Agricultural Technology Start-ups – Romania and Hungary Compared

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Abstract: *This paper departs from the hypothesis that in the era of agriculture 4.0, start-ups specialised in digital agricultural technology (AT) have the potential not only to rapidly grow, but also to have a beneficial impact outside the core countries of agricultural innovation. To validate this assumption, we compiled data about a sample of Romanian and Hungarian AT start-ups entering the market with self-developed digital solutions. Based on extensive desk research, we identified the main distinctive features of the surveyed start-ups, compared to their peers in advanced economies, and answered the related key research question: how meaningful is the impact of these start-ups on the much-needed upgrading of agricultural production in these countries? Our analysis reveals that although local AT start-ups in these countries do develop innovative solutions in the field of precision farming, farm management software, applications, and e-marketplaces, their number is below a threshold where they could have an impact on the upgrading of local agriculture. More importantly, the reduced size of the local market for technology and other hard-to-overcome barriers make it barely possible for them to grow as rapidly as some AT start-ups do in advanced economies.*

Keywords: *agriculture 4.0, agricultural technology start-ups, precision farming, Hungary, Romania.*

JEL classification: *Q16, O33, Q18.*

Introduction

Agriculture has recently become an important target of technology start-ups all over the modern world. Since digital technologies bear the promise to further revolutionize agricultural productivity, funding to agricultural technology (AT) providers has been increasing at an unprecedented rate. According to *AgFunder* (2022), the number of venture capital deals increased rapidly in 2021, with total funding amounting to $51.7 billion, representing an 85% increase over 2020.

Since AT start-ups' emergence and funding are highly concentrated – according to the report mentioned, US-based AT start-ups accounted for 41% of total funding, followed by China, India, and Israel[2] – and academic research discussing this phenomenon also focuses on advanced economies[3], there is scant research on AT start-ups in Central and Eastern Europe (CEE).

This is a clear gap in the literature for two reasons. Firstly, local AT start-ups

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[2] European countries (e.g., Germany, Netherlands, Spain) are distant followers.

[3] Examples include Mikhailov *et al.*, (2021), Singh *et al.* (2022). As regards the developing economies, the studies mainly tackle the factors influencing the adoption of advanced AT (e.g., Takahashi *et al.*, 2020).

may contribute to the innovation-driven development of a sector that has a considerably higher weight in the economies of CEE than on average in the EU[4]. More importantly, while there is remarkable market concentration in the area of specific AT solutions, e.g., advanced agricultural machinery (Birner *et al.*, 2021), the providers of other agriculture 4.0 technologies (e.g., farm management software, sensor-based monitoring and analytics, artificial intelligence-powered decision support solutions) are marked by a smaller concentration[5]. The main reason is the interaction intensity of custom-tailored solution provision, which compels the large, established agricultural production companies in these countries to collaborate with domestic solution providers (Szalavetz, 2020).

Consequently, AT start-ups specialised in digital solutions are likely to grow and rapidly internationalise also in CEE. Since these start-ups are critical channels of knowledge spillovers, they may have an impact on the qualitative development of the sector they target with their solutions. Hence, the analysis of their characteristics and development perspectives leads to important policy implications.

This paper addresses the above-mentioned perceived gap in the literature by exploring and analysing the landscape of digital AT start-ups in Hungary and comparing their performance with that of their Romanian peers. We rely on extensive desk research and dedicated, hand-collected datasets of Hungarian and Romanian digital AT start-ups. We aim to contribute to the research on (1) digital AT start-ups by highlighting their specifics in an under-researched context; (2) agriculture 4.0 by investigating this phenomenon through the lens of blurring industry/sectoral boundaries.

Our research questions are as follows: What characterises the landscape of digital AT start-ups in Hungary and Romania? Which are the main distinctive features of the surveyed start-ups compared to their peers in advanced economies? How meaningful is the impact of these start-ups on the much-needed upgrade of agricultural production in these countries?

The paper is organized as follows: Section 1 briefly reviews the literature on Agriculture 4.0 and presents the developments in this respect as a prime example of blurring industry/sectoral boundaries. Section 2 introduces the context, providing some details about the relevance of agriculture 4.0 in the two countries. Section 3 presents the applied research method. Section 4 reports and discusses the findings. Finally, in section 5, we provide some concluding remarks and elaborate on the policy implications of our results.

Literature review

Drawing on the comprehensive review by Maffezzoli *et al.* (2022), we apply a global value chain perspective to define agriculture 4.0, specifically, as *the infusion of digital technologies in and the consequent transformation of agricultural pre-production, production, production-related support, and post-production activities*. In the following paragraphs, we will analyse each of the four constituents of this definition as follows: (1) digital technologies, (2) value-adding activities, (3) transformation, and (4) infusion.

The relevant digital technologies – among others, autonomous robotic systems,

[4] While agriculture contributed on average 1.3% to the EU's GDP in 2021, the respective data for Romania was 4.42%, Hungary: 3.33%, Poland: 2.37%, Bulgaria: 3.24%. Source: https://www.theglobaleconomy.com/rankings/share_of_agriculture/European-union.

[5] Big players, such as SAP, IBM, or Microsoft dominate the market also in this field, but there is demand for the solutions of small local technology providers as well.

drones, big data capture and analytics technologies (such as sensors, machine learning, or artificial intelligence), image processing technologies, communication, and cloud computing technologies, geographic information systems, and so forth (see a detailed review in Abbasi et al., 2022) are highly heterogeneous and have numerous application possibilities. Maffezzoli et al. (2022) classified them into three groups, which facilitates their analysis also from the perspective of this paper, namely (1) precision farming equipment and the embodied digital technologies, (2) disembodied software tools, such as apps and farm management software, and (3) online platforms (agricultural marketplaces).

The first two groups comprise technologies that replace repetitive physical labour and assist farmers in planning, decision-making, and execution. In other words, these technologies automate and/or augment (Zuboff, 1988) pre-production, production, and production-related support activities. Online platforms, that is, e-marketplaces connecting producers, actors engaged in processing agricultural output, wholesalers (and retailers), and customers are related mainly[6] to post-production activities. Besides enhancing the efficiency of business-to-business transactions (procurement and distribution), these solutions also enable business model innovation, in terms of introducing a direct-to-consumer business model.

In summary, agriculture 4.0 technologies transform the practices of value creation in agriculture and enhance the efficiency of all value-adding stages (including the efficient use of agricultural inputs such as water (irrigation), fertilizers, feeds, crops, etc.). Over and beyond increased productivity and value-added, the structure of input costs also undergoes considerable change.

Regarding the last constituent of our definition, the infusion of digital technologies, we contend that Agriculture 4.0 is an excellent example of digital transformation blurring industry (or sectoral) boundaries. An important sign of blurred boundaries is that technological innovations in industries/sectors outside the focal industry/sector (in this case agriculture) catalyse a series of process and product innovations in another industry/sector. The blurring of industry/sectoral boundaries is driven by technological change and actors' strategic responses to this change, in terms of technology adoption and innovation.

From this perspective, agriculture 4.0 exemplifies that in the era of digital transformation, industries/sectors (including agriculture) combine specialised knowledge from numerous technological fields (Teece and Linden, 2017). The entry of technology companies in one of the most traditional, established sectors i.e., agriculture, marks the blurring of industry/sectoral boundaries (Szalavetz, 2022). These developments are manifested in a multiplication of inter-industry transactions. Examples include transactions between the representatives of mainstream agriculture production and representatives of emerging industries, including robotics, drones, AT (classified in numerous sectors, e.g., Industrial Internet of Things (IIoT), software, financial technology, material technology, biotechnology, and so forth.

It is against this background that we explore the development perspectives of local start-ups specialised in smart solutions for agriculture, operating in Hungary and Romania, that is, two CEE countries where agriculture has a much larger share of total

[6] Online platforms are not only in the downstream segments of the agricultural value chain: upstream marketplaces connect producers with input suppliers.

GDP than the EU average (see footnote 4).

Research context: The relevance of agriculture 4.0 in Romania and Hungary

Although from the perspective of official government strategy, both countries lay particular emphasis on the transition to agriculture 4.0[7], the fragmented land ownership that characterises both countries and farmers' low educational attainment in general and their low digital capabilities in particular, together with their low-income level are serious obstacles hindering a rapid digital upgrading in this sector (Bazsik et al., 2022; Nagy, 2022). According to Bazsik *et al.*, (2022), except for some outlier corporations, even the diffusion of technologies representing agriculture 3.0 is low.

Although these factors indicate a low size of the market for AT in these countries, surveys exploring farmers' knowledge and opinions on digital trends in agriculture (e.g., Anitei et al., 2021; Somosi and Számfira, 2020, Zeca, 2022) show that local farmers are aware of digital trends in agriculture and, more importantly, they perceive agriculture 4.0 as an opportunity rather than a threat[8].

This is no surprise, since over and beyond the promise of AT's beneficial effects on productivity, resource efficiency, and sustainability, the existing production constraints, for example, the increasingly pressing labour shortages in agriculture, also compel farmers to adopt smart labour-saving technologies (Vlăduț *et al.*, 2020).

Another factor suggesting appropriate business opportunities for local AT start-ups is that most AT solutions are not off-the-shelf technologies but require careful customisation and continuous support; it seems self-evident that local farmers who are not only sufficiently knowledgeable to recognize the potential of these technologies but also have the wherewithal to invest in and integrate these solutions, would look for local technology providers. At the same time, there are several software-based AT solutions that are in principle easy to scale through targeting the global markets and engaging in international business activities immediately after inception[9]. The fact that emergent local start-ups may have sizeable market opportunities outside the core countries of agricultural innovation calls for exploring the development perspectives of digital AT start-ups in the two countries.

Data and method

In the first phase of our research, we compiled a dedicated, hand-collected database of Hungarian digital AT start-ups. This database has been extracted from a review of European databases and websites focusing on start-ups[10] combined with an extensive review of business press articles.

The websites of potential sample companies were checked to verify for matching with our sampling criteria. We included only domestic-owned start-ups and scale-ups specialised in the development of digital technology-based smart agricultural solutions.

[7] Hungary published a Digital Agricultural Strategy in 2019 and Romania incorporates its sector-specific digital strategy in the National Rural Development Programme.

[8] 'Increasing the level of technology acceptance' is a subjective interpretation. Somosi and Számfira (2020) emphasised the flipside of the coin, pointing out that acceptance of AT is still far lower among Hungarian farmers than the acceptance of digital technologies in society as a whole.

[9] One example of a 'born-global' solution is a smart application (developed by a Hungarian start-up in the sample) that can accurately estimate the live weight of the cattle.

[10] More details are available here: https://www.eu-startups.com/; https://beststartup.eu/; https://europeanstartups.co/.

When deciding about the sampling strategy, we deliberately adopted a narrow focus, including only technology ventures specialised in (a) precision farming-related solutions (i.e., solutions based on Internet of Things technology, field imaging, sensors, etc., that assist farmers in controlling agricultural production activities, minimizing waste, cutting costs, and increasing resource efficiency through automated collection and analysis of data); (b) decision support solutions (i.e., farm management software and specific agricultural applications); (c) automation solutions and intelligent farming equipment; and (d) information platforms and marketplaces. Accordingly, we excluded AT start-ups specialised in biotechnology, e.g., geno-and phenotyping, and simulations. The first three of the above-listed four categories are related to *process innovation* in agriculture, the fourth group concerns agricultural *production-related support activities* (such as procurement and distribution), while the excluded biotechnology-specific solutions are related to *product innovation*.

Furthermore, we also excluded start-ups specialised in smart, alternative agricultural production (e.g., hydroponics solutions applied in an urban context and vertical farming), fintech solutions improving supply chain transparency, and nutrition and wellbeing-specific solutions. We have not included start-ups specialised in smart services provision that employ technology developed by other businesses, for example, drone-as-a-service companies for agricultural operations and start-ups specialised in the distribution and service provision of smart agricultural equipment developed by third parties.

This long list of excluded technologies indicates that agriculture 4.0 is ‘a large umbrella term’ comprising a multiplicity of heterogeneous solutions. This calls for a precise delineation of the companies that our research focuses on, to avoid obtaining a distorted picture caused by technology-specific characteristics.

By contrast, we did not apply an age limit when sampling the start-ups to be included, e.g., we did not exclude companies founded more than 10 years ago given that creating a new product/solution can be a long process. Agriculture 4.0 entrepreneurs, similar to other start-up founders, have to learn about the problems that they are providing solutions for. They have to develop, test, and validate their solutions, which could take months or even years. Starting from the investigated cases, it results that some entrepreneurs decided to establish a start-up only when their solution was ready for deployment or at least when they had a minimum viable product (Ries, 2011). Other entrepreneurs started by founding a company and consequently, in the first couple of years had no income from sales. When evaluating the characteristics of the sample, we have to consider the consequent distortions.

We did not exclude companies with zero turnover (we identified several start-ups without any revenues) but did not include companies that were not listed in official registers. Interestingly, we encountered several AT start-ups whose solutions have already received traction (for example, they have obtained an innovation prize), but we could not find them in the official database of Hungarian companies as they have not submitted a financial statement yet.

Altogether, our Hungarian sample comprises 18 start-ups. Most of them have been operating for three or four years but four companies were founded before 2015. At the end of 2022, the average age of the start-ups in the Hungarian sample was 5.5 years. We collected the available data on employment and turnover of the companies in the sample and included qualitative information based on interviews with founders, LinkedIn descriptions, and business press articles.

In the second phase of the research, we conducted a similar analysis to collect a data sample about the Romanian AT start-ups. We followed a similar procedure to identify Romanian start-ups that match our criteria. The recently issued report by Impact Hub / Activize (2022), providing a comprehensive overview of Romanian agri-food technology start-ups significantly facilitated this part of the sampling process. We checked and validated the companies listed in the cited databases to ensure that they match the sampling criteria. Our final sample comprises 17 Romanian start-ups. At the end of 2022, the average age of the start-ups for the Romanian sample was four years. Using media and internet resources, we compiled quantitative[11] and qualitative data about their characteristics, specialisation, and performance.

Results

Specialisation

Our first review of the companies listed in the databases from the selected sample revealed an interesting difference between the specialisation of AT start-ups in the two countries, namely that in Romania there are more AT companies specialised in connecting food producers with potential local customers and agricultural input providers. These smart platforms and marketplaces (online stores) also accommodate online payment and logistics services.

Although these digital platforms definitely belong to the category of smart digital solutions and contribute to the digitalisation of a specific value-adding phase within the agricultural value chain, for the sake of comparability, we included only two representatives of this type of offering in the Romanian sample.

A commonality that crystallised already from the first bird's eye review of the sample is that there are few start-ups specialised in the manufacture of smart agricultural equipment, such as autonomous agricultural machinery and robots. While we identified several smart service providers who offered drone-based monitoring and analytics services to farmers, instead of focusing on designing and manufacturing these capital assets themselves, these companies would collaborate with drone manufacturers or simply procure the physical assets necessary for the provision of smart services. The reason is obvious, manufacturing requires significant upfront investment and thus bears much higher risks than software-based technology development. Consequently, the majority of the 35 surveyed start-ups are specialised in precision farming, software, and other decision support-related solutions.

The main areas of sample companies' services include the monitoring of the growth and health of crops, livestock, soil parameters, and microclimatic conditions. Monitoring is based on data captured by sensors or images captured by drones. Combined with artificial intelligence-powered analytics, these solutions offer real-time information supporting farmers' decision-making processes. Decision-making refers, for example, to determining the volume and timing of fertiliser and pesticide application and irrigation. Some solutions offer early warning (early detection of illnesses of the livestock or crop damages, weed, etc.) or provide microclimatic predictions. Both country samples include companies (one respectively) that developed smart applications for agricultural use

[11] Data about the employment and turnover of the Romanian and Hungarian companies was retrieved from https://www.romanian-companies.eu/search.asp and https://e-beszamolo.im.gov.hu/oldal/kezdolap, respectively.

cases, another company (respectively) offering integrated farm management software, and another pair of companies are specialised in autonomous robotic solutions – used in vineyards and horticulture (H), and automating venom collection from an apiary (R).

Taken together, the specialisation of the AT start-ups in the two samples is highly similar, which is a key precondition for comparing their performance.

Performance

Our analysis of the employment data revealed that the two samples are highly similar in terms of having only a low number of employees. While the average number of employees in the Hungarian sample) is 3.5 (n=16), the maximum was 10 employees. The respective data in the Romanian sample is 3.56 (n=16). However, the Romanian sample includes a high-performing outlier company with 29 employees. Without this latter start-up, the Romanian average is 1.87.

The low number of formal employees (with employment contracts) is self-evident in the case of start-ups that may have no income for years. The author's prior interviews with Hungarian start-ups conducted in the framework of a different research (Szalavetz, 2015) revealed that while the development of smart solutions requires knowledge work input by high-skilled professionals, team members are either the co-founders of the start-up (but not necessarily formal employees) or external (contracted) professionals. These latter are paid by the owner(s) who may use angel investors' capital or venture capital funding to be able to pay them. Notwithstanding, the employment data of the surveyed start-ups is not in accordance with the conventional wisdom that start-ups and small firms are the most important factors behind job creation (e.g., De Wit and De Kok, 2014; Haltiwanger *et al.*, 2013). The contribution of the surveyed start-ups to job creation was minimal.

Regarding performance in terms of turnover, our findings are similarly discouraging. The average turnover of the companies in the sample (n=31) was €217,800 in 2021, which is not in accordance with the common perception of the growth performance of technology start-ups. Except for 5 companies, the annual revenue of the surveyed start-ups has never reached €200,000. Moreover, if we eliminate the high-performing outlier firms (two firms from the Hungarian and three from the Romanian sample) the average revenue amounts to ~ €67,000. There is a clear difference between the two samples: the surveyed Romanian firms have on average far higher sales performance than their Hungarian peers (the Romanian average was €344,718, and the Hungarian €98,816). The reviewed qualitative data indicate that several start-ups recognized the push factor that the low size of the domestic market for technology represents (Sass, 2012) and started to internationalise, but no comprehensive data was available in this respect.

Similarly, qualitative data indicates that the knowledge intensity of the solutions accounts for a much higher value-added ratio of the surveyed start-ups sales than that of the national average, but no specific data was available in this respect either.

The low overall performance of this sector suggests that a massive change in the agricultural development trajectories of the two countries is unlikely. However, innovative the solutions of the surveyed start-ups are, neither their number nor their performance qualifies them for becoming engines of innovation-driven growth. Few established agricultural firms are committed to integrating and exploiting the innovative solutions of local AT start-ups, or from the opposite perspective, few AT start-ups have been able to build the required customer base.

Innovation-driven growth occurs if growth in a sector/industry is primarily[12] generated by innovations that increase productivity (process innovations), lead to the emergence of new products, and/or increase demand through reducing transaction costs and/or the cost of products (provided this cost reduction is translated into reduced product prices). Additionally, innovators drive growth by introducing new intermediate inputs that are used by final output producers, who integrate these solutions into the value chain (Grossman and Helpman, 1991). Although all of the above-listed contingencies apply to the activities and outputs of the start-ups in the sample (their solutions generate process innovations in the user industries; the start-ups create new products that are used as intermediate inputs by agricultural companies; and some of them, e.g., e-marketplaces, contribute to the reduction of transaction costs) the number of these start-ups (in both countries) is so small that they cannot drive innovation-driven growth.

It seems necessary, in this respect, to provide additional details about the outliers (in terms of above-average performance) in the sample: two Hungarian and three Romanian start-ups. One of the Romanian outlier companies specializes in autonomous robotic solutions that are sold not only in agriculture but also in other sectors[13]. Another Romanian outlier, an agricultural consulting and R&D company also has an e-marketplace. An important offering of this company is a self-developed smart image-processing solution that is able to detect diseases in crops and monitor the parameters of soil: this is what qualifies it to be included in the sample. However, income from the e-marketplace distorts turnover data and makes this company hardly comparable with the other companies that develop smart agricultural solutions.

Consequently, we focused on the three remaining outliers: two Hungarian and a Romanian AT start-up. The main commonality revealed by the review of the qualitative data is that all are spinoffs (of large established companies and a university): one Hungarian start-up is a spinoff of a large pig farm, the other is a spinoff of a university, and the Romanian start-up is a spinoff of a large business software company. The Hungarian spinoff of the pig farm developed an integrated farm management software – first for its mother company and later, after a substantial (€800,000) venture capital investment by a government-owned venture capital fund, it entered the domestic and international markets. The Romanian start-up (founded in 2021) is responsible for the development, implementation, and support of multiple IT systems and solutions for the Romanian Ministry of Agriculture and various governmental agencies. Consequently, neither of these two outliers had to go along a typical trajectory of start-up evolution – they are outliers in every respect. The Hungarian university spinoff started a more typical evolutionary journey. Four years later it received non-reimbursable public funding (more than €1 million) supporting innovation. Currently, investment from a government-owned venture capital fund also supports its growth.

Concluding remarks and policy implications

This paper used the hypothesis that in the era of agriculture 4.0, AT start-ups that have emerged outside the core countries of agricultural innovation have the potential

[12] The innovation-driven growth is also associated here with Porter's (1990) third stage of national development, the first being the factor-driven stage, the second the investment-driven, the third the innovation-driven and the fourth is the wealth-driven stage.

[13] The demand for the non-agricultural robots of this company was particularly high in 2021, since it introduced an autonomous disinfection robot used in hospitals during the COVID-19 pandemic.

not only to grow rapidly, but also to have a beneficial impact on upgrading the local agriculture. To validate this assumption, we identified and compiled data about a narrowly defined sub-group of AT start-ups, limiting our selection to Romanian and Hungarian start-ups entering the market with self-developed digital AT solutions (proprietary technology). Our review revealed that such start-ups can emerge also outside the core countries of agricultural innovation. Like their peers in advanced economies, local AT start-ups develop innovative solutions that belong to the categories of precision farming, agricultural decision support systems, applications, and marketplaces.

The main difference is, however, that their number is below a threshold where they could have an impact on the upgrade of local agriculture. More importantly, the reduced size of the local market for technology and other deep-rooted and hard-to-overcome barriers that we have briefly touched upon in the 2nd section, make it barely possible for them to grow as rapidly as some AT start-ups do in advanced economies[14] – irrespective of the high local political ambition to promote innovation-driven efficiency increase in agriculture.

Consequently, the policy space (Mayer, 2009) for achieving rapid change is quite limited. Programmes that address the most important barriers hindering a large-scale adoption of smart AT solutions would take decades to bear tangible results (for example a meaningful improvement of farmers' digital capabilities). Agricultural advisory organisations and programmes helping farmers implement all the complementary innovations that are indispensable for the integration of smart solutions in their practices are highly important in this respect. Dedicated support to the integration of smart solutions (financial support combined with innovation vouchers that allow farmers to draw on AT applications-related to professional advice) would certainly be useful. However, it needs to be considered that farmers 'have to be skilled enough to become upskilled', that is, these policy instruments can be effective only in the case of the best agricultural units as Somosi and Számfira (2020) characterised it: the tip of the iceberg.

Instead of targeting demand (fostering the local market for technology and creating an enabling environment for AT adoption), policy measures supporting the survival and growth of local AT start-ups bear the promise of achieving more rapid and spectacular results. There is a clear difference between Hungary and Romania with respect to access to entrepreneurial finance. The 2022 report on the 'state of European tech' (Atomico, 2022) compares the amount of total venture funding raised in individual European countries to the share of the given country in total European GDP. According to the calculations presented in the report (p. 73), Hungary is among the top 'overweighted' economies (it ranks fourth in the EU) in terms of the share of the country in total venture capital raised in the EU compared to the share of the country in European GDP. In contrast, Romania is listed among the 'underweighted' countries in this respect.

Does the well-funded status of Hungarian start-ups make any difference? As confirmed by studies discussing venture capital funding in Hungary (Kállay and Jáki, 2020; Karsai, 2018), public venture capital funds account for the largest share of total venture capital funding. These studies make it clear in the example of Hungary that overly generous government support is no panacea. As for the surveyed Hungarian companies,

[14] High performance, combined with high future revenue potential, is usually well reflected by data on start-ups' exits. One example is Vandersat, a Dutch farm management software company that was acquired for $28 million in 2021. Prior to its takeover, Vandersat had annual revenues between $500,000 and 1 million. AgFunder (2022) lists many similar examples of exits by start-ups specialised in farm management, software, sensing, and IoT.

more than half of them[15] received public support in the form of non-reimbursable R&D grants and/or through direct equity investments by public venture capital funds. However, the overall performance of the surveyed Hungarian start-ups is by no means better – rather worse – than that of their Romanian peers.

Our research results call for consistent, long-term, systemic policy targeting the qualitative and quantitative improvement of the market for agricultural technology in these countries. There is no fast lane for the digital upgrading of agriculture.

Future research might benefit from analysing whether and how national and EU policy programmes targeting agricultural technology start-ups deliver. There are various relevant EU-level programmes[16], and the analysis of recipients' performance would significantly contribute to our understanding of the explanatory factors of entrepreneurial success in this – highly specific – field.

Another future research avenue that our results suggest is to include more countries and engage in a broader comparative analysis of the evolutionary trajectory of AT start-ups. This latter undertaking could uncover how AT entrepreneurship unfolds in different countries, i.e., whether AT entrepreneurship unfolds in a different way from how it unfolds in core AT regions and innovation hubs.

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[15] During our initial sample selection exercise, we identified four additional Hungarian AT start-ups that developed agricultural e-marketplaces and other smart AT solutions. They were not included in the sample because they were liquidated by 2022, irrespective of the fact that they had received substantial non-reimbursable public support (one of them, for example, has gained in total €500,000+ in four rounds).

[16] One example is the Test Farms programme, under the aegis of EIT Food. It links agricultural start-ups and farmers and thus helps start-ups test their solutions and showcase their services to potential customers and investors. Another notable programme is SmartAgriHub under the Horizon2020 instrument, contributing to the digitalisation of the European agriculture by fostering farmers' adoption of digital solutions through managing a Europe-wide network of digital innovation hubs. Another Horizon Europe project is X2.0, supporting AT start-ups' efforts to scale through mentoring services. Over and beyond these examples, several generic programmes supporting innovation and start-ups are available without any comprehensive investigation of whether these programmes can deliver.

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