Spatial Distribution of Hungarian Innovation-Driven Enterprises*

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The Magyar Nemzeti Bank's 2023 Growth Report identified 1,100 innovation-driven enterprises that demonstrated exceptional growth in the 2010s. These enterprises not only exhibited rapid expansion, but they also engaged in significant innovation during the previous business cycle. According to the descriptive findings of the report, these firms are mostly located in the capital and in counties where there are universities with multiple faculties. This study investigates whether the concentration in the capital city is a unique phenomenon considering the firm demographic characteristics of the counties. The prevalence of innovation-driven enterprises did not significantly differ in six counties compared to Budapest, when considering the scope of activity, size, ownership structure and age of these firms. These counties were Baranya, Csongrád-Csanád, Fejér, Hajdú-Bihar, Heves and Szabolcs-Szatmár-Bereg.

Journal of Economic Literature (JEL) codes: C21, O12, O39, O49

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1. Introduction – Identifying Hungarian innovation-driven enterprises

The Hungarian economy reached a pivotal juncture at the beginning of the 2020s. The extensive factors that had supported output through the utilisation of additional resources, which propelled the Hungarian economy in the 2010s, are now no longer sufficient to sustain growth without intensive efficiency gains. Hungary needs renewed impetus in innovation- and growth-oriented entrepreneurship, both of which are crucial foundations for a robust growth trajectory. While rapid growth and the domestic presence of distinct innovative production systems are necessary, they are not a sufficient condition for sustained and accelerated economic convergence. In line with literature recommendations, the entrepreneurial and innovation

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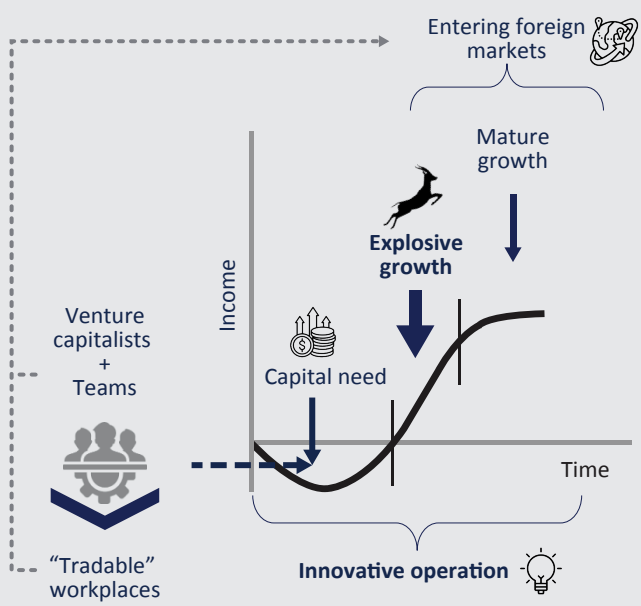
capacities of the Hungarian economy motivated a study analysing innovation activity and business performance at the firm level (*MNB 2023*). This dual focus led to the definition of innovation-driven enterprises (IDEs) in Hungary, as first introduced in the Magyar Nemzeti Bank's (the Central Bank of Hungary, MNB) Growth Report (*MNB 2023*).

The foundational basis for the definition was a paper by *Aulet and Murray* (*2013*), who delineated the fundamental differences that distinguish IDEs from traditional small and medium-sized enterprises (SMEs). These differences encompass five key aspects: (1) explosive growth following an investment-intensive start-up phase; (2) competitive advantage rooted in innovation; (3) addressing regional or global market demands beyond local needs; (4) the creation of tradable jobs; and (5) diverse ownership structures. These criteria have facilitated the adaptation of elements specific to the Hungarian economy and have enabled the identification of domestic innovation-driven enterprises through data analysis. Revisiting the concept proposed by *Aulet and Murray (2013*), this paper is unique in presenting considerations for domestic conceptualisation (*Figure 1*) along the growth trajectory of innovation-driven enterprises.

Figure 1
Growth curve of innovation-driven enterprises



Source: Based on Aulet and Murray (2013)

The theoretical growth curve of IDEs can be divided into three phases: the early phase, the explosive growth phase and mature production. The primary operational stages of the innovation process include research, development, pre-production, production and sales. Due to the capital-intensive investments required prior to manufacturing and product launch, IDEs encounter specific challenges during the early stage. A significant portion of the expenditure of innovation-driven enterprises occurs during this initial phase of the company's life cycle, leading to negative cash balances at start-up.

The initial stage of the schematic *growth curve* of innovation-driven enterprises integrates several elements from the list presented by *Aulet and Murray* (*2013*). To commence operations, IDEs require substantial investments, which have significant resource implications. Unlike typical small and medium-sized enterprises (SMEs), IDEs are characterised by external fundraising. The most well-known form of equity financing for IDEs is venture capital (VC), whereby investors acquire an ownership stake in the financed business. This practice has been a prevalent method of raising funds for high-growth start-ups in the United States for many decades. Venture capital firms provide not only financial support, but also valuable services to start-ups such as accelerating time to market, enhancing corporate governance structures and assisting in actively seeking and securing partners. Equity investors place significant emphasis on the founding team, attributing the outcome, whether success or failure, primarily to the team itself rather than to the business (*Gompers et al. 2020*). In economies with developed capital markets, the diversity of the founding team is a feature that enhances business performance through a variety of skills and knowledge (*Ruef et al. 2003; Beckman et al. 2007*). Consequently, the ownership of IDEs can be diverse, encompassing investor ownership and multiple founder members (criterion 5).

Aulet and Murray (*2013*) observe that innovation-driven enterprises typically, although not invariably, require a more highly skilled and heterogeneous workforce. It is important to note that the authors do not offer further clarification on the concept of tradable jobs (criterion 4). The term 'tradable jobs' can be interpreted in three distinct ways. Within the context of their paper, the first interpretation provided below most accurately conveys the notion of (foreign) tradable jobs.

Firstly, in the context of foreign market orientation, jobs in international industries often require skills and qualifications that are adaptable to the evolving demands of global markets and are subject to competition from foreign labour.[1] Secondly, literature on international economics, including the majority of recent studies, typically associates the tradable sector with the primary and secondary branches

[1] The export-specific experience of founders influences the export propensity of the IDEs; however, it does not correlate with export intensity (*Stucki 2016*).

of the economy, implicitly categorising services as non-tradable 'goods' (*Gervais – Jensen 2019*). Thirdly, the development of information and communication technologies (ICT) and the globalising world economy have facilitated and even augmented the international exchange of services. Consequently, the scope of tradable jobs has expanded to encompass service sector positions that can be performed remotely via internet access. This shift has led to the perception of tradable jobs as being location-independent.

The phenomenon of business growth, particularly rapid expansion, has been a significant subject of study in the fields of economics and statistics for several decades. The phase of the *explosive growth stage* is referred to as gazelle growth in the relevant literature, characterised by a sales revenue growth ratio of at least 20 per cent per annum, sustained over a period of three consecutive years. However, the definition of gazelle growth can vary depending on the selected growth criteria, size growth options and scope. Additionally, efforts to standardise these concepts are further complicated by the existence of various individual growth trajectories (*Delmar et al. 2003*).

For the foundation of exponential growth, the methodology of *Birch and Medoff* (*1994*) was employed, excluding the employment conditions. Commonly used headcount thresholds of 5 or 10 employees may exclude numerous microenterprises that typically exhibit high growth rates. Such exclusion can result in misleading policy implications, given the share of fast-growing microenterprises varies across countries, regions and industries; nonetheless, they contribute to nearly two fifths of job creation (*Daunfeldt et al. 2015*). *Daunfeldt et al.* (*2015*) stress that the inclusion of innovation performance within this group due to the high risk of failure of microenterprises is high. *Birch and Medoff* (*1994*), followed by *Birch et al.* (*1995*), investigated the job creation capacity of firms with sales of USD 100,000 or more during periods of rapid growth over different time horizons, maintaining consistency. *Birch and Medoff* (*1994*) examined US firms from 1988 to 1992, while *Birch et al.* (*1995*) analysed US firms from 1990 to 1994. In 2016, the annual average exchange rate was HUF 281.44 per US dollar. On average, the US price increase for 2016 was 1.62 times higher than during the period 1988–1994. As a result, USD 100,000 in HUF from 1988–1994 is equivalent to HUF 45.6 million in 2016 (281.44×1.62×100,000). This has been validated by the rounded HUF 50 million threshold chosen for the turnover threshold (*MNB 2023*).

Considering the specific characteristics of Hungary, it can be concluded that the success of a significant portion of domestic gazelles is illusory. Their exceptional performance is neither sustainable nor replicable, as it is not supported by internal company factors such as innovation, foreign trade orientation, highly qualified

human resources and managerial skills (*Szerb et al. 2017*). The unexplained increases in performance may be attributed to several factors, including:

- a periodic local demand recovery,
- temporary competitive advantages (including cost advantages),
- operation in contestable markets[2] (*Baumol et al. 1982*),
- rapidly saturating market niches,
- forward partnership agreements,
- corporate mergers and acquisitions,
- closure of loss-making departments,
- mergers and divisions, and
- one-off cash grants and selective incentives.

In the majority of countries where *high growth* has been analysed at the company level, the findings are consistent. Within this context, enterprises exhibiting unexplained rapid growth (*Szerb et al. 2017*) are often referred to as 'erratic one-shot grower' (*Delmar et al. 2003*) or 'one-hit wonder' firms (*Daunfeldt – Halvarsson 2015*).

Similar to the gazelle profile, knowledge production alone is insufficient for rapid economic development. In other words, high and sustained growth is not guaranteed in the innovative business sector. Although the types of innovation and their impact on firm growth have been studied extensively, many questions remain unanswered. *Szerb and Komlósi's* (*2016*) meta-analysis of the literature on high-growth firms also discusses the intricate relationship between innovation and growth. On the one hand, not all firms and types of innovation generate growth (*Samuelsson – Davidsson 2009; Parker et al. 2010; Heimonen 2012; Audretsch et al. 2014; Guarascio – Tamagni 2019; Bianchini et al. 2017*). On the other hand, both theoretical and empirical evidence suggests that innovation can, in certain cases, result in shrinkage (*Coad – Rao 2008; Goedhuys – Sleuwaegen 2010; Heimonen 2012*; more recently on failures, see *Bong – Park 2023, 2024*; and *Ponta et al. 2024*). Furthermore, the capacity to innovate varies across companies, and the impact of innovation on growth is influenced by several factors, including:

[2] *Magas* (*2017*), among others, provides an overview of the theory of contestable markets in his obituary of William J. Baumol.

- the state of the business cycle and macroeconomic factors (*Spescha – Woerter 2018*),
- technological readiness (*Lee 2010*),
- market structure (*Mazzucato – Parris 2015*), and
- demographic characteristics of the company (*Ács – Audretsch 1987*), as well as
- geographic location (among others *Audretsch et al. 2006*).

Szoboszlai et al. (*2024*) investigated the factors associated with rapid growth in the Hungarian innovative business environment. Their findings indicate that even in a robust segment of companies, such as innovative enterprises, the primary growth drivers include technological excellence, a highly skilled workforce and a focus on foreign markets. Additionally, *Szoboszlai et al.* (*2024*) found that potential access to venture capital increases the likelihood of rapid growth, although the coefficient is significant only at the 10-per cent level. Conversely, conventional loans reduced the probability of firm expansion. The authors attribute this negative statistical relationship to the fact that investments were made in the low-interest-rate environment at the end of the 2010s, but were not capitalised.

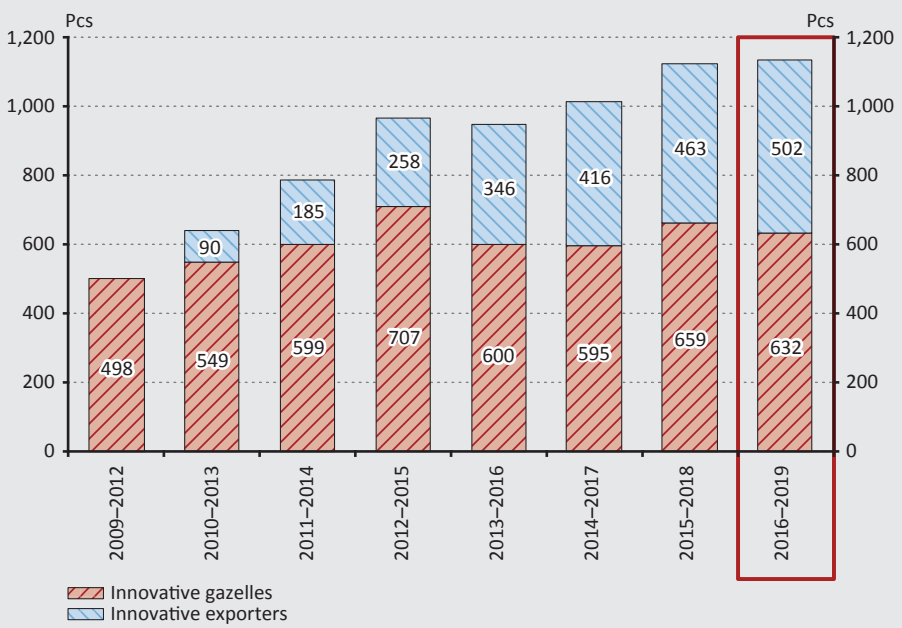
In the initial stages, innovation-driven enterprises, akin to traditional small and medium-sized enterprises, prioritise local markets to evaluate their product or service. Innovation serves as the pivotal factor facilitating expansion into international markets. When a product or service demonstrates success in the domestic pilot phase, a growth-oriented enterprise can secure a competitive edge in new markets through a dedicated innovative approach. As previously discussed, presence in export markets is a result of innovation-driven growth, either concurrently with or subsequent to the fulfilment of local demands. Consequently, entry into export markets may occur during the rapid (explosive) growth phase, although this is not explicitly defined as a prerequisite in the context of innovative gazelles.

The empirical literature continues to grapple with causal links and endogeneity issues concerning the relationship between innovative behaviour and foreign market activity. Empirical studies, such as those based on *Melitz* (*2003*), highlight a self-selection mechanism whereby the most productive and innovative firms emerge as successful exporters. Conversely, research focusing on firms engaged in foreign markets examines how export activities influence innovation performance and productivity changes (*De Loecker 2007*). Furthermore, foreign trade facilitates knowledge transfer. Through their export activities, firms participate in a learning-

by-exporting process, which subsequently impacts their R&D investment, innovation capacity and production efficiency (*Wagner 2007*).

In the 2010s, venture capital financing in Hungary was predominantly state-involved, and founder members were not considered in the identification process. Consequently, the classification of Hungarian innovation-driven enterprises was primarily based on innovation activity, rapid growth and export orientation. The data sources are detailed in the following section. Using a data-driven approach, the Hungarian IDE group comprises two categories: innovative gazelles and innovative exporters. The initial core group (2009–2012) consists of innovative and fast-growing enterprises (innovative gazelles), for which external market participation is not a prerequisite (*Figure 2*). An innovative gazelle remains classified as innovation-driven if it transitions to exporter status following rapid growth. This subgroup is referred to as innovative exporters. It is crucial to note that there are no qualitative distinctions between the two groups.

Figure 2
Types of innovation-driven enterprises (2009–2019)



Source: From Hungarian Central Statistical Office (HCSO), MNB, National Tax and Customs Administration (NAV), NRDIO, NIPO, crunchbase

2. Data

The economic performance of Hungarian businesses is reflected in their financial statements. For this analysis, we utilised a firm database derived from the balance sheets and profitability metrics of Hungarian corporate taxpayers. The primary income statement items pertinent to IDE identification are net turnover and, notably, turnover from exports. Companies were classified as exporters if their export sales accounted for at least 10 per cent of their net sales. Innovation-related characteristics were linked to economic data using tax identification numbers and company names (*Table 1*).

In addition to the accounting data, we incorporated information data from tax returns that detail explicit innovation activities beyond R&D tax incentives. We also utilised data from the National Research, Development and Innovation Office (NRDIO) and patent and trademark data provided by the National Intellectual Property Office (NIPO) to map innovation capacities. The basic business demographic characteristics used in the regression modelling are derived from the business register. The analysis focused on the segment of the multiply linked database that could become innovation-driven enterprises, defined as those with a turnover of at least HUF 50 million in the relevant sectors. These segments included 55,786 enterprises out of 1,134 innovation-driven enterprises resulting in 56,920 observations. The treatment group in the cross-sectional estimates presented later comprises the innovation-driven firms from the period 2016–2019.

Table 1
Definition and source of variables used in regression analysis

Variable	Type	Definition	Source
Dependent variable			
Revenue	Basic	Net turnover	NAV
Export revenue	Basic	Portion of net turnover derived from export sales	NAV
Gazelle?	Calculated	D=1 if the average real income growth over 3 years was at least 20 per cent per year on average	NAV
Does it export?	Calculated	D=1 if at least 10 per cent of net turnover is derived from export sales	NAV
Does it innovate?	Basic	D=1 if the company either holds a patent or trademark, or has received development aid from the NRDIO, or has claimed a tax credit for R&D activities conducted within its own field of activity	NIPO, NRDIO, NAV
Is it innovation-driven?	Calculated	If the company demonstrated rapid, gazelle-like growth through innovation, or is poised to engage in export activities	
Explanatory variables			
Age	Calculated	Number of years since the establishment of the company, or, if this information is unavailable, number of years since the first recorded entry in the database	Organisation register, NAV
Age square	Calculated	Variable square of age	Organisation register, NAV
Balance sheet total	Basic	Report data	NAV
Workforce	Basic	Statistics from tax returns	NAV
Size	Calculated	Eurostat definition; the European Commission's definition of SMEs is set out in Recommendation 2003/361/EC	NAV
Is it a foreign company?	Calculated	A foreign company is defined as an entity with at least 50 per cent of its capital registered by a foreign entity	NAV
County	Basic	Supplementary information is obtained from the tax return, or from the organisation register in the absence of such data	NAV, Organisation register
Sector	Basic	Supplementary information is obtained from the tax return, or from the organisation register in the absence of such data	NAV, Organisation register
Sector groups by technology and knowledge intensity	Calculated	Eurostat classification	NAV
Is it a special purpose enterprise? Community companies Non-profit companies	Basic	Statistical information is used to narrow the scope of companies within the competitive sector	Organisation register

Note: Variables in bold are included in the regression equations. The other variables are needed to define the dependent variable and the covariates.

The explanatory variables encompass firm demographic characteristics as outlined by *van Wissen* (*2002*), including firm age, size and location. The continuous variable for enterprise age is based on the date of establishment; if this is unavailable, the year of foundation is taken as the first year of publication in the firm panel. The size category variable, defined by Eurostat, considers the limits on the number of employees, turnover and balance sheet total.[3] The county variable indicates the location of the company's head office. These variables are complemented by the ownership structure and the square of the company's age. A company is classified as foreign if the non-resident ownership of its registered capital exceeds 50 per cent. The inclusion of the squared company age is justified by the observation that younger firms are often more inclined to innovate as they seek a competitive advantage and are more adaptable to change. As firms mature, their innovation activity may decline due to risk aversion and commitment to existing products and services. However, older firms may re-intensify their innovation efforts to maintain their market position leveraging their resources and experience (*Coad et al. 2016*). Additionally, a variable grouping firm activities is included, justified by the empirical relationship between a region's industrial history and the creation and operation of new firms, including innovation-driven enterprises. Regions with a history of certain industries are more likely to support entrepreneurship and business start-ups (*Lux 2016*). Sectoral groupings by technology and knowledge intensity are constructed following the statistical classification of economic activities in the European Community at the 2-digit level, based on R&D expenditure/added value ratio.[4] The 2-digit classification is summarised in *Table 2.* Innovation-driven enterprises showed a significant concentration by activity (*MNB 2023; Szoboszlai 2023*) with almost two fifths of enterprises concentrated in 23 specialised activities. However, it is not feasible to include all sectoral activities in the 4-digit breakdown due to the large number of degrees of freedom (620) bound. Even with a 2-digit activity representation, there would be fewer than 13 observations per binary sectoral variable in the innovation-driven domain.

[3] See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:n26026 .
[4] See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech_classification_of_manufacturing_industries

Table 2
Sectoral group classification

Sectoral group	2-digit sector codes
High-tech manufacturing	21, 26
Medium high-tech manufacturing	20, 27, 28, 29, 30
Medium low-tech manufacturing	19, 22, 23, 24, 25, 32, 33
Low-tech manufacturing	10, 11, 12, 13, 14, 15, 16, 17, 18, 31
Knowledge-intensive services	50, 51, 58, 59, 60, 61, 62, 63, 69, 70, 71, 72, 73, 74, 75, 78, 80, 85
Less knowledge-intensive services	35, 36, 37, 38, 39, 45, 46, 47, 49, 52, 53, 55, 56, 68, 77, 79, 81, 82, 90, 91, 92, 93
Agriculture	1, 2, 3

Source: Eurostat glossary

3. Methodology

The Growth Report 2023 (*MNB 2023*) and *Szoboszlai* (*2023*) examined the distribution of our innovation-driven enterprises based on a single criterion. To accurately model the probability of IDE occurrences, it is essential to filter out of cross-effects and include IDE categories. Identifying relationships between variables is a crucial aspect of data analysis. Multivariate regression enables the consideration of potential interactions among variables which is necessary for modelling the occurrence of IDEs. For instance, varying levels of company concentration and competitive conditions across sectors[5] may be observed. When size and sectoral classification are analysed separately, these co-movements (covariances) are not accounted for. Furthermore, multivariate regression analysis allows for the simultaneous quantification of the effects of all explanatory variables, resulting in more reliable estimates for predicting the dependent variable.

The form of the function used is determined by the category of the dependent variable (*Figure 3*). For binary outcomes, linear probability models, logistic regressions or probit regressions can be employed for estimation (*Maddala 1983*). When the dependent variable has more than two potential outcomes, the probability of group membership is modelled within a multilevel probabilistic or

[5] The comprehensive competition statistics database, which illustrates the market structure of domestic sectors, was updated and jointly published by the Hungarian Competition Authority and the Magyar Nemzeti Bank at the end of 2023. Detailed data and accompanying methodological guide are available here: https://gvh.hu/en/gvh/competition_culture_development/gvhmnb-competition-statistics-database/gvhmnb-competition-statistics-database.

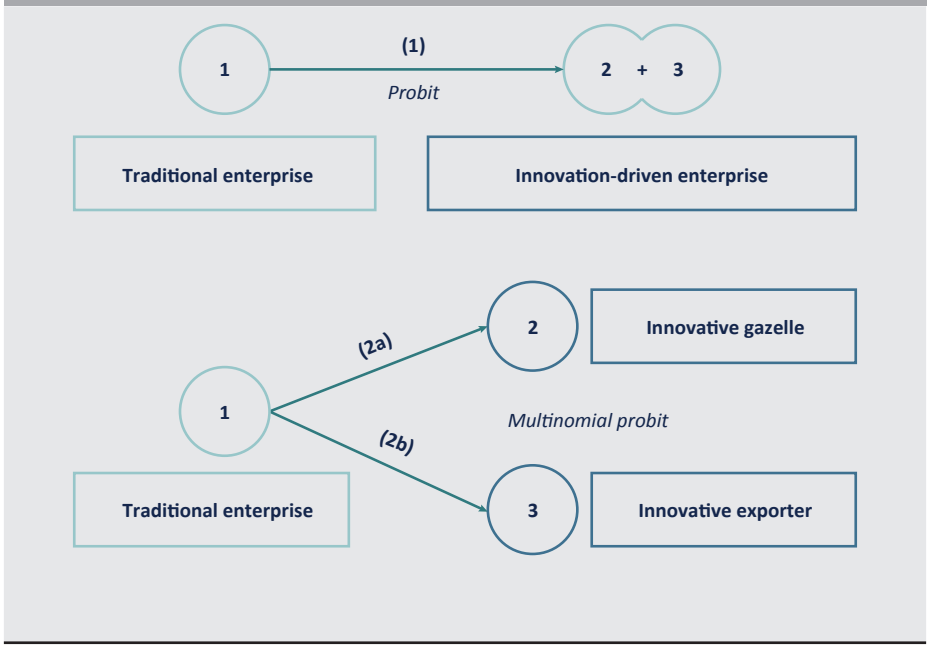
multinomial framework.[6] In the context of multinomial models, it is assumed that all relevant decision makers (in this case, Hungarian enterprises with a turnover of at least HUF 50 million in the specified sectors) select from the same set of observable outputs in the data set. The objective of the modelling is to stylise the occurrence of innovation-driven enterprises rather than to identify the factors that enable companies to become innovation-driven. This study does not aim to explore those facilitating factors. Instead, the research focuses on identifying the demographic characteristics of the entire group and two types of innovation-driven enterprises, with an emphasis on the territorial dimension.

In the first case (1), we model the probabilities of occurrence of innovation-driven enterprises relative to other businesses (*Figure 3, top panel*). The control group, to which IDEs are compared, comprises businesses that generated at least HUF 50 million in turnover in the sectors considered in the IDE identification (see *MNB 2023*: *Chapter 5*). In the probit specification (1), the innovation-driven pool is treated as a homogeneous group. Subsequently, by treating the two groups of innovation-driven enterprises separately while maintaining the same control group, we estimate the probabilities of belonging to the partial group within a multinomial framework (*Figure 3, bottom panel*). This approach allows us to determine whether innovative gazelles (2a) or innovative exporting firms (2b) are more or less likely to occur based on a specific criterion within the population by adjusting the predicted probabilities to 1. Innovative gazelles exporting in a slowing growth environment are defined as innovation-driven enterprises (innovative exporters) without any qualitative or ranking distinction.

The cross-sectional estimates the model situation as of 2016, as this represents the final year of observation during which gazelle growth can be anticipated. Consequently, this may imply that innovative exporters are the innovative gazelles of preceding years. Approximately 600 innovative gazelles satisfied the combined criteria of rapid growth and innovation activity in the period 2016–2019. Furthermore, the group of innovative exporters, which no longer qualifies as gazelles, augmented the pool of innovation-driven enterprises in Hungary by approximately 500 additional entities.

[6] It may be necessary to model the probabilities of occurrence separately by pairing the level values of the category variable (business enterprise | innovative gazelle | innovative exporter). In separate logistic regressions, the sum of the predicted probabilities does not necessarily equal 1, whereas in a multinomial framework, it does. In the former approach, each binary logistic regression model independently estimates the probability of its own output category, without considering the probability of falling into the other categories.

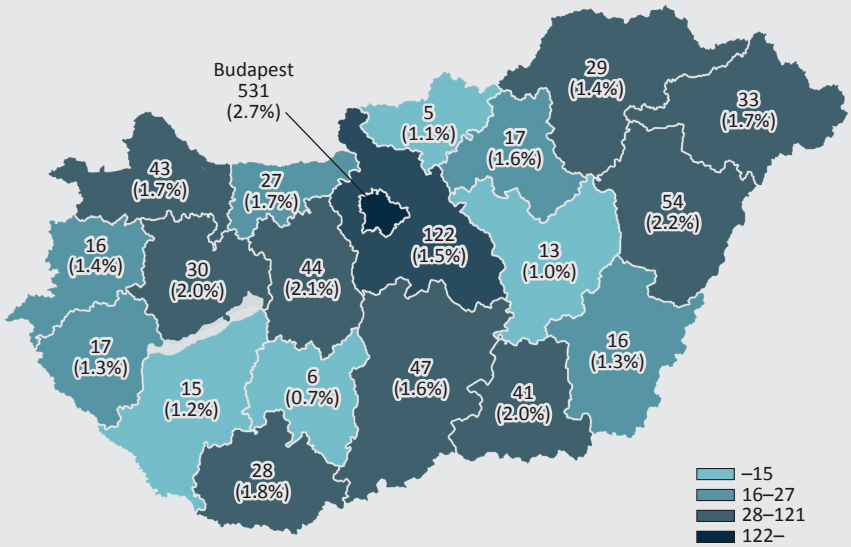
Figure 3
Flowcharts for probabilistic modelling



4. Findings

Consistent with the findings in the literature (e.g. *Budden-Murray 2017; Botelho et al. 2021*), Hungarian IDEs exhibit notable concentration in terms of location (*MNB 2023*). The observation that nearly half of innovation-driven enterprises are located in the capital city (*Figure 4*) may be misleading, as the probability of IDEs being present in an economic or spatial region is influenced by its 'immersion potential'. In 2019, 29 per cent of businesses operated in the capital, generating 43 per cent of national economic output, which provides a more nuanced understanding of the distribution. It is also crucial to consider sectoral, institutional and size-specific factors in defining innovation-driven enterprises. By definition, IDEs are drawn from enterprises in sectors engaged in foreign trade, excluding public, community, non-profit companies and special purpose entities (SPEs). The threshold for company size, for the reasons outlined above, was set an annual net turnover of at least HUF 50 million (*MNB 2023:52*).

Figure 4
Number and territorial distribution of innovation-driven enterprises (2016–2019) by county



Note: The figures in parentheses represent the percentage of innovation-driven enterprises within the county, specific to the relevant sector of activity, that have achieved a minimum turnover of HUF 50 million.

Source: Based on MNB (2023) and Szoboszlai (2023)

The estimation results are presented sequentially according to the models depicted in *Figure 3.* These results are utilised to filter out relationships among explanatory variables. Specifically, coefficients for the county categories in the specifications exclude the effect of the average sectoral, age, ownership and size characteristics of companies within a given region.

Demographic factors affecting the probability of becoming innovation-driven – model (1)

The explanatory variables are interpreted in the sequence presented in *Table 3.* Sector groups are categorised by technology and knowledge intensity: the coefficients for the various technology categories illustrate how the activities influence the likelihood of becoming an innovation-driven enterprise compared to the control group (traditional business enterprise). All coefficients are significantly positive and increase with technology intensity, indicating that, *ceteris paribus*, companies in all technology categories – primarily manufacturing – are more likely to become innovation-driven than those in less knowledge-intensive services (benchmark). This probability is higher in sectors with greater R&D expenditure as

a share of value added.[7] However, the coefficients associated with the high-tech and medium high-tech manufacturing categories and those associated with the medium low-tech and low-tech categories were not significantly different from each other in the post-estimation pairwise comparisons. This suggests that these categories have similar effects on the presence of innovation-driven firms, and that the finer statistical differences in technology level did not significantly impact the probability of becoming an innovation-driven enterprises. All else being equal, enterprises engaged in knowledge-intensive services as their primary activity are 2.4 per cent more likely to become innovation-driven compared to firms in less knowledge-intensive service sectors. *Ceteris paribus*, agriculture is slightly less likely (by 0.66 per cent) to have IDEs than less knowledge-intensive service providers. However, this does not necessarily mean lower production efficiency. *Fenyves et al.* (*2022*) demonstrated that Hungarian agricultural enterprises operated efficiently relative to their own technical standards between 2017 and 2019. If firms in a sector predominantly serve the domestic market, if external factors (e.g. weather, buyer-supplier relationships) have a strong impact on productivity, or if the typical firm size does not facilitate rapid growth, the estimated probability of an IDE occurrence may be lower compared to the benchmark group. Nonetheless, this does not inherently imply that the production processes are less productive.

The coefficient of variation for age indicates that, all other factors being equal, the probability of becoming innovation-driven increases by 0.3 thousandths per year of age. This marginal effect encompasses both the company's age and its square due to the quadratic relationship between these variables. Consequently, the marginal effect in *Table 3* is represented by the relationship $\partial y/\partial x = \beta_1 + 2\beta_2$. This implies that the marginal effect varies with the age of the company (x) and is not constant. The relationship between the age variable and its square thus jointly determines the marginal effect.

Ownership structure: The coefficient of the variable indicates that foreign-owned enterprises are somewhat less likely to become innovation-driven than domestically-owned ones with a difference of 6.4 percentage points. The result is noteworthy, despite the size of the impact.

Size category: The coefficients for different company size classes reveal that, when controlling for other variables, the probability of becoming innovation-driven increases with firm size. Compared to microenterprises, the probability of IDEs is 1.9 per cent higher in the small enterprise segment, 4.1 per cent higher in the medium enterprise segment and 6.2 per cent higher in the large enterprise segment.

[7] In its sectoral approach, Eurostat groups technology intensity by R&D expenditure as a share of value added. See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:High-tech.

Table 3
Regression results – stylising the probability of occurrence of innovation-driven enterprises

P(y = group of innovation-driven enterprises)	(1)	(2a)	(2b)
Technology and knowledge intensity (base: less knowledge-intensive service sectors)			
High-tech manufacturing	0.0417***	0.0178*	0.0239***
	(4.41)	(2.47)	(3.60)
Mid-high tech manufacturing	0.0337***	0.017***	0.0167***
	(7.37)	(4.60)	(5.70)
Mid-low tech manufacturing	0.0099***	0.0032*	0.0067***
	(4.96)	(2.09)	(4.76)
Low-tech manufacturing	0.0065**	0.0023	0.0042**
	(3.03)	(1.24)	(3.06)
Knowledge-intensive services	0.0244***	0.0152***	0.0092***
	(11.82)	(9.49)	(6.82)
Agriculture	–0.0066***	–0.004***	–0.0026**
	(–4.47)	(–3.43)	(–2.81)
Age ([i])	0.0003**	–0.00004	0.0003***
	(3.13)	(–0.42)	(5.81)
Ownership structure (base: domestic)			
Foreign	–0.0064***	–0.005***	–0.0014
	(–4.10)	(–4.40)	(–1.69)
Size of enterprise (base: microenterprise)			
Small	0.0194***	0.009***	0.0104***
	(14.46)	(8.73)	(12.40)
Medium	0.0406***	0.0117***	0.0289***
	(11.84)	(5.07)	(10.75)
Large	0.0616***	0.0136**	0.048***
	(7.37)	(2.75)	(6.52)
County (base: capital)	*Figure 5*	*Figure 6*	*Figure 7*
Pseudo R^2	0.101	0.101	
Observation number	56,920	56,920	

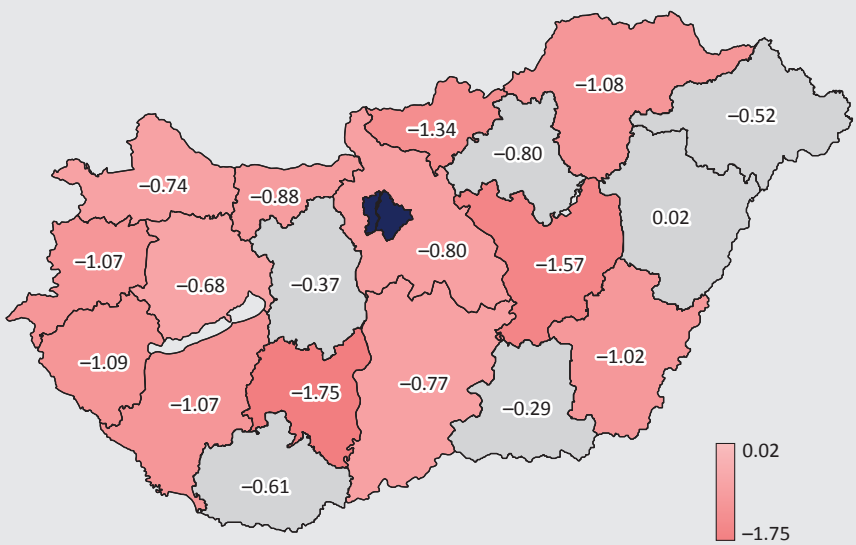
*Note: t-statistics in brackets, * p < 0.05; ** p < 0.01; *** p < 0.001. Marginal effects (dy/dx). ([i]) Marginal effect of company age and its square. The numbering of the models follows the numbering in Figure 3.*

Source: Calculated based on HCSO, MNB, NAV, NRDIO, NIPO, crunchbase

The county-level results are depicted in *Figure 5.* In addition to the aforementioned coefficients, the marginal coefficients in the majority of counties are, *ceteris paribus*, significantly lower than probabilities of occurrence in the capital city. However, the coefficients in six counties – namely, Baranya, Csongrád-Csanád, Fejér, Hajdú-Bihar, Heves and Szabolcs-Szatmár-Bereg – were not significant at the 5 per cent confidence level: This finding partially aligns with the knowledge regions identified in *Lengyel and Varga* (*2018*). Specifically, Baranya, Csongrád-Csanád and Hajdú-Bihar counties were classified as knowledge regions, Fejér and Heves as re-industrialising areas and Szabolcs-Szatmár-Bereg county as a rural region. It is also crucial to emphasise that the spatial distribution of the control group companies influences the estimated average marginal effects.

In summary, all firm demographic factors are associated with innovation-driven operation. However, while firm age and ownership exert a moderate (filtered) effect on the probability of occurrence of IDEs, a larger and increasing partial effect is observed by company size and scope of activity. In relation to these findings, *Szoboszlai et al.* (*2024*), through multivariate analysis of survey data from innovative enterprises, determined that the likelihood of rapid growth is enhanced by advanced technological infrastructure and a skilled workforce. There, even within such a robust (innovative) business segment, these factors remain critically important.

Figure 5
Probability of existence of innovation-driven enterprises in counties compared to Budapest



Note: Marginal effects (dy/dx). Counties with coefficients that are insignificant relative to the base value (Budapest) are depicted in grey. Due to rounding, the sum of the marginal effects presented in Figures 6 and 7 may slightly differ from the results shown in Figure 5.

Source: Based on HCSO, MNB, NAV, NRDIO, NIPO, crunchbase

In the next section, we examine how the decomposition of the innovation-driven pool within a multinomial framework refines the probabilistic picture presented above (model results (2a) and (2b)). This analysis highlights the observed differences.

Demographic factors affecting the probability of becoming an innovative gazelle and innovative exporter – models (2a) and (2b)

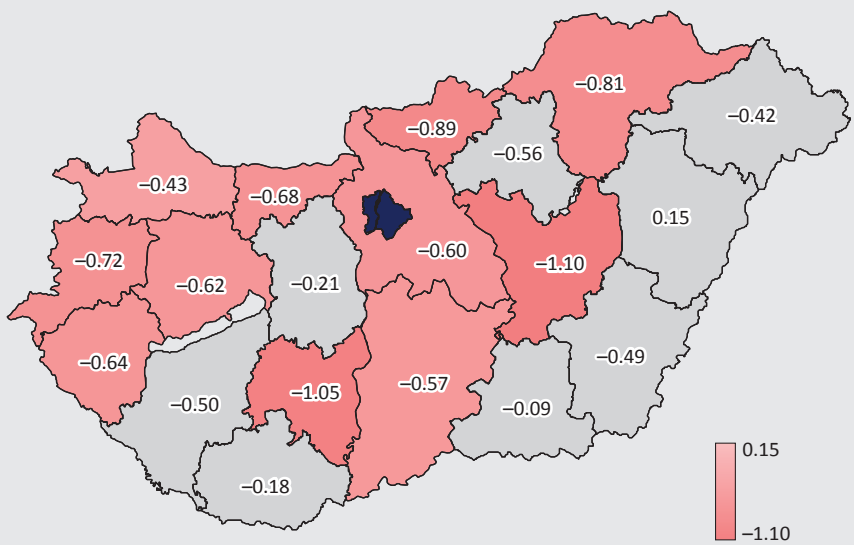
In regression models, the coefficients β describe the relationship between the explanatory variables and the dependent variable. When the combined output category is decomposed, the sum of the β coefficients equals the estimated coefficient of the combined case. The β coefficients for the different output categories are aggregated. This phenomenon is a fundamental property of linear regression models. This principle also applies to nonlinear models, such as dichotomous dependent variable probit models, where the shared output variable is explained with a single model framework rather than through multiple separate probit equations. Consequently, the multinomial probit can be viewed as an extension of the base case offering deeper insights into the company demographic characteristics (models (2a) and (2b)) of the innovation-driven enterprise types.

The 1,134 innovation-driven enterprises identified in the 2016–2019 period comprise two distinct groups (*Figure 2*)*:* 502 innovative gazelles and 632 innovative exporters. Analysis across sector groups reveals that the probability of occurrence of innovative gazelles is higher in the knowledge-intensive service sector, whereas low and medium-low manufacturing specialisation leads to a higher probability of innovative exporters. This pattern is consistent with the findings in models (2a) and (2b), where post-estimation coefficient tests indicated no significant differences between the pairwise coefficients for high-tech and medium high-tech categories versus medium low-tech and low-tech categories. However, it is noteworthy that while the coefficient on the medium low-tech manufacturing dummy variable is significant among innovative gazelles, the coefficient for the low-tech category is not. Similarly, the significance levels for the high-tech and medium high-tech category variables differed. Company age is an insignificant explanatory variable among innovative gazelles, suggesting that the effect identified in the previous combined specification was attributable to innovative exporters. By definition, innovative exporters are more mature (older) firms compared to innovative gazelles, as they remain within the IDE pattern beyond gazelle status (rapid growth period). Further analysis of the coefficients reveals that, for the innovative exporter, foreign ownership is an insignificant factor in explaining the probability of occurrence, but it is a significant negative coefficient in predicting the likelihood of becoming an IDE gazelle. An increase in company size is associated with a higher probability of being an innovative exporter. Specifically, medium firm size is associated with a 2.9 per cent higher probability of becoming an innovative gazelle, and large company size correlates with a 4.8 per cent higher probability among exporting IDEs. These respective marginal effects increase the probability of becoming an innovative

gazelle by 1.2 per cent and 1.4 per cent, respectively, which are statistically similar (*Table 3*).

The territorial dimension reveals distinct different between the two groups of enterprises. For innovative gazelles, the counties with significantly different (*ceteris paribus*) probabilities of occurrence compared to Budapest include Békés and Somogy. By contrast, for innovative exporters, only five counties – namely, Baranya, Békés, Jász-Nagykun-Szolnok, Somogy and Tolna – exhibit a significantly lower probability of occurrence than the capital. It is noteworthy that – according to *Lengyel and Varga* (*2018*) – these counties, with the exception of Baranya, are classified as rural regions based on their sectoral structure. This indicates that local characteristics, as defined by the concept of innovation-driven enterprises, strongly influence the frequency distribution of these enterprises and their subtypes when filtered by other company characteristics. Finally, the sum of the marginal effects in *Figures 6* and *7*, as presented *in Table 3*, corresponds the aggregate effects shown in *Figure 5*. The results demonstrate that the probability of occurrence of the entire pool is influenced by the probability of occurrence of innovative gazelles, after controlling to other factors. As innovative gazelles transition into innovative exporting companies, the probabilities depicted in *Figure 7* will adjust accordingly.

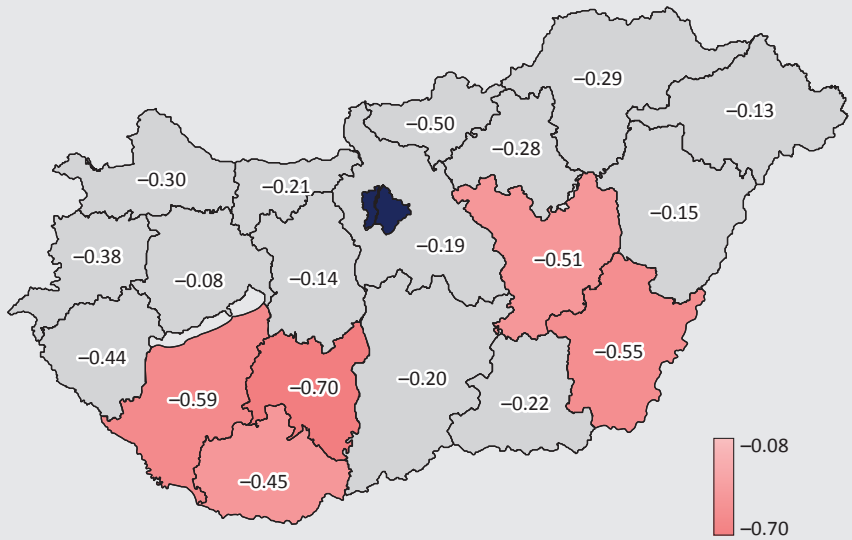
Figure 6
Probability of occurrence of innovative gazelles in the county relative to Budapest



Note: Marginal effects (dy/dx). Counties with coefficients that are insignificant relative to the base value (Budapest) are depicted in grey. Due to rounding, the sum of the marginal effects presented in Figures 6 and 7 may slightly differ from the results shown in Figure 5.

Source: Based on HCSO, MNB, NAV, NRDIO, NIPO, crunchbase

Figure 7
Probability of occurrence of innovative exporters in the county relative to Budapest



Note: Marginal effects (dy/dx). Counties with coefficients that are insignificant relative to the base value (Budapest) are depicted in grey. Due to rounding, the sum of the marginal effects presented in Figures 6 and 7 may slightly differ from the results shown in Figure 5.

Source: Based on HCSO, MNB, NAV, NRDIO, NIPO, crunchbase

5. Conclusions

The role of the innovation-driven enterprise is increasingly valued and dominant. This select group of approximately 1,100 companies is likely to attract heightened attention in the 2020s due to its significance to the national economy. This research examines the company demographic characteristics of innovation-driven enterprises within the context of the Hungarian economy, with a particular emphasis on the territorial dimension. Furthermore, the conceptualisation and application of innovation-drivenness have been tailored to Hungarian economic conditions, and this study is the first to develop these considerations at a scientific level and detail. Given the domestic context, including the terminology and the period of analysis, the data and methods employed in this research may be specific to the Hungarian economic environment. Consequently, similar studies conducted in other countries may yield different results.

The example of the world's leading industrial parks demonstrates that this prominent group of companies is characterised by a unique sectoral and geographical clustering. Previous domestic findings have also indicated that Hungarian innovation-driven enterprises operate in specialised markets such as engineering and natural sciences R&D, information technology, pharmaceuticals and biotechnology (*MNB 2023; Szoboszlai 2023*). This is reflected in the estimation coefficients for the groups categorised by knowledge intensity. The probability of becoming an innovation-driven enterprise within the analysed population of firms is increased by engaging in high-technology and knowledge-intensive activities and by expanding firm size, *ceteris paribus*, with higher coefficient values observed across subgroup. Additionally, company maturity (age) was identified as a factor that increases opportunities, albeit with a smaller estimated marginal effect. However, in terms of ownership structure, foreign control does not, *ceteris paribus*, significantly enhance the likelihood of innovation-driven operations.

In addition to activity-based concentration, spatial patterns emerged in the raw distribution of IDE firms. However, relying solely on the frequency distribution by county can lead to misleading conclusions. While the concentration of IDEs in the unfiltered data is dominated by the capital and counties with university towns, the relative probabilities of occurrence within a county are not necessarily prominent. The type of businesses operating within a county is also crucial, as it sets a specific condition for the local creation of innovation-driven businesses. From this perspective, six counties have asserted their own regional characteristics similarly to the capital region. Of these six counties, three – namely, Baranya, Csongrád-Csanád and Hajdú-Bihar – have been identified as knowledge regions in previous research. This partially confirms that, compared to other regions, the probability of IDEs is also significantly higher in counties that are home to universities with multiple faculties. However, it is important to emphasise that this is only one characteristic of the county-specific ecosystems, which are influenced by numerous other factors that play a decisive role in stimulating innovation and entrepreneurship. Furthermore, the balanced location of innovation-driven enterprises, which justifies Hungary's classification as a moderate innovator, may indicate that no county has yet reached the critical mass required to create regional local IDEs with a significantly higher probability. The innovative gazelles of the future will play a key role in this development, and according to the presented results and conceptualisation, they will have a profound impact on the development of the entire IDE pool.

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