interplay of cooperative and competitive forces leading to genuinely innovative (non-marginal, non-opportunistic) businesses and also to more regional well-being. This study aims at leveraging the city-based view on entrepreneurial ecosystems, to enable new ways of boosting the functionality of triple-helix minded programs, especially so for emerging economies and their cross-border regions.

Design/methodology/approach – Methodology is dual: (1) paying tribute to the history of entrepreneurial behavior and reviewing the diverse sources of support (institutional and otherwise), eventually leading to today's concentrations of successful innovative business, and (2) analyzing modern data on performance of city-centered EESs. Putting emphasis on path-dependence (meaning that history matters) the authors analyze data distributions of measures concerning city-centered EESs and also nation-wide entrepreneurial aggregates, searching signs of long-tail statistic, an indicator of path dependence. Furthermore the authors statistically analyze if and to what extend, key university performance indices translate into successful EESs. From these results, recommendation follow.

Findings – Historical developments and cultural backgrounds of different countries lead to different ways of support for new ideas and approaches. Entrepreneurship success is path-dependent and there are entrepreneurial approaches more easy – but others way more difficult – to imitate (e.g. "Hidden Champions"). Statistical analysis of entrepreneurial performance data confirms power law decay, which confirms the action

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of path-depend processes. Statistical models show that university performance is just weakly influencing entrepreneurial success. This leads to proposing a new, polycentric approach for organizing robust cooperation between the stakeholders, potentially capable of lifting low-score EESs into a more productive regime.

Research limitations/implications – Research limitation primarily concern data availability, as potentially useful information is not publicly available. The findings lead to further questions, and to questioning too optimistic expectations about cooperation readiness of the implied triple helix stakeholders. As pointed out repeatedly, other important players are non-university research organizations with more focused goals (national labs, etc.), which should be explicitly accounted for. Another directions is distinguishing between support for (a) short-term high-tech, and for (b) longer term, deep-tech entrepreneurs. The latter may require new evaluation techniques and specially tailored private-public partnerships. Finally, polycentric and polycentric cross-border cooperation requires more research into networked organizations.

Practical implications – Triple-helix based, cooperative agreements should rethink the effective functionality of EESs. City-centered, EESs tend to be most expressive in their projects but also subject to a stronger long tail-effect. This implies “success-breads-success” for the front-runners, enjoying very low ranking mobility. Lower-positioned EESs may profit from the mobility within this score region. However, the still lower positioned ones face strong downward rank mobility, implying that special effort (support) is needed. The authors’ proposal of polycentric cooperation, especially the cross-border variant, would credibly enable such support by bringing in both, more players and more levels of play, helping robust networking.

Social implications – This research has potentially profound social implications. Acknowledging the path-dependence of intellectual capital formation and emergence of entrepreneurial spirit in the modern sense helps to understand which techno-entrepreneurial endeavors would have increased chance of success of being brought up in the respective EES. It is also useful to identify the oversold (over-hyped) entrepreneurial projects. Concerning the cross-border polycentric organizations harboring EESs one may have to concede that national borders are sub-optimal, at least with regard to lifting up the entrepreneurial reputation of border-adjacent regions. Implicitly, opportunistic and marginal entrepreneurship (e.g. in Eastern Europe) would reduce.

Originality/value – This research claims originality for combining a qualitative-historical approach with a statistical modeling approach, which can explain the dynamic nature of the involved entrepreneurial processes (long-tails). While the historical approach is deemed to be necessary for understanding the reasons for the large differences in entrepreneurial success across nations and regions, the statistical modeling is helping to identify lower-score intervals within the entrepreneurial score hierarchy which are more easy, or, alternatively, very hard to escape. This in turn leads to adapted recommendations and mobilizing special efforts for creating new, potentially robust, cooperative arrangements beyond the triple-helix concept.

Keywords Triple-helix, Entrepreneurial ecosystem, Regional adaptation, Innovation, Path-dependence

Paper type Research paper

Introduction

In recent times there is much discussion about potentially successful paths to transform solutions into products, and, eventually, to obtain long lasting market acceptance. Over the last two decades, conditions for successful entrepreneurship became more involved, both, in terms of robust sustainability as well as in terms of continued financial backing. Especially affected are start-ups with radically new products (Groenewegen and de Langen, 2012) and “deep-tech” companies (Ventureradar, 2024). Success does not solely depend on personal creativity, determination and almost blind persistence of the start-up founders but, at least to the same extend, on the entrepreneurial ecosystem (EES) they are part of.

EES henceforth are cooperation networks between different stakeholders which turn out to be highly significant for economic development (Acs, Lafuente and Szerb, 2023; Brown and Mason, 2017; GEM, 2023). The triple helix (Leydesdorff, 2012) is a conceptual ideal rather than a systematic blueprint or social tool. EES attempt to implement this concept. It is not functioning by itself, and in that it differs, for instance, from a market. Nor is it a kind of resource-prey-predator system disguised in economic content. Both markets and prey-predator systems contain elements of individual and collective intelligence (Fioretti and

Policarpi, 2023). However, both also contain many agents which use few behavioral patterns in repetitive, high-frequency behavior. EES are more similar to a "DP-squared" problem setting (Ljungqvist and Sargent, 2018), where agents with asymmetric information are trying to optimize their influence on other optimizing agents. Technically, such systems are exceedingly difficult to solve as mathematical models, even in a purely deterministic setting.

In any pragmatic approach to this problem, one may accept sub-optimal guidance: One needs to recognize that an EES is composed of firms with a broad variety of behavioral patterns and a rather low frequency behavior, which is dictated by the nature of the firm's activity domain. For instance, the risk of announcing a "breakthrough" in computer-gaming, or similar domains, is way lower than the risk of announcing a new, highly effective medicine (or a new, revolutionary energy technology, etc.), not least owing to unforeseen and highly damaging, negative consequences. Ironically, low-risk innovations may generate much more profit than the riskier ones, especially so in the short run. This can result in a "trapping" or biasing EES development in strategically less desirable ways. It may lead to entrepreneurial mentality which favors individual ("egoistic") fast track success. This tends to undermine pre-competitive, multi-disciplinary cooperation which is essentially what EES should enable and sustain. Avoiding this trap is probably the most important challenge for the formation of successful EES.

Successful EESs spring up in different locations throughout the world. They may come in diverse shapes and configurations like composition of firms by (complementary) activity domains, partially owing to the influence of local characteristics and constraints. However, much to the surprise and frustration of regional and national development agencies, their eventual success is not based on clear rules. Apart from the immutable, and hence, almost trivial fact that many successful EESs are located in the regions/countries with influential Intellectual Capital or initiative-friendly cultural background, it proves hard to identify "systematic" success factors. The remedy proposed in the literature is to concentrate on the interplay between single firms (often start-ups), local universities and the state. This viewpoint has triggered a rich literature around "triple-helix" and extended approaches. Appart from the country-wise view on EES, a city-based view, including a city and its sourroundings, is also worth investigating.

Examples of diverse and successful city-based EES are:

- *Silicon Valley:* A global magnet for IT-related technology with a notorious proximity of venture capital. Puts forward a strong culture of "private initiative".
- Similar, successful, but lower in rank: *Oresund* (Sweden and Denmark), *Sophia Antipolis* (Southern France).
- *Cambridge Ecosystem*, boasting over 5,000 knowledge intensive firms, employing over 69,000 people, with £18bn aggregate turnover.
- *Tel Aviv:* creative Middle-East startup generator, having as background Technion University and demand generated by the military.
- *Berlin*: Became a hub after German reunification; reconnects to its former rôle as an intellectual and industrial center, having a vibrant cultural scene and (as yet) reduced cost-of-living.

City-centered EES (Bosker and Buringh, 2017; Bettencourt *et al.*, 2007) are cooperative with regard to their inside members while potentially competing with EES of other cities form the same other or countries. The top city-centered EES tend to concentrate power, in that their performance ranking position is very stable over time.

City-centered EES in economically emerging regions should enable establishing new businesses by building niche networks, which may wish to differentiate themselves markedly from other EES. This does not necessarily mean that the created or aided business operate themselves in industrial niche domains. To prevent migration of innovative, and often capital-hungry, start-ups into other networks (possible also into business friendly countries like the US or Australia, etc.) city-centered EES must be especially innovative themselves, offering services closely matching the needs of their start-ups, reducing red-tape and cautiously seeking to cooperate with other EES which offer complementary functions or services.

EES can also help to avoid possible malfunctions of modern, much accelerated, business procedures. An example is *opportunistic entrepreneurship*, which operates according to the following mechanism:

- Exaggerated reward for aggressive “private-personal” positioning or “overselling”. Taking advantage of this widely tolerated social behavior, some entrepreneurs succeed in presenting themselves as being valuable visionaries, even without having delivered any proof or generated any profits as-yet.
- The complementary part is the *ease of eliciting investor fantasy*. This may be useful to easily mobilize venture capital. But it also entails formidable risks of catastrophic financial losses, including that of abandoning whole lines of research and development.
- Investors believe that others also like to believe in a miraculous success of some high-risk, technically improbable, but heavily hyped projects. And eventually, to be able to pull out just-in-time before a crash. Examples include many of the presently fashionable “deep-tech” projects, which are carried out by small, and potentially understaffed, start-ups (European-DeepTech, 2023). This belief tends to reinforce opportunistic entrepreneurship.

Such potential malfunctions may lead to less negative consequences in powerful (large and rich) economies, which have plentiful capital to regenerate, and hence, even puts them at an additional advantage.

EES concentrate more or less tacit knowledge (Goffin and Koners, 2011) and facilitate access to resources (relations, talent/experience and other types capital), which are above the capabilities of the single firm, but which also adequately handle and advice on regional constraints. Specifically, information and knowledge about what would possibly be accepted by the markets and which business models do increase chances of success are sought after. Plenty of barriers to the development of successful EES (Höglund and Linton, 2017) do exist; Many examples can be found in East European countries. The challenges for overcoming these barriers in emerging economies – here explained for the case of East European countries – could be met by addressing the following:

- Eastern European countries have historical legacies of limited collaboration between government, universities and businesses. If unaided, building trust and changing mindsets takes long time. A catalyst for triggering EES development is needed. The question is, which triple helix agent should be given the leading role, and if such role assignment matters at all. In some economically advanced countries innovative EES emerge by intense business practice alone, but in general, the very creation of such ecosystems can be regarded as being business in itself.
- Any Eastern European country is to some extend confronted with talent migration. Here, a triple-helix inspired, dependable EES may prove pivotal in reversing talent

migration to concentrate skills and to improve visibility. Then financial resources mediated by venture capitalists, business angels and other investors will follow.

- Tailoring a triple-helix inspired model to the specific needs and strengths of each Eastern European country and region is desirable.

The purpose of the present research is to identify functional patterns of ESS and to selectively support the forwarded explanations by statistical models based on national and city-level EES performance scores. Our statistical models (explained in the Methods section) in part confront EES performance scores with data on performance measures of the local or regional universities. The hypotheses to be verified, attempt to indirectly characterize the underlying processes according to score distributions and thereafter attempt to identify the strength and directions possible causation to be found in the EES data (explained in the Results section).

The models also attempt to offer insights into possible causes for persistent success and causes for barriers to the development of emerging EES (partially commented in the Literature review section). This combination of qualitative and (confirmatory) statistical analysis fills a gap in the literature, as existing research is concentrating on either a exploratory social-science approach or on statistical models for narrower technical questions.

Taking into account the concentration effects of path-dependence in EES formation, a performance score lift of "disadvantaged" or emerging EES asks for high intensity, long-term effort on part of all triple-helix partners. As payoff does not appear in the short-term, such an effort may be difficult to motivate and to maintain. Hence, we propose some adapted triple-helix structures which can make it easier to recognize and to accept the multiple-win perspectives by the ESS participants (presented in the Discussion section). This kind of constructive approach is underrepresented in the literature.

Literature review and hypothesis development

EESs (Acs, Lafuente and Szerb, 2023) can be traced back to ancient times – although in very embryonic stages (Manning and Morris, 2005). For instance, the ancient city of Alexandria (Egypt) emerged as a knowledge and a commercial center with the patronage and supervision of the administrative authority. A more decentralized system of EESs appeared in ancient Greece with its state-cities and colonies, which fostered an effective environment for science and innovation and acted as trading hubs for economic exchanges made possible by craft specialization (Manning and Morris, 2005).

Later, at the end of the Middle Ages, during the Renaissance (14th – 17th Centuries) we can see more sophisticated EESs (Malanima, 2022; Vindt, 1998), for instance in Florence, Italy, which have all the main necessary characteristics: science and innovation, an efficient financial system, being an international hub of trade and the involvement from the politics and administration – the powerful deMedici family supported a culture of creativity and innovation by providing an extensive patronage, both to artists and to scientists. These EESs benefited from:

- the development of universities – knowledge centers,
- the guilds and apprenticeship systems – facilitators of knowledge transfer,
- the development of trade routes and commercial hubs: Florence, Venice, Genoa and Amsterdam – are all facilitators for (a) exchange of ideas, (b) mobilizing resources and (c) identifying opportunities for entrepreneurship.

- Royal power interests – Kings and Queens offered their patronage and supported initiative and risky projects, often facilitating experimentation and innovation,
- the development of banking and financial system including early forms of venture capital.

Hence, we suspect that there exist important connections between historical long term cultural evolution and developments and of EES success cases. Furthermore, it motivates why location is important (beyond that of convenient geographical proximity). And, especially also, why entrepreneurial success may not be easily reproduced by (memetic) imitation, which would imply that "offering favorable framework conditions" is just not enough. In light of these arguments our first hypothesis is:

H1. The differences in entrepreneurial attitudes and effective entrepreneurial activity in different geographical regions and across cultures have historical roots.

This calls for understanding the main historical causes of differentiation (part H-1.1), and subsequently (part H-1.2) to find statistical hints, which technically further underline the hypothesis. In the following, we explain these two steps more closely:

Part H-1.1 is of a qualitative nature and may be confirmed by further discussing the literature as follows. History makes sense beyond anecdotal purpose if we accept that path-dependence (Arthur, 1994, 2021) is one of important drivers of the economic process. This includes the sometimes hard to understand divergences of commercial success of single firms, their growth paths or the "preferential" treatment of some firms by financial markets, to name a few. We propose that such effects translate into composites of economic agent types, such as EES. Hence, attempting to lift low-scored EES out of underdevelopment by applying standard guidance and some financial or fiscal support may fail. Important innovative historical epochs (Vindt, 1998) may illustrate the origins and causes of the differences expressed by hypothesis *H-1.1*, namely by considering some examples from Western Europe:

- Florence during the Renaissance (14th–17th Centuries)

Key Players: Wealthy merchant families, artisans and intellectuals. Characteristics: Evolving hub of trade, finance, art and science. Patronage to artists and scientists, fostering a culture of long-term creativity and innovation. Impact: The Renaissance led to significant advancements in art, architecture, science and literature, profoundly influencing European culture (Malanima, 2022).

- Industrial Revolution in Britain (18th–19th Centuries)

Key Players: Inventors like James Watt, industrialists such as Richard Arkwright and financial institutions. Characteristics: The rise of mechanized production, development of new technologies (e.g. the steam engine) and establishment of mechanized factories. The legal and financial systems supported entrepreneurial activities. Impact: Transformation of economies from agrarian to industrial, significant technological progress and the birth of modern production-centered capitalism (Floud and Johnson, 2004; Vindt, 1998).

20th century

Regions like the Silicon Valley in California emerged as global hubs for technology and innovation. Universities like Stanford, venture capital and a culture of conditional collaboration contributed to their success. Purpose-built communities like Science Parks focused on research and development (Nahm, 2000) fostering innovation in highly specific sectors, like biotech, new materials or IT. Government programs played an increasing role in supporting entrepreneurship through funding, tax incentives and infrastructure development, conceding the fact market forces alone are insufficient for EES formation eventually leading to triple-helix concept and similar initiatives (Leydesdorff, 2012).

21st century

Globalized EESs: Owing to the internet and communication technologies, EESs are no longer geographically bound. Focus on social impact: emphasis on social entrepreneurship, with businesses also engaging in social and environmental challenges. Rise of innovation hubs: Cities around the world are actively fostering EESs to attract talent, startups and investment (StartupBlink, 2023; StartupGenome, 2023; European-DeepTech, 2023; Brown and Mason, 2017; Höglund and Linton, 2017; Bettencourt *et al.*, 2007).

As illustrated by these examples, the evolution of EES is related to know-how and to acquiring and to disseminating principled knowledge. This is also captured adequately by following the development of formalizable and tacit knowledge types as forwarded by research into Intellectual Capital (Edvinsson and Malone, 1997; Demartini and Beretta, 2019).

In general, being able to accumulate and maintain a critical mass of intellectual capital enables streams of innovative, science-based and disruptive solutions to various pressing problems differs from merely having a strong drive toward intense entrepreneurial activity. However, in some particular locations both do co-exist. This is especially the case when a strong local research output in applied sciences meets a keen entrepreneurial spirit. While the former may be a result of acquiring a critical mass (over time) the latter may be more directly grounded in behavioral culture and in urgent societal needs (Goffin and Koners, 2011; Sachs, 2019; Wagner, 2015).

One may connect the very existence of sponsored applied sciences and enough entrepreneurs willing to invest in "high risk" technology to a historical period, especially in Western and parts of Central Europe. Here, surplus capital starts to appear in the late Middle Ages, and a strong interaction between economic development and non-material values – trending toward science – is gaining traction (Aulin, 1997). This development started before the age of the Renaissance and went on to divide West from East for ages. This may also be at the roots of the relative lethargy of East-European entrepreneurship in engaging with genuinely innovative projects. Interestingly, many IT-related activities draw on highly formalized knowledge and procedures, which – at least in principle – should be much less sensitive to cultural mind-sets being evolved over long historical periods. This may explain the many highly successful IT-contributions of firms from all over the world, regardless of local technological tradition, cultural background or political system (democratic versus dictatorial) of their host country. We propose the following three types of EES-related developments.

Type A development: From a historical viewpoint, we find in Western Europe examples of federalist organization tradition in Northern Italy, The Netherlands, the Hanseatic League and South-West German provinces. Some of them were (and are) located in widely independent city-states. Here we offer an explanation for city evolution based on power balance – as a complement to the more fashionable geo-logistical approach (Bosker and Buringh, 2017). Such widely independent entities were (and are) characterized by a strong entrepreneurial drive, including skills in international trade and sophisticated finances – all traits which may now lead to "advantages of cities over countries" (Fujita *et al.*, 1999).

Type B development: The West-European counterpart to federalist *type A* examples were the historically strong colonial powers, especially England and France, boasting of more centralized organization. The early formation of highly influential organizations like The Royal Societies (London and Edinburgh, 1660) and French Academy of Sciences (Académie des sciences, Paris 1666), Institute de France (Paris, 1795) fostered and disseminated important scientific insights, which led to a series of modern industries (Hahn, 1971; Bryson and Turney, 1979). Recently, a renewed interaction of academies with society is called for Quéré (2010).

Type C development: Both (*type A* and *type B*) historical developments eventually lead to various kinds of strategically planned organizational combinations, strongly driven by the technological and logistic needs of World Wars I and II. Such interventionist measures were heavily used by war-time Germany and Japan and reciprocated – with more democratic legitimacy – by the USA, France and the UK. The lessons of WW II learned from using advanced military technology reinforced in the US the determination of creating and expanding National Laboratories (LANL – Los Alamos, LLNL – Lawrence Livermore, PPPL-Princeton, to name just a few of the 17 labs working today under the Department of Energy alone). There is a particular concentration of such laboratories in the wider San Francisco area, which also hosts many technically-minded, successful entrepreneurs. Similar situations repeat in various locations around the US (MIT, Caltech, etc.) or within the UK (London-, Oxford-areas, etc.).

Type C development may be seen as a model of national coordination leading to successful EES, often applied by large, powerful and rich countries. With proper adaptations, it is also being used by sufficiently developed (techno-educationally sophisticated) but much smaller and less powerful countries (Israel, S-Korea, Taiwan, etc.) enabling them to seed highly successful EESs as cooperation networks (StartupBlink, 2023; StartupGenome, 2023).

Part H-1.2: For the statistical motivation, which supports the historical dimension of EES (i.e. part H-1.1 of *H1*), we use a tracer of network-based systems as indirect evidence for the long memory nature of EES. In economics, the somewhat counter-intuitive distribution of wealth (and poverty) was noted way back by Pareto (Pareto, 1896) and such network-generated outcomes become again fashionable under the impression of new connectivity offered by e-business. Here, at least, its validity remains somewhat debatable since Anderson (Anderson, 2008) announced the benefits for niche vendors reaching many more clients and Elberse (Elberse, 2008) showing an increasing share (concentration) of best-sellers, which co-exists with some more niche sales. This results in a more complex situation combining a kind of "winner-take-all" effect relating to a few maximally popular products or vendors, and, simultaneously, in a rather restricted sense, also an increase in niche sales. Can these systems features be detected for EES as well? Which statistical method can be used to assess this in at least an indirect way? And can these features then be useful for helping develop EESs and their visibility? Answer to these questions will be given in the Methods, Result and Discussion sections.

Our next hypothesis (H-2) connects to the first (H-1) by observing the nature of the most popular domains for start-up activities. As documented by influential sources of EES-related information (e.g., StartupBlink, 2023; StartupGenome, 2023) the main activity domains for start-ups are at present *Fintech* (financial), *Edtech* (education), *HR-Tech* (human resources), *Prop Tech* (real estate), *Clima Tech* (environment), *Health Tech* (healthcare), *Future-of-Work*, *E-commence*, *Dating Apps* and *Recreational*. Although being "high-tech", their aims and promises are very general and rather vague. This is also true for the rarer types of start-ups from the "deep-tech" domains (European-DeepTech, 2023). However, both have a trait in common, namely that they are not primarily advertised and evaluated by content but by the amount of capital raised in successive investment rounds. This means that start-ups, which are in command of an effective relations-management, are more likely to succeed than others. This may indeed be poorly understood by many task-oriented entrepreneurs (engineers, etc.) with a strong technology commitment. EES from emerging economies are unlikely to have the clouts to mobilize substantial amounts of investment via attention of the major financial markets. Hence, their chances of improving on the performance score scale are extremely slim – unless there are at least two distinct regimes of influence regarding the dependence of entrepreneurial scores on factors other than professionalized investment rounds. As a proxy for these additional factors, we use performance criteria of local universities, which seems sensible in the context of triple-helix structured ESS. Hence, our second hypothesis to be tested against data is:

H2. Top level scored and intermediate level scored EES (*t*-type and m-type, say) operate in different regimes as far as the influence of local university performance is concerned.

The *m-types* may stand for a mostly task-oriented, or more narrow "problem-solving" approach, while the *t-types* are more general in scope, and strongly relation-oriented. *M-types* are innovative resource providers, and do excel in synergy exploitation. The latter also comply more easily with the triplex-helix concept of multi-stakeholder integration. The more fashionable *m-types* triggered a historical shift from problem-solving toward gaining product acceptance and public attention. This means profitable sales and investor goodwill. Oftentimes investor goodwill suffices for leveraging a firm's life-cycle, hence satisfying opportunistic entrepreneurs and first-to-market investors.

Figure 1 depicts a stylized transition toward a more complex mode of organization, which is often needed to meet client expectations or to effectively sell under competitive market conditions. Frequently, new products and services do not serve "natural" but rather derived needs. Therefore, their use calls for various types of assistance, leading to more complex patterns of division of labor on the vendor side. In the box below we summarize important features of the transition in the first row, and thereafter, in the second row, the complementary roles of agents within the EES as would be implied by the triplex-helix concept.

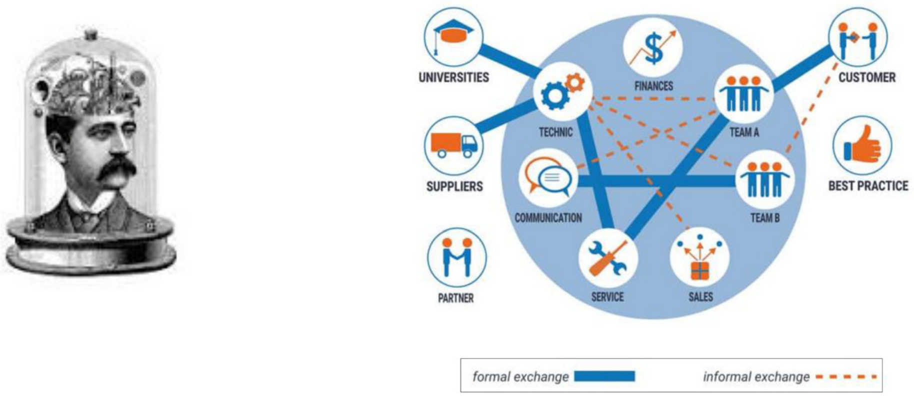
Hence, the primary strategic objective for non-marginal – that is genuinely innovative – firms is that of:

From a ***problem-solver,*** *of* ***polymath type:*** secretive, in house, mastering all relevant disciplines for essential product design	To a ***market conqueror,*** *of* ***innovation networking type:*** collaborative, distributed; the product is too complex to be mastered by individuals	**The open (free) market** is the sole long-term success validator
This role can be relocated to university or other, more focused research units	This role can be taken over by technologically knowledgeable intermediaries	New ideas / prototypes / highly creative teams can be retained as strategic assets by non-commercial entities (governments, state agencies)

- Transforming solutions into products, obtaining attention and market acceptance.

A further strategic objective, which drastically increases the client base, is that of

- Democratizing by product policy



Source: Author’s own work

Figure 1. The transition from problem-solver to market conqueror

Examples of huge American past and present successes grounded on “democratization” are:

- Ford-T, etc.: “individual mobility for all”,
- MS-Windows, etc.: “computational services for all”,
- Google, etc.: "information access for all",
- Facebook, etc: “networking service for all”, and
- Different approaches to bring about “Artificial Intelligence for all”.

Product democratization is achieved by cleverly repackaging existing solutions, “inventing” use cases (products find multiple uses) and betting on f*irst-mover advantage* (Arthur, 1994) by means of heavy early investments. Other developed countries applied similar strategies: Present and past examples include VW of Germany, Canon of Japan, Ibis-Hotel chains of France, to name a few. One may also observe, that traditionally strong innovators are less skillful in reaching huge market success. Innovative firms from the UK, and hi-tech industries from around the EU, often experience difficulties in competing against powerful, hyper-capitalized companies from overseas. This clearly indicates the urgent need of triple helix inspired structures for developing more successful European EES.

Methods

Concerning our hypotheses, the statistical methodology used consists in data pre-processing and in data analysis. First, we identify secondary data sources for analyzing typical patterns occurring in the context of EES. Subsequently we propose group structures for EES for data collected at the country- and on the city-level. Note the growing importance of cities relative to countries in the global economic context (Bettencourt *et al.*, 2007). As consistent EES panel data seem to be scarce, a more formal investigation finds out whether one can make sense of the long-tail concept solely applied to latitudinal EESs data available.

This then enables certain indirect explanations, partially inspired by the analyzes of sales networks in e-business by confronting university performance variables (GLEU, 2024) with EESs scores obtained for the year 2023 from *StartupBlink – Global Startup Ecosystem Index* and *Startup Genome – The Global Startup Ecosystem Report, r*espectively (StartupBlink, 2023; StartupGenome, 2023). The data used from these sources are five positive metric university performance variables as inputs (possible predictors), namely:

(1) "u.acrep": academic reputation score of the university;

(2) "u.facul": reputation score of the universities faculty;

(3) "u.cite": citation score of the faculty;

(4) "u.intl": score related to involvement of international faculty; and

(5) "u.intresn": score related to international relations networking,

and the positive metric target variable "escore", referring to the EES performance score, compiled in the above data sources. The targets were used separately at the country level (with multiple university to country assignments) and at the city-level (the host city of the EES). Special care is taken to sensibly match locations of universities to locations of the EES. If a direct geographical match was not possible, then the most proximal assignment was used. In our analysis, we use the 100 top scoring cities (with EES) plus 19 entries from some lower performance score EES around cities from Eastern Europe.

In different areas of science, economics and business there is by now a tradition of studying phenomena or events, which should not be observed as frequently as they effectively are in reality. The latter implies that such events are unlikely to be generated by a Gaussian (or "normal") statistical law. These include (natural and human made) catastrophes, accidents, but also the occurrence of useful inventions. Hence, such events tend to occur *more often then expected* under assumption of a normal-law, and they are commonly described as being "fat tailed." Hence, fat- or long-tailed statistical densities are more pronounced toward their extremes than are the Gaussians; they do not decay exponentially fast, but according to a power law instead. A recent account for significant applications thereof is (Roman and Bertolotti, 2022).

The technical procedure to verify for the presence of long-tails is to log-log plot the sorted performance data and to compare them with a (simulated) set of Gaussian data differing in variation but with identical boundary points. If the log-log data plot is linear over a significant connected portion (i.e. if the EES performance data follow a power law) then an underlying long-tail or long-memory process is confirmed for practical purpose (Corominas-Murtra *et al.*, 2015).

These effects result in a more complex situation, combining a kind of "winner-take-all" effect relating to, for instance, the few maximally popular products or vendors, and, simultaneously, in a restricted sense, also an increase in niche sales. Can some similar effect be found for the popularity of EES? The positive answer would validate our hypothesis *H-1.2* in that long-tails would confirm the (historical) memory of EES evolution process. Furthermore, our data allow for comparing EES performance scores at the country level with those at the city-level, which is detailed in the Results section.

In the sequel we fuse two data sets, namely the entrepreneurial scores of city-centered EES and five university performance variables of universities taken from the vicinity of the respective EES. As there are no longitudinal data from which to obtain information about the dynamics of EES we proceed by analyzing the distribution of the scores which allows to draw some conclusions of the nature of the processes, both viewed on the (aggregate) country level as well as on the city-level of EES. As is well known from the literature of dynamical systems with extended memory (Turcote and Rundle, 2002; Corominas-Murtra *et al.*, 2015), and also from social network dynamics (Roman and Bertolotti, 2022), processes with decay-like relations (as are the potentially decreasing performance scores in the rank of the EES) may exhibit, among others, two important alternative features, namely:

(1) exponential decay, or
(2) power-law decay.

These features may not cover the whole domain in a decay diagram. A system which contains extended power-law decay may be identified with fat-tailed distributions and with having long-range memory.

To process hypothesis H-2, a basic and reliable way to judge whether one may expect dependencies (which are causal dependencies by the nature of the variables) is to visually inspect the scatterplots between all variable pairs. Owing to relative data sparseness, using linear correlations is the only reasonable option and it immediately delivers correlation coefficients and their significance levels.

The aim is to compare the correlation structure between the five different metrical variables relating to university performance, reputation and networking (independent variables) and entrepreneurial scores (dependent or target variables) of the 100 top scoring cities with the correlation structure, which results from adding data of 19 more EES, which have lower performance scores and which happen to be from around Eastern European cities. Observed differences will reflect the different degrees, to which EES performance scores depend on the performance of local universities.

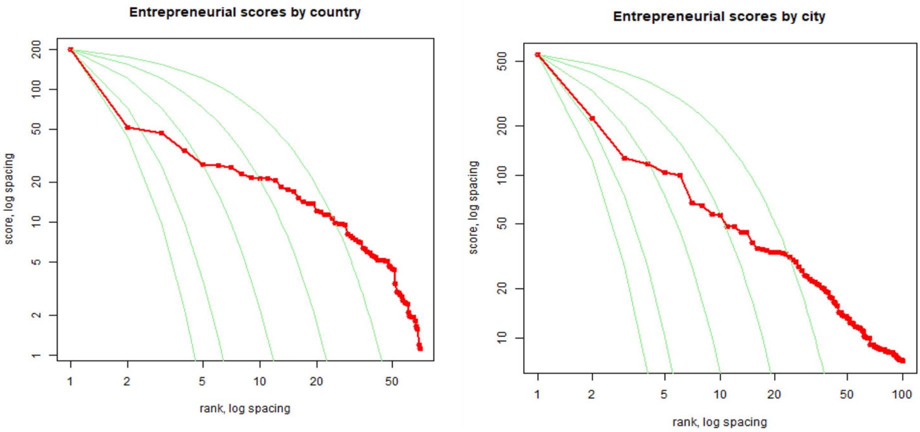
For processing hypothesis H-2 along a more refined direction, we include two types of grouping of the EES, and thereupon estimate linear (explanatory) statistical models for each grouping. The first grouping subdivides EES into *above average* and *below average* performance cases. The second grouping is totally unsupervised, in letting groups form by k-means clustering ($k = 2$) of the data. These models reveal which variables do explain EES performance scores, in which groups and at what significance level. The Appendix contains models on a grouping using medians instead of averages. Finally, a quantile regression on the entire data set can inform about the presence of non-linearity in the data.

Results

H1 was subdivided in part *H-1.1* and part *H-1.2*. In general terms it asserts a strong historical dependence of EES performance. This may pose high barriers to the imitation of the most successful EES. Part H-1.1 was positively validated in the Literature Review section. This is an unpleasant result for emerging EES hoping the climb the performance score ladder – unless there is a two-sided effect similar to that proposed by Elberse (2008) for the case of best-seller concentration in co-existence with niche sales in the long tail, as is detailed in the Literature review section.

Hence, if *H-1.2* validates, there are chances for many EES, which are empirically distributed in the “long tail”, to improve their scores. Opportunities for niche EES are now much amplified, by using instruments from e-science, e-government and e-business, including a creative use of AI. However, this calls for strongly collaborative attitudes, which seems to be counter-intuitive business behavior, especially so in emerging South East Europe.

The notion of the fat tail (or long tail) refers to a slower then exponential decay, signaling an underlying process with long-term memory. In Figure 2 we plot the empirical decay of entrepreneurial scores of 100 city-centered EES against a set of curves with exponential decay starting at exactly the same (highest) score, i.e. at the upper left value of the plots. Note that the log-log axes used makes this distinction clearly visible, hence basically confirming hypothesis *H-1.2*. In Figure 2 we also see two slightly different empirical data curves, both

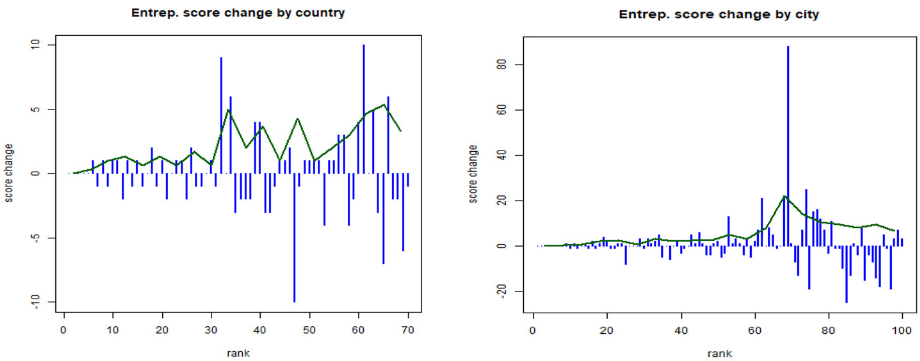


Notes: Power-law decay of country entrepreneurial performance rank compared exponential decays (left panel) vs. power law decay of city entrepreneurial rank (right panel)
Sources: Own computation using the R software; Author's own work

Figure 2. Evidencing the power-law like characteristics of the data

containing clearly visible domains with power-law dependence (the point-line curves with portions of linear-like decay). The long-tail effect is more pronounced for the city-centered EES (right panel), which indicates that this is the better view upon chances of improvement or change of EESs.

This is then also confirmed by the complementary Figure 3. Here both, the country- and the city-centered views indicate more rank volatility in the EES with lower performance scores. The extreme peaks may be interpreted as chances of up-grading but also of down-grading in EES performance, respectively. Especially the city-view shows high volatility and



Sources: Own computation using the R software; Author's own work

Figure 3. Rank change in entrepreneurial scores at country level (left panel) and the same at city level (right panel)

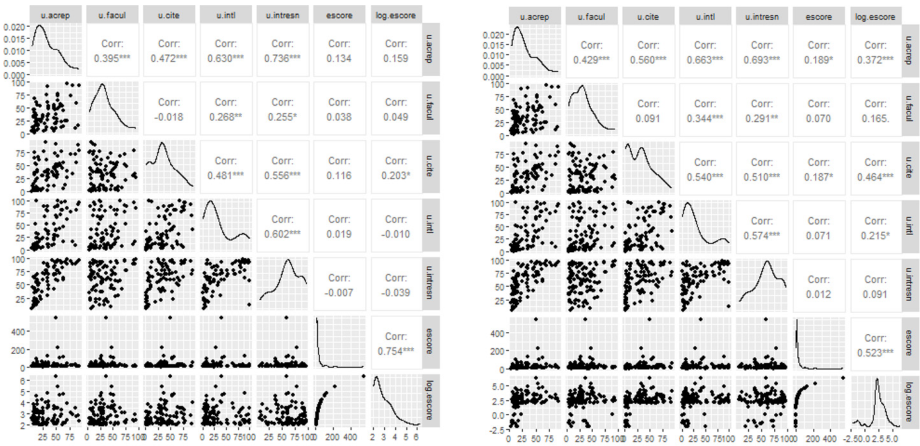
also increased chances of up-grading in mid-to-low range score cases, and rather slim chances of improvement for very low score cases.

We conclude that there is strong evidence of underlying processes leading to long-tailed distributions, which are linked to power-laws (as opposed to "exponential decay"), and which in turn is linked to path-dependence, and which then means relevance of historical events ("history matters"). This has a double meaning, namely (a) that EESs with lower scores (those "in the tail|") may be able to profit and effectively develop in time, but also (b) that "first mover advantages" have a very strong and lasting effect over time, by "shutting out" rival EES. At the top of the score scales, there is no or just minimal ranking variation between the (few and far off) top EES locations. Furthermore, the power-law effects are more pronounced in city-centered EES data than in the county-centered variant. This means that catching up between countries is more involved or hardly possible, which is in agreement with some trends expressed in the literature and further validates our ***H1*** in a broad sense.

Both views also indicate slim chances of changing scores in the high score cases. The latter may be interpreted as a variant of "winners-take-all" cases, in concentrating resources and capabilities of just a few EESs which outperform all the others combined. Many of them capitalize on past first-mover advantages, which then tend to lock out lower-scored competitors (Arthur, 1994, 2021).

The assertion of hypothesis *H-2* is at first approached by observing the correlation structure between the five different metrical university performance/reputation criteria and the entrepreneurial scores or target variables (see variable description in the Methods section).

The main diagonal of both matrix-like plots from Figure 4 are envelopes of the histograms of the respective variables. The histograms of "escore" hides information which become visible in the histograms of "log.escore". The left panel of Figure 4 which stands for the 100 EES used in Figures 2 and 3 depicts the fact that there is (almost) *no significant correlation between any of the inputs and the two targets* (the two leftmost columns and the first five row entries) while *the correlation between the inputs are mostly significant.* The



Notes: Left panel: the 100 EES from the first list;
Right panel: Same with 19 East European EES added
Sources: Own computation using the R software; Author's own work

Figure 4. Scatterplots of all variable pairs, the five university performance variables and the target

latter structure is to be expected owing to the nature of these inputs while the former lack of correlation may come somewhat as a surprise. Adding 19 EES from Eastern Europe changes this picture slightly but in a fundamental way. As depicted in the right panel of Figure 4 *significant correlations between inputs and targets do show up, between academic reputation (u.acrep), citation score (u.cite) and the targets respectively, being more pronounced for target log.escore* (as the latter more clearly lifts out the 19 added lower score EES).

Hence the question follows: Is this splitting into a group with negligible or no correlations and a second extended group with significant correlations stable enough, and can a similar result be observed for other, related groupings as well? To this end we considered a larger number of alternative groupings which indeed confirms this proposition. We grouped EES with performance score below and above the average ranking position, below and above the median ranking position and also according to a criterion, which does not directly depend on ranking, namely using *k*-means clustering on the five university performance related inputs (the first five variables of the scatterplots in Figure 4).

Figure 5 contains the results for linear regression models build on the five university scores (the first five matrix entries from the plots of Figure 4) as input variables. The targets of the models are the original EES-score and the log thereof, respectively. The split for the model data was done on the rank sorted ESS, namely for the cases below the average (first line) and those above the average rank. First note that a highly significant intercept found in three of the four models just forwards the mean. From the figure's first row we see that the *below mean EES* do not result in any significant model while the log variant just forwards the mean. The high *p*-values referring to the overall statistical well-posedness of the models shows that they are not well-posed. The above average cases (second row) lead to models in which variables u.acrep and u.cite (academic

```
Linear regression for EES scores on 1-28 rank sorted EES
Residuals:
   Min     1Q Median     3Q    Max
-93.79 -39.82 -20.81   1.78 449.05

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  61.9362    86.3009   0.718    0.481
u.acrep       1.4047     1.5684   0.896    0.380
u.facul       0.3843     1.4691   0.262    0.796
u.cite        0.3344     1.3978   0.239    0.813
u.intl        0.1306     0.9749   0.134    0.895
u.intresn    -1.1903     1.8108  -0.657    0.518
---
ignif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 109.7 on 22 degrees of freedom
Multiple R-squared:  0.05386, Adjusted R-squared:  -0.1612
F-statistic: 0.2505 on 5 and 22 DF,  p-value: 0.9351
```

```
Linear regression for EES log.scores on 1-29 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-0.9408 -0.4303 -0.1812  0.2775  2.1769

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.897217   0.597245   6.525 1.46e-06 ***
u.acrep      0.009042   0.010854   0.833    0.414
u.facul      0.004519   0.010167   0.444    0.661
u.cite       0.003099   0.009673   0.320    0.752
u.intl       0.001757   0.006747   0.260    0.797
u.intresn   -0.010314   0.012532  -0.823    0.419
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7593 on 22 degrees of freedom
Multiple R-squared:  0.06519, Adjusted R-squared:  -0.1473
F-statistic: 0.3068 on 5 and 22 DF,  p-value: 0.9035
```

```
Linear regression for EES scores on 29-119 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-9.4356 -3.3895 -0.1584  2.8833 14.0197

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  9.64675    1.60491   6.011 4.46e-08 ***
u.acrep      0.10589    0.04676   2.264 0.026096 *
u.facul      0.04787    0.02801   1.709 0.091158 .
u.cite       0.11001    0.03089   3.561 0.000609 ***
u.intl      -0.02920    0.02832  -1.031 0.305471
u.intresn   -0.10629    0.03309  -3.213 0.001859 **
---
Signif. Codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 5.401 on 85 degrees of freedom
Multiple R-squared:  0.271,   Adjusted R-squared:  0.2281
F-statistic: 6.319 on 5 and 85 DF,  p-value: 4.932e-05
```

```
Linear regression for EES log.scores on 29-119 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-3.5329 -0.3984  0.2345  0.7534  1.6820

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.532346   0.360724   4.248 5.49e-05 ***
u.acrep      0.021946   0.010511   2.088 0.039795 *
u.facul      0.006568   0.006296   1.043 0.299827
u.cite       0.024334   0.006944   3.504 0.000733 ***
u.intl      -0.004203   0.006365  -0.660 0.510827
u.intresn   -0.017730   0.007437  -2.384 0.019341 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.214 on 85 degrees of freedom
Multiple R-squared:  0.2627,  Adjusted R-squared:  0.2193
F-statistic: 6.057 on 5 and 85 DF,  p-value: 7.639e-05
```

Notes: Targets = Original EES score (first column) and log-score (second column)
Sources: Own computation using the R software; Author's own work

Figure 5. Linear models for EES scores on below (first row) and above (second row) average cases of rank sorted EES

reputation and citations) contribute positively and u.intresn (international networking score) contributes negatively to the target variable (Original EES score – first column and log-score - second column). The original and the log-variant also produce here similar results with regard to direction and significance of influence. The low *p*-values for overall statistical well-posedness of the models clearly confirm their validity. A variant with above- and below-median models, as well as two quantile regression models, can be found in the Appendix.

As a second example we turn to a split resulting from a *k-means* clustering, applied to the input vectors (the five university-related scores). This split (grouping) does not depend in any way on the ranking of the EES-cities, and is hence expected to produce at least partially dissimilar results. To make results comparable, we technically limit ourselves to using just two clusters ($k = 2$).

Figure 6 contains the results for linear regression models build on the two clusters as described above. Apart from the different data-domains of the models, the meaning of the four table insets are the same as those from Figure 5. The first line contains the models build on Cluster 1 and the second line those on Cluster 2, respectively. From the figure's first row we conclude that t*he only significant (negative) direction of influence is u.intresn (international networking score)* and in the log-variant *(right column) u.acrep (academic reputation) is added as positive influence at a medium significance level*. For the second cluster (second row) *u.cite (academic citations)* is added as positive influence at a high significance level. While first model is statistically overall somewhat weak (but still acceptable) the other three modes are statistically well-posed as indicated by their low overall *p*-values.

We conclude this section by noting that, overall, there is a surprisingly low influence of university performance/reputation and its networking on the entrepreneurial performances score of the geographically proximal EES. This may indicate that "bilateral" cooperation

```
Linear regression for EES scores on CLUSTER 1
Residuals:
   Min     1Q Median     3Q    Max
-81.65 -40.62  -3.50  18.45 392.52

Coefficients:
            Estimate  Std. Error t value   Pr(>|t|)
(Intercept) 384.4867   103.4552   3.716 0.000747 ***
u.acrep       1.2153     0.8664   1.403 0.170030
u.facul      -0.2583     0.5743  -0.450 0.655782
u.cite       -0.2678     0.7834  -0.342 0.734667
u.intl       -0.5540     0.5421  -1.022 0.314214
u.intresn    -4.1773     1.2971  -3.221 0.002873 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 84 on 33 degrees of freedom
Multiple R-squared:  0.2917,  Adjusted R-squared:  0.1844
F-statistic: 2.718 on 5 and 33 DF,  p-value: 0.03656
```

```
Linear regression for EES log.scores on CLUSTER 1
Residuals:
    Min      1Q  Median      3Q     Max
-1.8301 -0.4169 -0.1866  0.5948  1.8892

Coefficients:
             Estimate Std. Error   t value Pr(>|t|)
(Intercept)  7.134707   1.131485   6.306 3.94e-07 ***
u.acrep      0.026670   0.009476   2.815  0.00817 **
u.facul     -0.007028   0.006282  -1.119  0.27127
u.cite       0.003332   0.008568   0.389  0.69990
u.intl      -0.009926   0.005929  -1.674  0.10352
u.intresn   -0.058229   0.014186  -4.105  0.00025 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.9187 on 33 degrees of freedom
Multiple R-squared:  0.4498,  Adjusted R-squared:  0.3665
F-statistic: 5.397 on 5 and 33 DF,  p-value: 0.0009824
```

```
Linear regression for EES scores on CLUSTER 2
Residuals:
    Min      1Q  Median      3Q     Max
-26.498  -9.009  -2.766   4.992  68.833

Coefficients:
            Estimate Std. Error t value  Pr(>|t|)
(Intercept) 15.48013    5.18325   2.987  0.00382 **
u.acrep      0.27197    0.17424   1.561  0.12281
u.facul      0.13943    0.11252   1.239  0.21919
u.cite       0.38544    0.08872   4.344 4.38e-05 ***
u.intl      -0.12669    0.12062  -1.050  0.29697
u.intresn   -0.30571    0.09476  -3.226  0.00187 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 14.78 on 74 degrees of freedom
Multiple R-squared:  0.2782,  Adjusted R-squared:  0.2294
F-statistic: 5.705 on 5 and 74 DF,  p-value: 0.0001665
```

```
Linear regression for EES log.scores on CLUSTER 2
Residuals:
    Min      1Q  Median      3Q     Max
-3.5722 -0.4641  0.2024  0.8961  1.9390

Coefficients:
             Estimate   Std. Error   t value Pr(>|t|)
(Intercept)  1.448573   0.458726   3.158 0.002301 **
u.acrep      0.049387   0.015420   3.203 0.002008 **
u.facul      0.010957   0.009958   1.100 0.274750
u.cite       0.040581   0.007852   5.168 1.94e-06 ***
u.intl      -0.001922   0.010675  -0.180 0.857631
u.intresn   -0.030138   0.008386  -3.594 0.000584 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.308 on 74 degrees of freedom
Multiple R-squared:  0.3852,  Adjusted R-squared:  0.3436
F-statistic: 9.272 on 5 and 74 DF,  p-value: 6.914e-07
```

Notes: Targets = Original EES score (first column) and log-score (second column)
Sources: Own computation using the R software; Author's own work

Figure 6. Linear models for EES scores on clusters which result from *k-means*, with $k = 2$ with cluster 1 (first row) and cluster 2 (second row)

between universities and firms is insufficient, and possibly, also rather inefficient. The reasons are not too hard to imagine, as academic creativity and thinking follows other principles that the entrepreneurial kind. This seems to remain valid and stands the test of time despite countless (oftentimes futile) efforts of trying to infuse “entrepreneurial awareness” into academia.

Interestingly enough, the influence of varying academic performance is weak to totally insignificant in the top range cases of EES performance scores. This improves to a certain extend in the lower ranges of EES scores. However not all academic performance measures have a positive contribution. Especially the international networking seems to be “detrimental” for EES performance (but not for universities themselves). This result may hide the fact universities with intense international networking are simply not much interested in cooperating with local entities.

The qualitative modeling results are quite insensitive to different two-cluster groupings of ESS. The results is always consisting of a group of high-score EES insensitive to university performance variation and a group of lower levels EES being in different ways more sensitive to university performance variation.

The second hypothesis asserts a (causal) dependence of the city-centered EES score on different performance and networking variables of universities from reasonably near locations. The latter (universities) stand for mainly task-oriented “problem-solving” approaches, while the former (EES) are using more relationship-oriented, functional modes as implied by the triplex-helix concept. In general, the statistically measured dependence is weak to non-existent. Exceptions are certain models build on subpopulations obtained by forming groups of ESS. This may come as a surprise, but should be noted with some caution, as part of the result stems from the fact that, overall, very high-ranking universities are located in areas where EES have rather mixed scores. Furthermore, some dependence of EES scores on single university performance or networking variables does indeed appear, in some cases at highly significance levels. This strongly depends on what grouping or subdivision of the city-centered EES is used. Therefore, as explained above, multiple groupings and modeling approaches are used. Depending on the grouping used, the models differ in both, their significantly contributing coefficients, and also in their overall appropriateness of the statistical model. It is noteworthy that some significant coefficients are negative, especially those concerning EES performance relating to international networking. The latter points toward the importance of national (if not regional) relations for entrepreneurs. This however, may be interpreted in two different ways, namely:

- “deep tech” start-ups, which – owing to scarceness of domain experts – essentially depend on international connectivity, are non-existent or are just very few and therefore irrelevant for the EESs; or
- international connectivity is a highly private affair of single firms.

These details add explanatory power to the – technically – confirmed hypothesis ***H2***: while fundamental changes in technological opportunity are mainly induced by task-oriented, “problem-solving” approaches – a role which can be attributed to universities and research institutions, increasing entrepreneurial performance through innovation needs a more relationship-oriented approach, in which knowledgeable intermediaries, governments and state agencies enable effective innovation networking within EES and eventually lead some of their firms into becoming conquerors of open markets.

Discussion and conclusion

Our statistical analysis confirms both hypotheses. First, EES performance is essentially power-law distributed, implying its long-term memory (historical dependence) and it also underlines that the city-focused EES view is the more relevant and the more informative approach. This aligns with ideas expressed in the literature according to which "… the economic importance of cities grows relative to that of countries" (e.g. Bettencourt *et al.*, 2007). It also reveals that chances of intermediately scored EES to climb the performance ladder are quite good while there is extreme stability at the top – a double nature of the long memory process. Second, some significant dependencies between university performance measures and EES performance show up – but only for certain subsets from the entire EES population. Furthermore, somewhat to a surprise, not all dependencies are positive.

Overall, dependencies are rather weak for both, the city-centered EES and the national aggregates over EES data models. Strategies, planning horizons and performance criteria of academia and business simply do not coincide – although they are certainly not outright contradictory. This points to an important gap, which cannot be filled by governments or regional administrations alone. In and around EES from powerful national economies – with traditionally strong Intellectual Capital and a strong drive toward intense entrepreneurial activity grounded in behavioral culture – one finds other important players, other than firms and universities. Institutes focusing on long-term research programs like, for instance, the National Laboratories in the US/INRIA and CEA in France/Max Planck and Fraunhofer Institutes in Germany, and many others, are widely acknowledged for producing valuable Intellectual Capital and technical solutions to challenging problems. Their R&D domains are typically well outside of the immediate domains of interest of firms. How can then lower scored EES from emergent countries compensate for not having such comfortable advantages? The price to be paid is to put much more effort into collaborative action. The aim must be to become a player with sufficient power. A robust strategy for such countries and their regions to better match the power of their far bigger competitors is turning to polycentric structures (Ostrom, 2010; Ostrom *et al.*, 2012). Polycentric structures are more than just conventions to cooperate, in that they also contain *mechanism design* and other procedural details.

A credible realization for numerous sites in Europe with larger near-border cities would be to group the adjacent cities into cross-border, multi-functional units or *virtual super-cities*, which keep the identities of its members but share expensive, long-term commitments, like one major airport, a logistic super-center, a mass transit system and one common EES. Universities would be diverse and specialized, possibly according to a common strategy. In general, solving strategic issues and fixing participatory procedures should be given priority. Physical location disputes should be handled swiftly.

Technically, the chances of building such a long-term alliance would increase if the participating cities share a similar intellectual capital heritage, which would ease the coordination of both, technological and business goals. Such an alliance would be coordinated by rotating responsibility, while sustaining a rule-based competition between the single cities. Proximal location of the participating cities is very important indeed, in that it enables them to function as a single (virtual) super-city.

Table 1 proposes activation steps for realizing an EES within a polycentric alliance of cities with lower entrepreneurial score, as could be established in a series in cross-border regions of Europe (and anywhere else if intellectual capital formation of participants converges). It underlines Type C development from the Literature review section. Activation Steps 2 and 3 offer plentiful opportunities, including those of creating real power and international attraction. These programs are expected to foster highly innovative initiatives

Table 1. A qualitative view of the activation steps for EES emergence enabled by polycentric alliances

Context	Activation – Step 1	Activation – Step 2	Activation – Step 3
Ecosystem leadership			
		Characteristics	
Accelerating ecosystem growth	There is no leadership. There are individual, non-correlated actions without unity and strategy	A strategy for developing entrepreneurship is forming at the local level but the implementation still lack energy	Some centers of leadership emerge. These are joint into a polycentric alliance
		Objective	
Find entrepreneurially minded persons and grow a more connected local community	Activating entrepreneurially minded persons by showing them opportunities and resources	Connect different initiatives and start to coordinate the actions and share resources	Eliminate political and administrative barriers of enabling a functioning polycentric alliance. Join cooperation complementary to the formation of the EES
Community			
		Characteristics	
The quality of local communities is measured by startup experience, connectedness, as well as by startup output and output growth	The community has no or no clear vision of the future	There are some initiatives to increase the local connectedness	Many stakeholders contribute to the sustained development of the entire entrepreneurial ecosystem
		Objective	
Focus on growing and building a large and more connected community	Develop a sense of cohesion and to start meetings to inform and align interests	Activate local entrepreneurs, talent, and investors	Join them into a polycentric EES community; establish efficient cross-border coordination

(*continued*)

Table 1. Continued

Context	Activation – Step 1	Activation – Step 2	Activation – Step 3
Domains			
		Characteristics	
Technological choices; many technology paths and commercial opportunities	Tendency toward opportunistic entrepreneurship/domains with more rudimentary technology	Venturing into more advanced technology domains, contacting global players for subcontractor roles	Reputation for the products of firms from the polycentric EES is gradually building
		Objective	
Build on and develop local economic strengths	Identify some specific domains where the local ecosystem would have some competitive advantages	Develop focused programs to accelerate ecosystem growth	Develop pockets of success that lead to sizable successful exits
Global relationship			
		Characteristics	
The global system becomes increasingly important in the late activation phase	Understanding that national borders may be Sub-optimal as delimiters of close local cooperation	Relationships within the regional area (national region, accounting for about 4–6 counties)	Global relationships emerge, as a polycentric EES gains momentum
		Objective	
Empower the community to tap into global sources of knowledge and other types of capital	Establish relationships within the local area (city and county level)	Establish relationships within the national area and/or cross border regions (national region, accounting for about 4–6 counties)	Increasingly connect with and learn from the global startup community

(*continued*)

Table 1. Continued

Context	Activation – Step 1	Activation – Step 2	Activation – Step 3
Funding			
		Characteristics	
Most and especially the best startups raise funding outside the ecosystem	There is virtually no funding for startups besides bank loans and self financing	Funds that search for eligible startups appear. Investors-founder matching is done through personal network of contacts	The city-wise investor community is relatively inexperienced and often lack slonger-term strategy; this may be improved in a poly-centric virtual city environment
		Objective	
Support the formation and operations of angel groups to increase deal flow and expertise	Inject capital to reduce the risks of the activity domain	Inject capital in VC firms to support the development of one or two dominant startup sub-sectors in the ecosystem	Emerge as a regional leader in a targeted area and lead to polycentric ecosystem growth
Startup Support			
		Characteristics	
Startup experience in an EES community	No startup experience in an entrepreneurial ecosystem	Some isolated groups that have some entrepreneurial experience start to appear	Long term orientation, advisors, mentors, owing to much bigger polycentric talent reservoir. Community behaviors for commercial success
		Objective	
Founders support enabling investment absorption	Help startups to transform ideas into products providing knowledge and resources	Support startups to attract larger investments; market scaling	Long term founders support

Source: Own compilation

which boost regional development, reputation and improvements of quality of life, potentially attracting talented work-force from all over the world.

Finally, maintaining a high level of innovation is of central importance to EES. One may not necessarily expect fundamental/disruptive innovation from firms of any kind, although there may be noteworthy exceptions. The main reason of a firms' existence is to cleverly recombine known and tried solutions, principles and technologies to transform them into vendible goods and services. Time will tell if the much hyped Entrepreneurial Universities (GLEU, 2024) can bring genuine academic interest closer to the entrepreneurial causes. In this regard, EES based on the triple-helix concept, may offer a stabilizing effect. A key step is the transition from Innovation Networks to Collaborative Innovation Networks. This poses challenges to start-ups as they may rightly ask the simple question of "who gets what?", followed by the more involved problem of "how to avoid revealing valuable knowledge to my competitors?" Such mistrust may reduce the willingness of cooperation. As a consequence, the power of big players may further increase. However, many networked mechanisms create dynamics which have non-standard statistical features, which may be exploited to the advantage of different players within EES.

As evidenced by the results of the statistical data analysis, there are chances but also important barriers for actual low-score EESs, as they are emerging for instance in Eastern European regions. We also note, that city-centered EESs are the most promising candidates for such change, as they suggest paths toward polycentic super-cities.

The study contributes to understanding mechanisms responsible for the emerging:

- divergence in EES development, mainly from a triple-helix viewpoint, and assessing chances of "catching-up" within the EES hierarchy; and
- behaviors in such ecosystems that can enhance innovation.

Our general recommendations for lower performance-score EESs as are most of those from Eastern Europe are:

- creation of cross-border networks (may be more effective than chasing nearby EES); and
- support for polycentric EESs, which can provide enhanced innovation support and compensate for power deficits and lack of determination of single EES.

The latter links to the concepts and mechanisms of general, societal "polycentrism" and to the "beyond market" forces in the sense of Ostrom (2010), Ostrom *et al.* (2012), hence bringing EESs more in line with resource scarceness as well as with the reduction of negative externalities (Nordhaus, 2013; Wagner and Weitzman, 2015; Sachs, 2019).

The results of this research depend in part on the quality and the amount of the data available. Although we think that data used are indeed quite representative, the results should stand the test of more complete data. Such include more performance measures and other feature data on universities, handling better and different types of "proximity" besides the crude geographical approximation used. Including data about the proximal research institutions, which are more focused than universities and data about assumed roles of different actors within the EES is also needed.

Concerning the lifting of low score EES on the international performance scale, pertaining especially to EES from Eastern Europe, one would like to empirically investigate ways of "activating" EES development, and assigning them probabilities of eventual success. One may envision a type of entrepreneurial education, which centers on avoiding gaming behavior in the sense of "opportunistically" optimizing domain choice for gaining government aid and other similar short-horizon goals. Such behavior would spoil the very triple helix idea, namely welding a long term community, which is able to exploit various synergistic effects.

Furthermore, one should exploit ways of how to change investment culture, if it is still oriented toward "passive" investment (e.g. real estate, land, marginal businesses, etc.) into one which favors:

- innovative and directly productive; and
- longer term, higher-risk technology projects.

Such behavior requires more trust in what both, venture capital but also crowd-funding can achieve. Finally, procedures should be defined which shield EES against excessive partisan political influence.

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Appendix

Following the main text, we list in Figure A1 the results for linear regression models build on the five university scores as input variables, having as targets the EES-score and the log-score, respectively. The regressions were also done on the rank sorted EES for the case *below the median* and those *above the median* rank. As pointed out in the main text, a highly significant intercept alone is almost trivial as it simply "forecasts the mean" (it may appear in the original- or in log-target variant). From the results listed in the table we see that the *below median EES* do not result in notably significant models. The log variant points weakly to the influences also found also in Figures 5 and 6 of the main text. A similar result is observed for the *above median EES* cases (second row). From the *p*-values referring to the overall statistical well-posedness of a model, we further infer that the below median models (first row) are inadequate while the below median models are at least well posed.

While the below- and above-median data and the induced models certainly differ, a possible reason for the weak (and somewhat confusing) result may be uncovered by a quantile regression, here owing to data sparseness, on (0.3,0.6,0.9)-quantiles, the result of which is depicted in Figure A2 below.

In each subplot of the figure a variable coefficient is anchored at one of the three quantile values used. The line visible is just connecting these three values for clarity. The shaded corridors represent corridors of uncertainty while the interrupted straight lines indicate the confidence band. The changing slopes of the connection lines indicate in both variants (original, and log-valued) that a non-linear model may be more adequate. However, the wide uncertainty corridors hinder the modeling procedure in finding a statistically significant linear skeleton model for each quantile. A technical reason for the latter is again data sparsity, which cannot be improved upon easily, since the

```
Linear regression for EES scores on 1-59 rank sorted EES
Residuals:
   Min      1Q Median     3Q    Max
-70.83 -25.62 -10.58   1.77 481.02

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 47.62234   30.07631   1.583    0.119
u.acrep      1.05229    0.75675   1.391    0.170
u.facul      0.04735    0.54635   0.087    0.931
u.cite       0.52967    0.60355   0.878    0.384
u.intl      -0.15718    0.43829  -0.359    0.721
u.intresn   -0.95121    0.69909  -1.361    0.179
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 76.78 on 53 degrees of freedom
Multiple R-squared:  0.05583, Adjusted R-squared:  -0.03324
F-statistic: 0.6268 on 5 and 53 DF,  p-value: 0.68
```

```
Linear regression for EES log.scores on 1-59 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-1.1642 -0.5329 -0.1771  0.3373  2.6343

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.403399   0.301735  11.279 1.06e-15 ***
u.acrep      0.014198   0.007592   1.870   0.0670 .
u.facul      0.001394   0.005481   0.254   0.8002
u.cite       0.012097   0.006055   1.998   0.0509 .
u.intl      -0.003160   0.004397  -0.719   0.4754
u.intresn   -0.016281   0.007013  -2.321   0.0241 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.7703 on 53 degrees of freedom
Multiple R-squared:  0.1374,  Adjusted R-squared:  0.056
F-statistic: 1.688 on 5 and 53 DF,  p-value: 0.1536
```

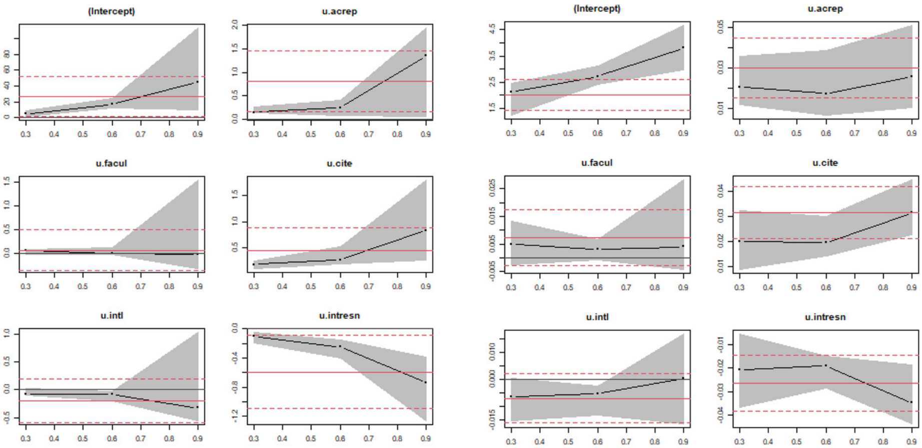
```
Linear regression for EES scores on 60-119 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-4.9150 -2.6317  0.7252  1.8005  7.0792

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  5.025406   1.203894   4.174 0.000109 ***
u.acrep      0.087390   0.033976   2.572 0.012892 *
u.facul      0.003844   0.020432   0.188 0.851460
u.cite       0.055676   0.022272   2.500 0.015495 *
u.intl      -0.001831   0.022751  -0.080 0.936146
u.intresn   -0.037350   0.023119  -1.616 0.112021
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 2.967 on 54 degrees of freedom
Multiple R-squared:  0.3682,  Adjusted R-squared:  0.3097
F-statistic: 6.294 on 5 and 54 DF,  p-value: 0.0001141
```

```
Linear regression for EES log.scores on 60-119 rank sorted EES
Residuals:
    Min      1Q  Median      3Q     Max
-2.9222 -0.5233  0.4153  0.8012  2.0797

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.636156   0.518106   1.228   0.2248
u.acrep      0.031596   0.014622   2.161   0.0352 *
u.facul      0.001380   0.008793   0.157   0.8759
u.cite       0.023247   0.009585   2.425   0.0187 *
u.intl      -0.006258   0.009791  -0.639   0.5254
u.intresn   -0.008493   0.009950  -0.854   0.3971
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.277 on 54 degrees of freedom
Multiple R-squared:  0.2901,  Adjusted R-squared:  0.2243
F-statistic: 4.413 on 5 and 54 DF,  p-value: 0.001927
```

Notes: Linear models for EES scores on below (first row) and above (second row) median of rank sorted

Sources: Author's own work ; Own computation using the R software

Figure A1 Linear models for EES scores on below (first row) and above (second row) median of rank sorted EES



Notes: Left panel: Intercept and the five independent variable coefficients for target EES-score, right panel for the log of the same target
Sources: Own computation using the R software; Author's own work

Figure A2. Quantile regression of EES scores (the target) against university performance scores

data volume is limited by nature. However, the general picture from Figure A2 is consistent with the qualitative observation from the main text, namely that the strength of dependencies between the variables differ on reasonably generated subsets of EES, but that the directions of influence do largely agree.

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