

THESES OF THE DOCTORAL (PhD) DISSERTATION

**THE BLOCKCHAIN PRODUCTIVITY PARADOX: VALUE
CREATION, ORGANIZATIONAL TRUST, AND
ADAPTATION BARRIERS IN CORPORATE PRACTICE**

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Debrecen, 2026

1. BACKGROUND, OBJECTIVES AND PRESENTATION OF THE RESEARCH HYPOTHESES

1.1. Research background and motivation for topic selection

My motivation for choosing this topic and the development of my research focus dates back eight years, since I have been actively engaged with cryptocurrencies and the innovative decentralized technologies behind them. During this period, I continuously monitored technological advancements, market news, and the latest domestic and international scientific research. As a marketing master's student at the Faculty of Economics and Business of the University of Debrecen, I participated in the Scientific Students' Associations Conference (TDK) with my paper titled "Marketing in the World of Crypto Assets". In this early research, I primarily investigated the relationship between marketing tools and cryptocurrencies, but I also elaborated on the operation of Blockchain Technology (BCT), its corporate architectural characteristics, and its potential areas of business application.

My commitment to technology and innovation is demonstrated by my admission to the Talent Management Program of the University of Debrecen (DETEP) in February 2022, where I focused on the present and future of cryptocurrencies, their operational mechanisms, and their transformative impact on traditional financial and currency systems. During my research, I examined the extent to which crypto-assets can replace traditional, centralized currencies in the global economy. As scientific recognition of my work, I was awarded the New National Excellence Program (EKÖP) scholarship twice during my studies, and I presented my research findings at numerous domestic and international conferences. My scientific conclusions were published in peer-reviewed domestic and international journals.

1.2. The research problem and the scientific relevance of the topic

The global economy of the third decade of the 21st century is defined by the exponential spread of technological advancements of the Fourth Industrial Revolution and the imperative of digital transformation (SCHWAB, 2017). The digital transition taking place in the global economy is no longer merely an optional tool for efficiency enhancement, but a strategic necessity for corporate survival, sustainable growth, and the preservation of international competitiveness (BHATIA ET AL., 2024; DADSENA ET AL., 2024). One of

the most disruptive yet divisive pillars of this process is blockchain technology, which, since the pioneering work of NAKAMOTO (2008), has stepped out of the speculative shadow of cryptocurrencies and become a potential key factor in corporate value creation, data management, and automation (IANSITI & LAKHANI, 2017).

One of the most costly elements in the operation of global economic systems is the lack of trust and the resulting transactional friction. NORTH's (1990) institutional economics thesis highlights that economic actors sacrifice vast resources to enforce contracts, monitor compliance, and finance various intermediary systems (banks, auditors, lawyers). The promise of blockchain technology is most decisive in this dimension: it offers a decentralized distributed ledger technology (DLT) that guarantees data immutability through cryptographic procedures, creating a state of "trustless trust" (TAPSCOTT & TAPSCOTT, 2016; CASEY & VIGNA, 2018). Theoretically, this minimizes agency costs, eliminates third-party intermediaries, and radically reduces transaction costs (SWAN, 2015; BISWAS & GUPTA, 2019; PATHAK ET AL., 2025).

However, the primary research problem focused on in my dissertation is the sharply contradictory "Blockchain Productivity Paradox," which is evident in both the literature and practice (BALCI & SURUCU-BALCI, 2021; LI ET AL., 2021). According to GARTNER's (2023) hype cycle, the technology is currently in the "trough of disillusionment". Companies are investing massive sums into developments, but the return on investment and macroeconomic efficiency gains often fail to materialize or do so with significant delays. This phenomenon is the digital equivalent of Solow's productivity paradox (BRYNJOLFSSON, 1993; HASSAN ET AL., 2023; NAGY, 2025). While early models envisioned radical cost reductions, in reality, high implementation, maintenance, and energy-intensive operational costs often outweigh short-term profits. Thus, the technology is not a simple software update but a foundational technology whose true value is only realized through the complete transformation of the institutional ecosystem and trust structures (CASATI ET AL., 2024).

The second critical problem area is the relationship between trust and data-driven operation (data integrity). Blockchain is often mistakenly treated as an autonomous "trust machine," whereas it is merely a carrier medium that makes recorded data immutable but cannot verify its physical factual accuracy (BIANCONE ET AL., 2025). The "Oracle problem" and the

"Garbage In, Garbage Out" (GIGO) phenomenon point out that the efficiency of blockchain heavily depends on organizational capabilities and the quality of physical input data (DANESE & ROMANO, 2025). According to BARNEY's (1991) Resource-Based View (RBV), technology can only generate a competitive advantage when combined with organizational capabilities (QUEIROZ & WAMBA, 2019). If "garbage" enters the system, the blockchain merely makes the error immutable.

The third socio-economic problem, particularly decisive from a domestic perspective, is the technological gap of Small and Medium-sized Enterprises (SMEs). While experimental or fully implemented projects of multinational companies dominate supply chains, the domestic SME sector is severely lagging behind, posing a serious risk to their integration into global value chains (JACKSON & ALLEN, 2024; CHOTIA ET AL., 2025). It is questionable whether this lag in the domestic market is solely due to financial constraints or cognitive, psychological barriers (described by the TAM, UTAUT, and TRI models) (DAVIS, 1989; PARASURAMAN, 2000). The situation is further complicated by the fact that the Hungarian ecosystem is uncharted; official statistical nomenclatures (TEÁOR) do not detect the technology, leaving both decision-makers and the market "flying blind" (KALOCSAI & KALOCSAI, 2019).

1.3. Major objectives of the research

The outlined contradictions, the productivity paradox, data integrity challenges, and the invisible struggle of domestic SMEs, make it clear that the corporate application of blockchain cannot be treated purely as an IT issue. The objective system of my dissertation is built on strict deductive logic, progressing from macro-level international theories to domestic micro-level corporate reality. I formulated a total of eight specific objectives, which rely on three main pillars: (1) the synthesis of international literature, (2) the empirical modeling of large enterprise value creation, and (3) the exploration of the adaptation barriers of the domestic SME sector.

The primary objective is to clarify the economic nature of the technology and to systematize the contradictions found in the scientific literature based on international sources.

- *Objective C1:* Systematizing the corporate value creation mechanisms of blockchain technology and establishing a corporate-theoretical delineation based on a systematic literature review (PRISMA).

My aim is to use the PRISMA methodology to reveal what promising benefit factors appear in the scientific discourse between 2015 and 2026, and to create a unified synthesis from these to support corporate decision-making.

- *Objective C2:* Exploring the spatial structure and sectoral distribution of the domestic blockchain ecosystem, and creating a functional cluster model typifying the activities of the actors, without claiming exhaustiveness.

The method discards the exclusive use of traditional corporate databases (e.g., OPTEN, e-beszámoló) because they do not detect operational technological integration. Instead, the research is built on a three-level digital OSINT footprint analysis (examining media, labor market demands, and annual financial reports). The objective is not the comprehensive identification of domestic actors, but rather to provide empirical evidence of the direct domestic presence and actual application of the technology.

At the second level, I examine the actual performance impacts of the technology through the lens of European large enterprises, based on the framework defined by the European Commission, with special regard to separating direct and indirect effects.

- *Objective C3:* Measuring the impact of the technology on logistical processes in a large enterprise environment.

Empirical investigation of whether the technology (e.g., distributed ledger and transparency) genuinely reduces tracking time and administrative burdens in the supply chain, thus verifying the operational efficiency of the technology.

- *Objective C4:* Exploring the relationship between transactional security and the technology.

The literature often treats the security of blockchain as an axiom. My aim is to statistically prove that this security is not an automatic consequence, but a function of the presence and quality of data integrity.

- *Objective C5:* Examining the correlations between customer relationship management (CRM) and the technology.

My goal is to explore how the technological background can be transformed into a measurable customer experience, and what role consumer trust plays in this as a mediating variable.

- *Objective C6:* Investigating the moderator role of corporate digitalization in the utilization of the technology.

Proving that higher digital maturity amplifies the positive effects of blockchain, while low maturity hinders a return on investment.

At the third level, I research the causes of the technological lag of domestic SMEs, combining organizational (TOE) and individual (TRI, TAM, UTAUT) decision-making models.

- *Objective C7:* Identifying the main obstacles hindering technological adaptation in the domestic SME sector, with special regard to the role of technological readiness and perceived usefulness.

Clarifying whether financial constraints or cognitive barriers (lack of knowledge, distrust) dominate the domestic market.

- *Objective C8:* Separating the internal and external drivers of adaptation intention.

Examining whether companies open up to the technology due to internal innovation compulsion (proactive strategy) or pressure from the market environment, partners, competitors, (reactive, forced strategy).

1.4. Research hypotheses and their theoretical deduction

To answer the formulated objectives, based on international literature antecedents and identified research gaps, I established the following eight hypotheses:

H1: Blockchain technology does not behave as a disruptive cost-reducing tool at the corporate level, but as a foundational technology, the economic benefits (cost efficiency) of which are only realized in the presence of data integrity and organizational trust as mediating variables.

According to IANSITI & LAKHANI (2017), BISWAS & GUPTA (2019), and GÜRPINAR ET AL. (2025), the introduction of foundational technologies initially involves high costs and the restructuring of organizational structures. A condition for value creation is the establishment of new institutional trust structures, which explains the productivity paradox.

H2: In the domestic blockchain market, economic actors such as agriculture, logistics, and retail apply blockchain to the same extent as IT and financial companies, and research institutions.

According to international literature, the integration of technology into business processes to ensure traceability is growing exponentially in agriculture, logistics, and commerce (KAMILARIS ET AL., 2019; WONG ET AL., 2020).

H3: The application of blockchain technology exerts a direct and significant positive effect on the logistical efficiency of large enterprises.

The research of WANG & YANG (2022) and SABERI ET AL. (2019) empirically demonstrated that in supply chains, real-time data sharing based on a distributed ledger instantly reduces information asymmetry. In logistics, unlike administrative functions, the impact of the technology prevails immediately and directly.

H4: The impact of blockchain technology on transactional security is not direct, but prevails exclusively through increased data integrity.

ALI ET AL. (2024) and LIAO ET AL. (2025) point out the GIGO principle: blockchain is essentially a carrier technology. The sense of security in transactions stems from the fact that the physical and digital connection of the data (data integrity) is authenticated. If this is compromised, the presence of blockchain does not enhance security.

H5: There is no direct relationship between technological adaptation and customer relationship performance; the positive effect is entirely mediated by increased consumer trust.

Based on the results of ABUGHAZALEH & ABDELRAHIM (2021), the end-user is not interested in the underlying technical architecture. The improvement in CRM performance depends solely on whether the company can successfully convert the transparency provided by blockchain into consumer trust.

H6: The existing digital maturity of the organization has a significant moderator effect: at a higher maturity level, the positive force exerted by the technology on logistical efficiency is amplified.

According to JACKSON & ALLEN (2024) and AN ET AL. (2024), technological competence is critical when adopting complex systems. Low digital maturity causes disruption ("technological shock"), while it creates synergy and a quantum leap in efficiency for mature companies already using cloud-based or ERP systems.

H7: In the domestic SME sector, the primary barrier to blockchain adaptation is not technological complexity or cost, but the lack of technological awareness and the low level of perceived business usefulness.

The Technology Readiness Index (TRI) and TAM models (PARASURAMAN, 2000; LIN ET AL., 2007) highlight that cognitive distance and the lack of understanding of abstract advantages are much stronger barriers in the early adaptation phase than pure financial investment needs.

H8: The intention of SMEs to use blockchain is more strongly influenced by external environmental pressure (expectations of competitors, partners) than by internal organizational innovation willingness.

Based on DIMAGGIO & POWELL's (1983) institutional theory and OLIVEIRA ET AL.'s (2014) TOE framework, SMEs are subordinate actors in supply chains and follow a reactive strategy. Their adaptation is triggered by the coercive isomorphism (dictate) of dominant partners, not by internal proactivity.

The relationship between the objectives and hypotheses of the dissertation is summarized in Table 1.

Table 1: Summary of research objectives, hypotheses, and methods

Objective (C)	Research Hypothesis (H)	Investigated Variables / Focus Area	Applied Methodology
C1 – Cost-benefit framework	H1 – Foundational technology nature	Cost structure, Return on Investment, Value creation	PRISMA, Secondary analysis
C2 – Domestic ecosystem map	H2 – Domestic adopters	Presence of blockchain tech., weight of sectors	OSINT and Cluster analysis

Objective (C)	Research Hypothesis (H)	Investigated Variables / Focus Area	Applied Methodology
C3 – Logistics impact measurement	H3 – Direct positive impact	Logistics efficiency, Traceability	PLS-SEM
C4 – Security correlations	H4 – Mediation via data integrity	Transactional security, Data integrity	PLS-SEM
C5 – Customer relations	H5 – Mediation via trust	CRM performance, Consumer trust	PLS-SEM
C6 – Role of digital maturity	H6 – Moderator effect	Digital maturity, Implementation success	PLS-SEM
C7 – SME adaptation barriers	H7 – Awareness vs. Cost	Awareness, Perceived usefulness	Qualitative in-depth interviews and content analysis
C8 – Intention of adaptation	H8 – Dominance of external pressure	Intention to use, Environmental pressure	Qualitative in-depth interviews and content analysis

Source: Own compilation

2. DATABASE AND DESCRIPTION OF THE METHODS USED

Due to the complexity of the formulated interdisciplinary research objectives and the socio-technical nature of the corporate application of blockchain technology, the dissertation employs a mixed research methodology. Within this framework, the primary theoretical foundation and empirical data collection were implemented in complementary, structured phases. The research rests on four main methodological pillars (Figure 1): (1) systematic literature review based on the PRISMA protocol, (2) open-source intelligence (OSINT) for mapping the domestic ecosystem, (3) qualitative in-depth interview procedure to understand the cognitive barriers of the SME sector, and (4) quantitative, PLS-SEM based structural equation modeling for the empirical testing of large enterprise value creation.

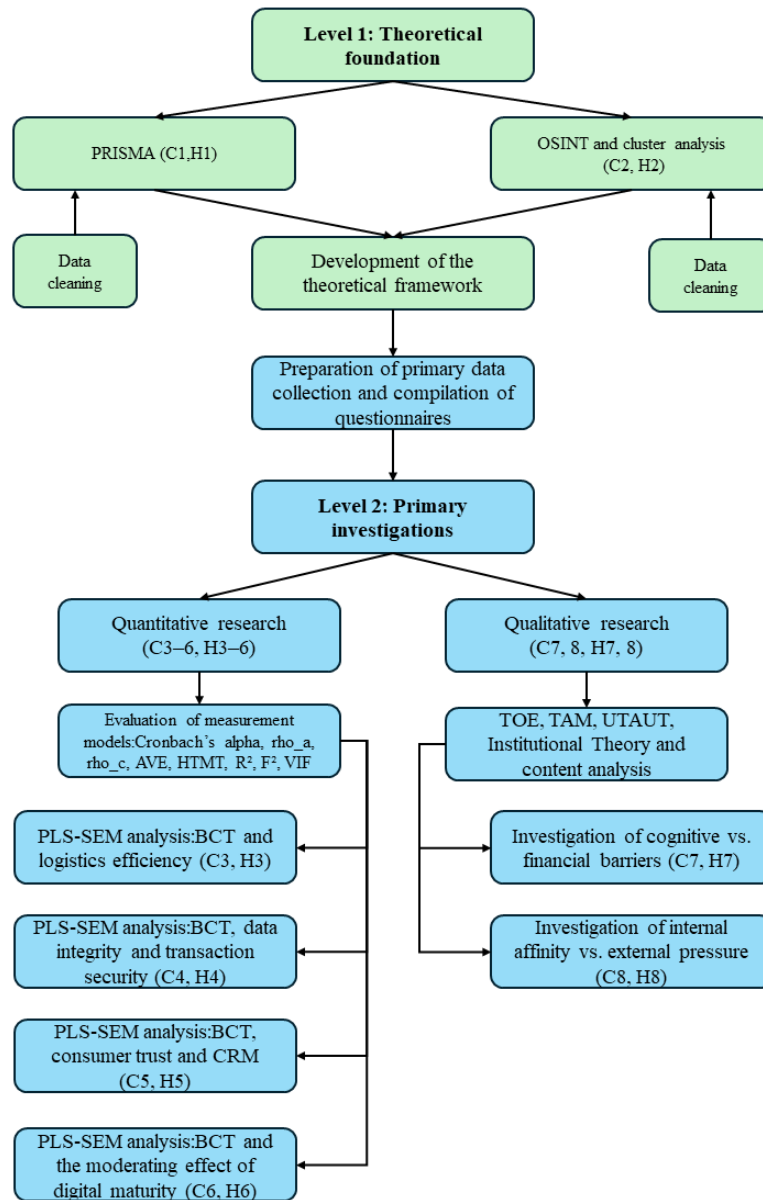


Figure 1: The research model

Source: Own compilation

2.1. Systematic literature review

The investigation of the corporate adaptation of blockchain technology is a highly fragmented area; thus, to ensure maximum transparency, reproducibility, and scientific reliability, the compilation of the literature base was conducted following the strict guidelines of the updated 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (PAGE ET AL., 2021). The advantage of the systematic procedure over traditional narrative summaries is that, by minimizing biases, it allows for the objective mapping of the boundaries of the current body of knowledge (TRANFIELD ET AL., 2003; SNYDER, 2019).

2.1.1. Data collection and search strategy

To locate relevant scientific publications, I utilized two globally recognized interdisciplinary databases that guarantee high scientific quality.

Table 2: Databases and applied search parameter

Parameter	Scopus search protocol	Web of Science search protocol
Search field	TITLE-ABS-KEY	Topic
Search string	("blockchain" OR "distributed ledger technology" OR "DLT" OR "smart contract*") AND ("adoption" OR "implementation" OR "business value" OR "supply chain" OR "SME" OR "small and medium enterprise*" OR "cost-benefit" OR "efficiency") AND ("TOE" OR "technology-organization-environment" OR "TAM" OR "technology acceptance model" OR "UTAUT" OR "resource-based view" OR "RBV" OR "trust" OR "barrier*")	("blockchain" OR "distributed ledger technology" OR "DLT" OR "smart contract*") AND ("adoption" OR "implementation" OR "business value" OR "supply chain" OR "SME" OR "small and medium enterprise*" OR "cost-benefit" OR "efficiency") AND ("TOE" OR "technology-organization-environment" OR "TAM" OR "technology acceptance model" OR "UTAUT" OR "resource-based view" OR "RBV" OR "trust" OR "barrier*")
Time interval	2015 – 2026	2015 – 2026
Document type	Article (ar), Review (re)	Article, Review Article
Language	English	English

Parameter	Scopus search protocol	Web of Science search protocol
Fine-tuning	Exclusion of purely technological (cryptographic) terms indirectly via management keywords	Filtering on the "Refine Results" panel to ensure management and economics focus
Access	All Open Access, Final Publication Stage	All Open Access

Source: Own compilation

The searches were conducted in the Scopus and Web of Science (WoS) Core Collection databases. The creation of the search string was based on a three-dimensional (Technological, Business/Output, and Theoretical dimensions) search matrix built on Boolean algebra (AND, OR). The theoretical dimension included the dominant technology acceptance models (TOE, TAM, UTAUT), as well as the Resource-Based View (RBV) of the firm. The searches were restricted to the "TITLE-ABS-KEY" (Scopus) and "Topic" (WoS) fields, strictly focusing on the time interval between 2015 and 2026, and targeting English-language, peer-reviewed journal articles (Article, Review Article).

2.1.2. The screening, inclusion, and quality assessment process

As a result of the iterative (repeated) execution of the search protocol, I recorded 2,142 raw hits from the WoS database and 1,848 from Scopus, totaling 3,990 raw hits. Based on the deductive, multi-stage funnel model, after standardizing the datasets and removing duplicates (1,334 records) as well as out-of-focus elements, 524 unique studies advanced to the primary screening phase.

During the screening, I applied strict Inclusion Criteria (IC) and Exclusion Criteria (EC). Articles focusing purely on IT/cryptographic algorithms without a management aspect (EC1), as well as non-peer-reviewed "gray literature" (EC3), were excluded. After screening based on title, abstract, and keywords, followed by a full-text critical examination of 387 articles, 232 studies were selected for the final analysis. The quality assessment guaranteed that only the results of studies that had undergone a rigorous peer-review process were included in the model creation. The screening of the search results was carried out using a deductive, multi-stage funnel model, the process of which is illustrated in Figure 2.

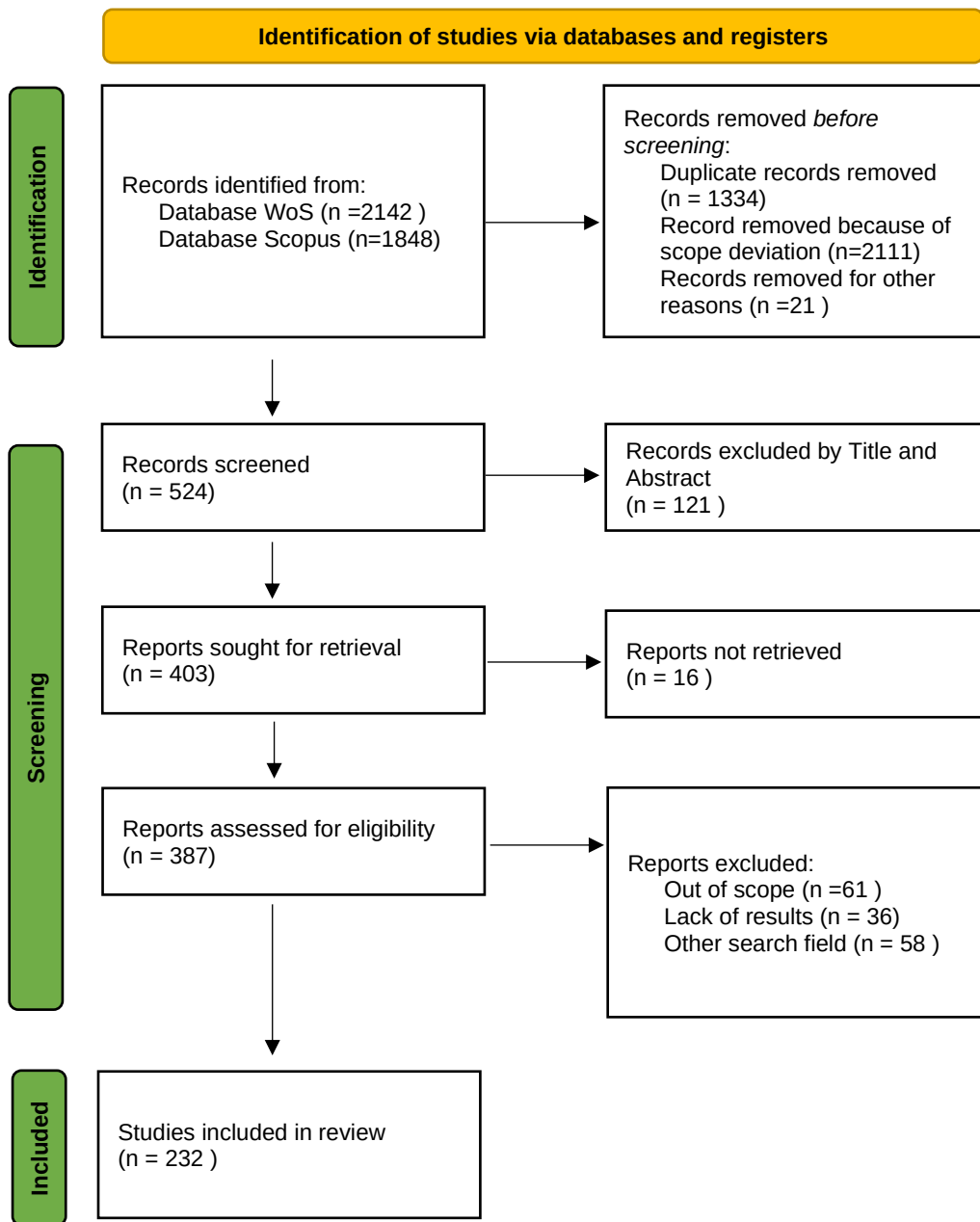


Figure 2: PRISMA flow-chart

Source: Own compilation based on PAGE ET AL. (2021)

2.2. Open Source Intelligence data collection

Revealing the spatial structure and sectoral distribution of the domestic blockchain ecosystem encountered obstacles using traditional methods. Official statistical nomenclatures (e.g., TEÁOR) focus on the final economic product, and thus fail to detect the operational presence of horizontal technologies like blockchain. To overcome this, the dissertation applied an Open Source Intelligence (OSINT) based digital footprint analysis, which is capable of identifying technological depth (LAKOMY, 2024).

2.2.1. Data fusion and triangulation

The data collection took place in an automated, three-step process built on the triangulation of sources (HAYES & CAPP, 2018). The investigation covered three pillars: (1) professional and media discourses, (2) labor market indicators (job advertisements, GitHub repositories), and (3) transparency control of annual financial reports and R&D reports. Data extraction (web-scraping) was performed using the Parsera framework from designated public sources. To process the resulting unstructured volume of data, I applied Natural Language Processing (NLP) procedures, which unbiasedly identified explicit technological references (e.g., Smart Contract, DLT, Tokenization) (PELLET ET AL., 2019; SUN ET AL., 2025). The resulting matches were followed by manual validation against the supplementary appendices of the companies' financial reports, thus creating the validated target database containing 64 relevant domestic entities, from which the functional cluster model was also built.

2.3. Qualitative analysis

The investigation of the causes of the technological gap and the cognitive factors hindering blockchain adaptation among domestic Small and Medium-sized Enterprises (SMEs) was implemented with an exploratory, qualitative research design.

2.3.1. Sampling and data collection tool

During data collection, I followed the principle of purposive, stratified selection. The sample (N=22) was deliberately diversified: it covered five key industries (IT, retail, manufacturing, agriculture, fintech) and five domestic counties (Pest, Hajdú-Bihar, Csongrád-Csanád, Szabolcs-Szatmár-Bereg, Baranya). The inclusion criterion was that the interviewee had to hold a strategic decision-making or operational management position at the given SME.

Table 4: Sampling composition of qualitative interviews

Interview code	Industry / Activity	County	Respondent's position	Company size (employees)
INT-01	IT - Software development	Pest	Managing Director	35
INT-02	Agriculture - Arable farming	Hajdú-Bihar	Head of Family Farm	12
INT-03	Manufacturing - Metal structures	Szabolcs-Szatmár-B.	Production Director	45

Interview code	Industry / Activity	County	Respondent's position	Company size (employees)
INT-04	Retail - Groceries	Csongrád-Csanád	Managing Owner	28
INT-05	IT - Cybersecurity	Baranya	Technical Manager	18
INT-06	Fintech, consulting	Pest	Head of Development	42
INT-07	Retail - Building materials	Szabolcs-Szatmár-B.	Logistics Manager	22
INT-08	Manufacturing - Plastic injection molding	Pest	Production Administrator	55
INT-09	IT - Software testing	Baranya	Engineer	25
INT-10	Agriculture - Crop production	Hajdú-Bihar	Shift Supervisor / Chief Mechanic	32
INT-11	IT - Database administration	Csongrád-Csanád	Systems Engineer	26
INT-12	Agriculture - Fruit farming	Szabolcs-Szatmár-B.	Farm Manager	8
INT-13	Retail - E-commerce logistics	Pest	Logistics Team Leader	38
INT-14	Manufacturing - Furniture industry	Csongrád-Csanád	Plant Manager	24
INT-15	Retail - Building engineering	Hajdú-Bihar	Senior Warehouseman	15
INT-16	IT - Web development	Szabolcs-Szatmár-B.	Lead Developer	5
INT-17	Manufacturing - Plastic recycling	Hajdú-Bihar	Engineer	48
INT-18	IT - Compliance / Data protection	Baranya	Legal Advisor	12
INT-19	Retail - Machine parts	Csongrád-Csanád	Warehouse Manager	18
INT-20	IT - Network monitoring	Pest	Junior Analyst	22
INT-21	Manufacturing - Textiles	Baranya	Shift Supervisor	52
INT-22	IT - Business Intelligence	Hajdú-Bihar	Analyst	14

Source: Own compilation

Data collection was conducted in the form of semi-structured in-depth interviews. The theoretical framework of the interview outline was provided by the Technology Acceptance Model (TAM) (DAVIS, 1989), the Unified Theory of Acceptance and Use of Technology (UTAUT) (VENKATESH ET AL., 2003), the TOE framework (TORNATZKY &

FLEISCHER, 1990; OLIVEIRA ET AL., 2014), and the theses of Institutional Theory regarding coercive isomorphism (DIMAGGIO & POWELL, 1983). One of the main unique elements of the methodology was the application of so-called structured anchor questions (1-7 Likert scale) alongside narrative responses. Furthermore, to isolate cognitive barriers and pure investment costs from each other, I used the method of "negative proof" (LIN ET AL., 2007). During this, via a thought experiment (assuming 100% grant funding and free integration), I assessed whether adaptation resistance persists even after financing constraints are eliminated. The evaluation of the recorded interviews was carried out using qualitative content analysis based on deductive category formation (MAYRING, 2014) and coding frequency analysis.

2.4. Quantitative analysis

For the empirical investigation of the large enterprise value creation mechanisms of blockchain technology, as well as the effects of mediating and moderating variables, I applied a deductive, quantitative research design and partial least squares structural equation modeling (PLS-SEM).

2.4.1. Target population, data collection, and sample size

Primary data collection was implemented in the form of a structured, cross-sectional online questionnaire survey. The target population consisted of European-based large enterprises operating complex supply chains that demonstrably apply blockchain technology in their business processes. Large enterprise status was defined based on the European Commission's recommendation (>250 employees, >€50 million revenue) (EUROPEAN COMMISSION, 2003).

The approach to the 137 relevant companies identified through preliminary industry screening was targeted. Data collection took place between March 2025 and January 2026, resulting in 54 valid, fully completed responses (N = 54). In the context of the PLS-SEM methodology, this relatively small sample size also ensures high statistical power (HAIR ET AL., 2019). This is supported by BARCLAY ET AL.'s (1995) generally accepted "rule of 10", according to which the minimum sample size must reach ten times the number of predictors associated with the most complex regression (in the model, this number is 3, so the statistical minimum is 30 individuals, which the sample exceeds).

Table 3: Composition of the sample

Demographic characteristic	Category	Frequency (N)
Industry	Transportation, logistics, and supply chain	14
	Manufacturing and industrial production	10
	Financial services, banking, and insurance	10
	Technology, telecommunications, and media	6
	Healthcare and life sciences	5
	Food and beverage manufacturing	5
	Retail and wholesale trade, consumer goods	4
Level of blockchain adaptation	Early phase (pilot projects)	28
	Partial adaptation in specific areas	20
	Actively expanding blockchain-based initiatives	2
	Fully integrated into corporate operations	4
Total		54

Source: Own compilation

2.4.2. Measurement instruments and operationalization

The indicators of the eight latent variables (constructs) included in the research, such as Technology impact, Data integrity, Transactional security, Logistics efficiency, Consumer trust, CRM performance, and Digital maturity, were developed deductively based on the international literature validated within the PRISMA framework. I measured the variables

on a symmetrical, 7-point Likert scale, which the algorithm treated as a metric variable (HAIR ET AL., 2022).

2.4.3. Data analysis strategy: Evaluation of the PLS-SEM model

Hypothesis testing was performed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) methodology with SmartPLS 4 software. This algorithm is specifically optimized to maximize the predictive power of complex models (HAIR ET AL., 2022). The evaluation strictly followed the two-level procedure of methodological protocols.

1. Evaluation of the outer measurement models

In the first step, I examined the psychometric reliability of the measurement models. The outer loadings for all indicators remaining in the model exceeded the critical threshold of 0.708. Internal consistency was measured based on Cronbach's alpha, composite reliability (ρ_C), and the Dijkstra-Henseler robust exact indicator (ρ_A). All values ranged within the required optimal band between 0.70 and 0.95 (DIJKSTRA & HENSELER, 2015). Average Variance Extracted (AVE) served to verify convergent validity, where each construct significantly exceeded the minimum expected value of 0.50 (FORNELL & LARCKER, 1981). To prove discriminant validity, I used the HTMT (Heterotrait-Monotrait ratio) matrix, accepted as the newest standard. The results confirmed that the HTMT values nowhere exceeded the conservative limit of 0.85 (HENSELER ET AL., 2015; LIM, 2024), thus the model's constructs were also statistically well separated from each other.

2. Evaluation of the inner structural model

Following the validation of the measurement models, I evaluated the inner structural paths. To exclude the distorting effect of multicollinearity among predictors, I examined the VIF (Variance Inflation Factor) values. Since all of the obtained VIF values (1.000 - 2.118) strictly remained below the threshold of 3.0 prescribed by HAIR ET AL. (2022), the problem of multicollinearity could be excluded (DIAMANTOPOULOS & SIGUAW, 2006).

The predictive accuracy of the model was measured with the coefficient of determination (R^2) and the complexity-adjusted R^2 (R^2_{adj}) value. For the main target variables, such as CRM performance ($R^2 = 0.559$) and Consumer trust ($R^2 = 0.542$), the model showed strong

explanatory power, while for logistics efficiency it showed moderate explanatory power. Predictive relevance was validated by the Stone-Geisser Q² indicator calculated via the Blindfolding procedure, where the value of every endogenous variable significantly exceeded zero. The SRMR indicator measuring the discrepancy between the empirical data and the theoretical model was 0.064, which is well below the critical limit of 0.080 defined by Hu & Bentler (1999), proving the model's excellent fit.

The final hypothesis testing (determining the p- and t-values of the path coefficients, indirect mediation effects, and the moderator effect) was performed in the SmartPLS software using a 5,000-subsample non-parametric Bootstrapping procedure (ZHAO ET AL., 2010). To ensure methodological robustness due to the relatively small sample size, the results of the PLS-SEM and Bootstrapping procedures were also validated using a classical, regression-based triangulation through Baron and Kenny's (1986) four-step framework. Beyond the PLS-SEM algorithm, this analysis reliably and statistically supported the existence of the indirect-only mediation effects regarding data integrity and consumer trust (H4 and H5). Furthermore, alongside statistical significance, I also analyzed the effect sizes (f^2) measuring practical relevance (COHEN, 1988), which proved the strong, large effect sizes of indirect paths, such as the relationship between trust and CRM performance.

3. MAIN FINDINGS OF THE DISSERTATION

3.1. Testing the research hypotheses and major findings of the empirical investigations

H1: Blockchain technology does not behave as a disruptive cost-reducing tool at the corporate level, but as a foundational technology, the economic benefits (cost efficiency) of which are only realized in the presence of data integrity and organizational trust as mediating variables.

The first hypothesis (H1) assumed that at the corporate level, blockchain technology does not behave as a disruptive cost-reducing tool, but as a "foundational technology," the economic benefits (cost-efficiency) of which are only realized in the presence of data integrity and organizational trust as mediating variables.

The results of the systematic literature review (232 peer-reviewed journal articles examined based on the PRISMA protocol) clearly refuted the early views based on technological determinism, which envisioned radical and immediate intermediary cost reductions (SWAN, 2015). The research confirmed the pioneering theory of (IANSITI & LAKHANI, 2017), according to which blockchain is an infrastructural, foundational technology similar to TCP/IP. In the early phase of implementation, companies often face the "cost-benefit paradox" (KOUHIZADEH ET AL., 2021; GÜRPINAR ET AL., 2025; NAGY, 2025): the integration of the technology, the transformation of the IT architecture, and the provision of appropriate expertise involve significant expenses, while profitability often falls short of expectations.

The synthesis proved along the lines of Transaction Cost Economics (TCE) and the Resource-Based View (RBV) that the reason for the lack of direct return is that blockchain in itself, as pure software code, does not create a competitive advantage. The innovative economic impact (the radical reduction of information asymmetry, ex-post opportunism, and auditing costs) is created exclusively through a mediated mechanism, where cryptographic protocols generate data integrity, and this in turn generates system-level trust among partners (BISWAS & GUPTA, 2019; KLÖCKNER ET AL., 2023). **Based on this, the H1 hypothesis was clearly confirmed and accepted.**

H2: In the domestic blockchain market, economic actors such as agriculture, logistics, and retail apply blockchain to the same extent as IT and financial companies, and research institutions.

The assumption of the second hypothesis (H2) was that in the domestic market, actors in the real economy (agriculture, logistics, retail) apply the technology to the same extent as IT and financial (FinTech) companies.

The database, created by fusing Open Source Intelligence (OSINT) and NLP (Natural Language Processing) to overcome the limitations of traditional statistical (TEÁOR) classifications, identified 64 relevant domestic entities (LAKOMY, 2024). The proprietary, functional cluster model built from the data showed an industry asymmetry: the market is absolutely dominated by Information Technology (20 entities), FinTech (13 entities), and Research and Development (9 entities). In contrast, the actors of classical supply chains, retail and logistics, were represented by only 3 companies. This empirical finding highlighted the macroeconomic anomaly that the domestic market is currently strictly supply-driven. On the developer (supply) side, competencies are present even at an international level, but on the "strategic adopter" (demand) side, the integration of the technology is marginal. **Since the assumed sectoral balance was not met, the H2 hypothesis was rejected.**

H3-H6: The structural equation model of large enterprise value creation and the testing of hypotheses H3–H6

The objective of the quantitative data collection conducted in the European large enterprise environment (N=54) was to statistically isolate the direct and indirect effects of the technology using PLS-SEM. The final result of the analysis is presented in Figure 3.

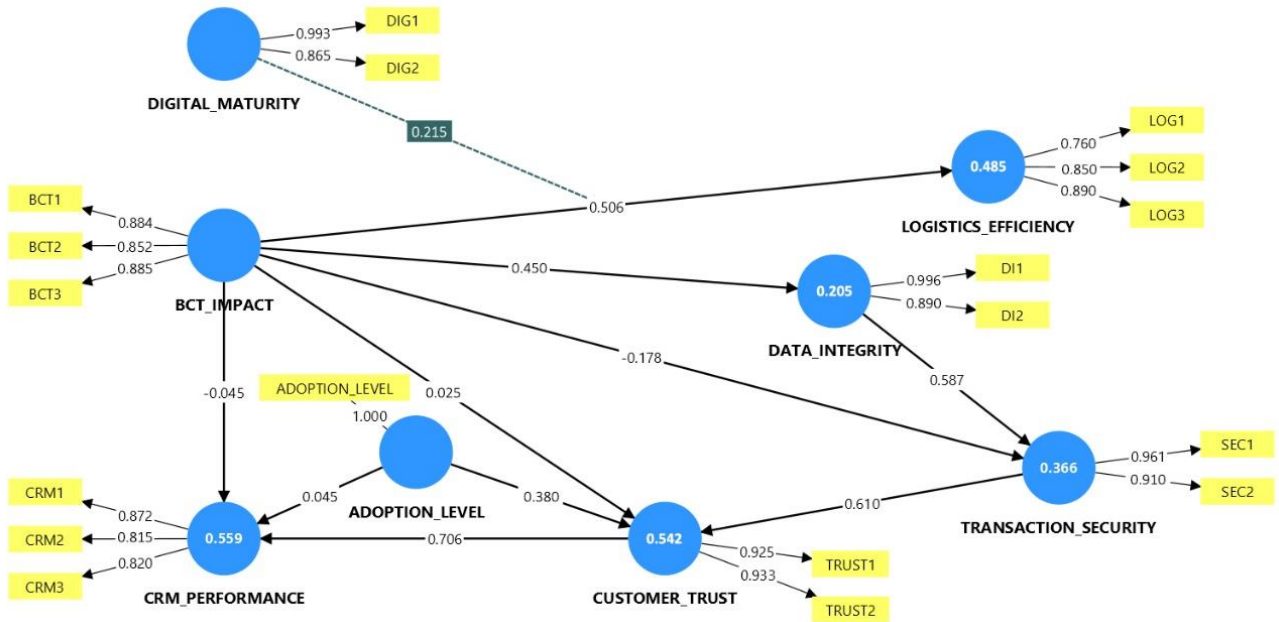


Figure 3: The structural model of PLS-SEM and path coefficients

Source: Own compilation using SmartPLS 4.0 software

The structural model tested using the 5,000-subsample Bootstrapping algorithm had excellent fit indices (SRMR = 0.064) and high predictive power regarding the main target variables (CRM performance: $R^2 = 0.559$; Consumer trust: $R^2 = 0.542$; Logistics efficiency: $R^2 = 0.485$).

H3: The application of blockchain technology exerts a direct and significant positive effect on the logistical efficiency of large enterprises.

The H3 hypothesis focused on whether the application of blockchain technology exerts a direct and significant positive effect on the logistical efficiency (transparency, traceability) of large enterprises. The results of the PLS-SEM model showed an extremely strong, direct, and significant relationship between the two latent variables ($\beta = 0.506$, $t = 5.952$, $p < 0.001$). The results confirm the literature assumptions (WANG & YANG, 2022; SABERI ET AL., 2019) that in the complex, multi-actor networks of supply chains, the operational intervention is immediate. Real-time data sharing, the presence of the shared distributed ledger, and the automation of smart contracts reduce information asymmetry and traceability time to such an extent that no additional mediating variables are needed on this branch of the model to exert a positive effect. **Based on the statistical results, the H3 hypothesis was accepted.**

H4: The impact of blockchain technology on transactional security is not direct, but prevails exclusively through increased data integrity.

The H4 hypothesis assumed a full mediation chain: the impact of blockchain on transactional security is not direct, but prevails exclusively through increased data integrity. The path coefficients of the model proved that the technology significantly increases data integrity ($\beta = 0.450$, $p < 0.001$), which then significantly, with a large effect size ($f^2 = 0.542$), increases transactional security ($\beta = 0.587$, $p = 0.038$). At the same time, the direct relationship between the technology and transactional security was not statistically significant at all ($\beta = 0.025$, $p = 0.781$). This result is a case of "indirect-only mediation" (ZHAO ET AL., 2010), and empirically proves the validity of the highly debated "Oracle problem" and the "Garbage In, Garbage Out" principle in the literature from a management perspective (CALDARELLI ET AL., 2020; ALI ET AL., 2024; LIAO ET AL., 2025). The technology is merely a closed, protected framework: if the input data coming from the physical world (e.g., from an unauthenticated IoT sensor or manual entry) is faulty, the blockchain merely makes the fraud immutable, but does not increase security. **Based on the statistical results, the H4 hypothesis was clearly accepted.**

H5: There is no direct relationship between technological adaptation and customer relationship performance; the positive effect is entirely mediated by increased consumer trust.

The H5 hypothesis also assumed full mediation in the dimension of customer relationship management (CRM) performance: there is no direct relationship between technological adaptation and CRM performance; the positive effect is fully mediated by increased consumer trust. The Bootstrapping procedure confirmed that the level of technological adaptation robustly increases consumer trust ($\beta = 0.380$, $p < 0.001$), which improves CRM performance with a massive effect size ($f^2 = 1.115$) and outstanding significance ($\beta = 0.706$, $p < 0.001$). The direct path between adaptation and CRM proved to be completely irrelevant and non-significant here as well ($\beta = 0.045$, $p = 0.453$). The result fully confirms the paradigm of ABUGHAZALEH & ABDELRAHIM (2021): cryptographic algorithms are invisible to end users. The investment only results in loyalty and increased customer experience if the company successfully converts technological immutability into socially

interpretable transparency and consumer trust. **Based on this, the H5 hypothesis was accepted.**

H6: The existing digital maturity of the organization has a significant moderator effect: at a higher maturity level, the positive force exerted by the technology on logistical efficiency is amplified.

According to the H6 hypothesis, the existing digital maturity of the organization has a significant moderator effect: at a higher maturity level, the positive force exerted by the technology on logistical efficiency is amplified. The PLS-SEM analysis conducted by including the interaction term (Digital maturity $\times$ Blockchain impact) showed a positive and highly significant moderator effect ($\beta = 0.215$, $t = 3.307$, $p = 0.001$). Although the effect size of the interaction ($f^2 = 0.045$) is moderate, this is considered typical in social science research. The empirical result supports the "technological shock vs. synergy" theory of JACKSON & ALLEN (2024): blockchain represents a higher level of digitalization. In the case of an existing, cloud-based and integrated (ERP) architecture, it acts as a catalyst, while with low digital maturity, its introduction leads to a severe implementation shock. **Based on the statistical results, the H6 hypothesis was accepted.**

In sharp contrast to the results of large enterprise value creation models (PLS-SEM), the qualitative research exploring the innovation and adaptation willingness of domestic small and medium-sized enterprises (SMEs) identified fundamental cognitive gaps. The analysis of semi-structured in-depth interviews conducted with 22 domestic company leaders and operational decision-makers took place within the frameworks of the Technology Acceptance Model (TAM), UTAUT, and Institutional Theory, using deductive category formation (MAYRING, 2014).

H7: In the domestic SME sector, the primary barrier to blockchain adaptation is not technological complexity or cost, but the lack of technological awareness and the low level of perceived business usefulness.

The H7 hypothesis focused on the fact that in the domestic SME sector, the primary barrier to blockchain adaptation is not technological complexity or specific financial cost, but the lack of technological awareness and the low level of Perceived Usefulness (PU) (DAVIS, 1989). One of the central methodological elements of the qualitative interviews was the

thought experiment of so-called "negative proof" (LIN ET AL., 2007). During this, respondents had to evaluate a situation in which a grant 100% finances the blockchain investment, and experts perform the integration for free, thereby eliminating financial barriers.

The results refuted the traditional "resource-poor" paradigm: 21 out of 22 company leaders answered with a firm no or strong hesitation, and only a single actor proactively accepted the "free technology". The reasons for rejection deeply validated the hypothesis's assumptions: SME decision-makers make decisions on an extremely pragmatic cost-benefit basis, where abstract concepts such as "system-level trust" or "distributed consensus" cannot be converted into immediate, monetizable profit. In addition, respondents identified hidden barriers such as production downtime due to training, the lack of network partners (critical mass), as well as the irrational fear stemming from immutable transparency and Article 17 of the GDPR (right to erasure), and the risk of revealing trade secrets.

**Table 5: Summary of anchor questions for cognitive and operational barriers
(average values on a 1-7 scale)**

Industry segment	Verification of H7	PEOU
IT sector (N=8)	6.37	4.25
Agriculture (N=4)	7.00	6.50
Retail/Logistics (N=5)	6.40	5.80
Manufacturing / Industrial production (N=4)	6.75	6.00
Fintech (N=1)	6.00	3.00
Overall average	6.50 (High barrier)	5.11 (Medium barrier)

Source: Own compilation

Regarding Perceived Ease of Use (PEOU), significant differences emerged between industries: while understanding the technology did not cause a problem in the IT sector, in traditional manufacturing and agricultural sectors, abstract cryptographic concepts generated strong cognitive resistance and closure. The frequency analysis showed that the lack of visible business benefits (21 mentions) far preceded high costs (15 mentions) in the ranking of rejection reasons. **Based on all this, the H7 hypothesis was clearly and comprehensively confirmed.**

Table 6: Mention frequency table to support the H7 hypothesis (N=22)

Coded adaptation barrier	Number of mentions	Explanation in light of the H7 hypothesis
1. Lack of visible business benefit / ROI	21 / 22	Almost all respondents (except Fintech) identified the lack of immediate, monetary return as the primary barrier. This clearly proves that PU is the most critical factor.
2. High implementation/operational cost	15 / 22	Cost is a significant barrier, but in many cases subordinate to the lack of benefits. Most respondents indicated: if there were clear benefits, the cost would be manageable.
3. Complexity / Lack of adequate IT knowledge	16 / 22	Especially strong in manufacturing, retail, and agriculture.
4. Data security / GDPR and trade secret fears	14 / 22	A special form of cognitive barriers: SMEs fear transparency, competitors, and in the IT sector, the violation of Article 17 of the GDPR (right to erasure).

Source: Own compilation

H8: The intention of SMEs to use blockchain is more strongly influenced by external environmental pressure (expectations of competitors, partners) than by internal organizational innovation willingness.

According to the assumption of the H8 hypothesis, the intention of SMEs to use blockchain is more strongly influenced by external environmental pressure than by internal organizational innovation willingness. This was investigated by integrating Institutional Theory (DIMAGGIO & POWELL, 1983) and the UTAUT model (VENKATESH ET AL., 2003). Based on the interviews, the innovation strategy of Hungarian SMEs in the field of decentralized systems is structurally reactive. In 15 out of 22 cases, respondents gave the maximum value of 7 to the statement that they would never implement the technology on their own, only if they were forced to do so. Internal innovation affinity was almost exclusively identifiable in the case of FinTech and a few specific IT companies, while it remained marginal in traditional sectors. The qualitative data made it clear that the adaptation of the technology can currently be initiated by two external, top-down coercive forces. The first is the dictate of dominant multinational clients at the top of global value chains (e.g., automotive companies, global retail chains): if the client makes blockchain-

based tracking mandatory in the supply chain, SMEs are immediately willing to overcome cognitive and financial barriers in the interest of economic survival and "staying in the game". The second strong driving force is the pressure of regulatory and legislative compliance (e.g., ESG directives, NÉBIH, NAV regulations, EU Digital Product Passport).

Table 7: Evaluation of Institutional Theory and TOE factors (H8 hypothesis)

Industry segment	Coercive pressure	Competitive pressure	Internal affinity
IT sector (N=8)	6.12	4.62	5.50
Agriculture (N=4)	7.00	4.50	1.75
Retail/Logistics (N=5)	7.00	4.80	2.20
Manufacturing / Industrial production (N=4)	7.00	4.25	1.25
Fintech (N=1)	5.00	7.00	7.00
Overall average	6.54 (Very high)	4.68 (Medium)	3.50 (Low)

Source: Own compilation

The application of the UTAUT model highlighted that for domestic SMEs, performance expectancy (PE), effort expectancy (EE), and facilitating conditions (FC) act drastically against adaptation. Infrastructural conditions are lacking in many places (e.g., lack of adequate bandwidth or internal IT staff). The only real and dominant driving force is Social Influence, which in this case means partner pressure stemming from a subordinate market position.

Table 8: Mention frequency table to support the H8 hypothesis (N=22)

Decision-making motivation	Number of mentions	Explanation in light of the H8 hypothesis
External Coercion: Expectations of multinational partners / Clients	19 / 22	The most common answer for the cause of future adaptation.
External Coercion: Legislative / Regulatory requirements (EU, NAV, NÉBIH)	17 / 22	Regulatory coercion is the second strongest theoretical driver that can force the use of blockchain.
Competitive pressure (Mimetic isomorphism)	10 / 22	Imitating competitors is present but only secondary: companies would only follow the competition if it had already demonstrably gained a market share with blockchain.

Decision-making motivation	Number of mentions	Explanation in light of the H8 hypothesis
Internal innovation affinity (Strategic proactivity)	3 / 22	Only Fintech and one or two specific IT companies stated that they would integrate independently to gain a competitive advantage.

Source: Own compilation

The mimetic pressure based on imitating competitors is currently only at a medium level, as in most industries there is no successful domestic precedent that would generate a fear of missing out (FOMO) in others. **Based on the results of the qualitative analysis, the H8 hypothesis was confirmed.**

4. NEW AND NOVEL RESULTS OF THE DISSERTATION

The fundamental objective of my doctoral dissertation was the complex, multidimensional exploration of the corporate value-creating capacity and impact mechanisms of blockchain technology, as well as the adaptation barriers experienced in the domestic economic ecosystem (with special regard to the SME sector). During the research, I consciously strived to go beyond technological determinism and to create a unique analytical framework by integrating management sciences and technology acceptance models. Based on the synthesis of the primary and secondary research phases (PRISMA, OSINT, PLS-SEM, qualitative in-depth interviews), I formulated the following new and novel scientific results:

(1) Novel scientific result: the reinterpretation of the corporate value creation mechanism of blockchain technology based on the PRISMA protocol, refuting early technological determinism.

Justification: In contrast to the approaches previously dominant in the international literature describing the technology as a linear cost-reducing software, through the systematic synthesis of 232 journal articles (C1, H1), I theoretically proved that blockchain behaves as a "foundational technology" in a corporate context. It is a novel result that by integrating the Resource-Based View (RBV) and Transaction Cost Economics (TCE), I confirmed: Blockchain Technology in itself does not create a competitive advantage. Its disruptive economic impact and the resolution of the productivity paradox are created exclusively in a mediated manner, through the transformation of immutability and organizational trust.

(2) New scientific and methodological result: the application of the OSINT-based data fusion technique and the creation of a proprietary functional cluster model of the domestic blockchain ecosystem.

Justification: Given that domestic statistical classification systems (TEÁOR) are inadequate for identifying horizontal, hidden technological infrastructures, I applied an open-source intelligence (OSINT) digital footprint analysis methodology, unique in domestic and international management research (C2, H2). It is a new result that with the help of this data fusion, I revealed the true structure of the domestic market consisting of 64 entities, without

claiming exhaustiveness. The created functional cluster model empirically proved the asymmetry of the domestic ecosystem: the market is supply-driven, where developers dominate, while the presence of economic strategic adopters is marginal.

(3) New scientific result: the empirical separation of the direct and mediated impact mechanisms of blockchain technology in a large enterprises environment, using the PLS-SEM model.

Justification: During the quantitative investigation using structural equation modeling (N=54 European large enterprises), I proved that the technology affects organizational performance through different impact mechanisms. I identified as a new result (H3, C3) that blockchain is capable of exerting a direct, immediate positive effect solely in the area of logistics efficiency. In contrast, I proved the existence of full mediation in the cases of transactional security (H4) and CRM performance (H5). I empirically verified the management-perspective critique of the Oracle problem and the GIGO (Garbage In, Garbage Out) principle: the mere presence of the technology does not increase security and customer experience, these outcomes are realized exclusively in the presence of data integrity and consumer trust as indispensable mediating variables.

(4) Novel scientific result: the empirical proof of the significant moderator effect of the organization's digital maturity on the success of blockchain adaptation.

Justification: Further developing the results of international technology acceptance research (TOE) and testing them specifically on decentralized systems, I proved (H6, C6) that the company's existing technological readiness amplifies the positive force exerted by blockchain technology on logistical efficiency. Its novelty lies in empirically refuting the strategy of the immediate "technological leap" often mistakenly applied in corporate practice. It was proven that blockchain integration alongside low digital maturity causes internal resistance and implementation shock, highlighting that BCT represents a higher level of corporate digitalization, and not its initial step.

(5) New scientific and methodological result: the application of the "negative proof" thought experiment, which revealed that the

adaptation barrier of the domestic SME sector is fundamentally cognitive, and not of financial origin.

Justification: The domestic literature most frequently explains the digitalization lag of SMEs by the lack of resources and high investment costs. During my qualitative in-depth interview research (N=22), by applying an innovative situational model, the assumption of 100% grant-financed, free implementation, I refuted this paradigm (H7, C7). As a new result, I proved that domestic SME decision-makers would reject the implementation even in the case of zero cost of the technology. The real barrier is the lack of abstract technological awareness, the absence of immediate, monetizable perceived usefulness (PU), as well as the irrational fear stemming from immutable transparency (and GDPR compliance), and the secretive business culture.

(6) New scientific result: the extension of the Institutional Theory and the environmental dimension of the TOE model to the domestic SME sector, proving the exclusive motivational role of coercive isomorphism.

Justification: By synthesizing technology acceptance models (TAM, UTAUT) and institutional theory on a domestic sample, I proved (H8, C8) that the blockchain usage intention of small and medium-sized enterprises is almost entirely determined by external environmental pressure, more precisely by coercive institutional isomorphism. The novelty of the result lies in capturing domestic specificities: the software innovation strategy of the domestic SME sector is deeply follower-oriented. The introduction of the technology is not motivated by an internal desire to develop or to overtake competitors, but exclusively by the dictate of dominant multinational partners of global supply chains, and the tightening EU and domestic regulatory (e.g., ESG, NÉBIH) compliance pressure. For domestic SMEs, the adaptation of technology is not a tool for gaining market share, but a mandatory condition for merely "staying in the basket" and surviving in global value chains.

5. THE PRACTICAL APPLICABILITY OF THE RESULTS

The research results of the doctoral dissertation highlight that the successful corporate integration of blockchain technology goes far beyond software procurement and the mere upgrading of IT infrastructure. The correlations revealed during the research, with special regard to the productivity paradox, the mediating role of data integrity, and the cognitive barriers characterizing domestic Small and Medium-sized Enterprises (SMEs), provide direct and pragmatic guidance for the various actors in the domestic economic ecosystem. The practical applicability of the research results can be divided into four main decision-making levels: (1) governmental and institutional level, (2) technological service providers' level, (3) large enterprise integrators' level, and (4) the level of strategic decision-makers in the SME sector.

5.1. Governmental, policy, and institutional level applicability

The "negative proof" method applied during the qualitative research clearly highlighted that in the case of domestic SMEs, the digitalization lag and the lack of blockchain adaptation cannot be handled exclusively with financial tools. Since the rejection of the technology is primarily driven by cognitive barriers and the lack of perceived business usefulness, the transformation of future Industry 4.0 and digitalization grant funding systems is justified. Beyond supporting hardware and software procurement, grants must include educational, strategic consulting, and business process re-engineering components as mandatory elements so that the level of "technological awareness" increases meaningfully.

Another critical institutional task is clarifying the legal framework and regulatory uncertainties. The apparent, irreconcilable contradiction between the immutability of distributed ledgers and European data protection norms (especially the "right to erasure" under Article 17 of the GDPR) represents a serious deterrent among corporate decision-makers (DEHGHANI ET AL., 2022; KAFEEL ET AL., 2023). To resolve this, legislators and competent supervisory authorities (e.g., NAIH, NÉBIH) must issue clear, practical stances and guidelines on how these systems can be operated safely without violating current trade secret and data protection norms.

5.2. Practical guidance for technological service providers and software developers

The open-source intelligence (OSINT) analysis showed that the Hungarian blockchain ecosystem is currently strongly supply-driven, and the proportion of "strategic adopters" is marginal. For the high-level domestic developer capacity to be paired with real market demand, IT providers need a paradigm shift in product development. For companies, technological complexity, the time spent on training, and the effort associated with operation are currently too high barriers. Developers should shift from communicating cryptographic details (hash functions, consensus protocols) towards selling BaaS (Blockchain-as-a-Service) solutions that are clean, solve business problems, and can be easily integrated into companies' existing cloud-based or ERP systems (e.g., SAP).

The visual and quantifiable demonstration of the return on investment (ROI) is essential. Providers must demonstrate through concrete case studies how smart contracts can replace manual invoice reconciliations, and how they reduce tracking processes from days to seconds, thereby generating immediate administrative savings that can be expressed monetarily.

5.3. The role of large enterprises and integrators of global supply chains

The quantitative PLS-SEM investigation empirically proved that blockchain does not increase transactional security by itself, but only through the mediation of guaranteed data integrity. This finding has direct practical relevance for large enterprise implementing the systems in managing the "Oracle problem" and the GIGO (Garbage In, Garbage Out) principle (CALDARELLI ET AL., 2020; ALI ET AL., 2024; LIAO ET AL., 2025). Large enterprise investments can only be successful if the blockchain integration is strictly linked with automated Industry 4.0 data collection devices (e.g., IoT sensors), thereby minimizing manipulation stemming from human, manual data entry at the entry point.

In addition, dominant buyers must recognize that the mere technological coercion of the supply chain (coercive isomorphism) can lead to implementation shock among SMEs. Instead of administrative dictates, proactive supplier mentoring, sharing of training costs, and the development of joint technological interfaces are needed to preserve the stability of the entire network.

5.4. Strategic guidance for decision-makers in the domestic SME sector

The results of the qualitative research point out that the innovation strategy of domestic SMEs is deeply reactive and follower-oriented. However, decision-makers inevitably need a proactive strategic mindset shift, recognizing that in global supply chains, the cryptographic verification of sustainability, the circular economy, ethical sourcing, and carbon footprint will soon be a condition for mere economic survival and market access. Anticipating European Union directives (e.g., Digital Product Passport, ESG directives) and domestic regulatory requirements (NÉBIH, NAV), companies must begin preparing their internal processes for structured data provision.

As a preliminary step, SMEs must first establish the foundations of their digital maturity. The research empirically proved that blockchain represents a higher level of corporate digitalization, not its initial step. Before joining decentralized networks, consolidating internal IT systems, and establishing appropriate base databases and strict data governance rules are an unavoidable prerequisite. Built on an outdated IT infrastructure, blockchain technology will not result in efficiency, but in operational disruptions, internal resistance, and significant cost increases (productivity paradox).

The findings of the research provide a clear, evidence-based framework for domestic companies so that they apply blockchain technology not as an incomprehensible IT burden, but as an unavoidable strategic tool for inter-organizational trust-building and transparent, long-term sustainable economic cooperation.

6. PUBLICATIONS ON THE TOPIC OF THE DISSERTATION

1. **Nagy, P.** (2023). Blokkláncok szerepe az üzleti életben. *Jelenkori Társadalmi és Gazdasági Folyamatok*, 18(Különszám), 345–351. <https://doi.org/10.14232/jtgf.2023.kulonszam.345-351>
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Registry number: DEENK/468/2026.PL
Subject: PhD Publication List

Candidate: Péter Nagy
Doctoral School: Doctoral School of Management and Business
MTMT ID: 10086200

List of publications related to the dissertation

Articles, studies (8)

1. **Nagy, P.:** Decoding the blockchain productivity paradox in smes: a qualitative investigation of cognitive barriers and institutional pressures.
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The Candidate's publication data submitted to the Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.



30 June, 2026