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RESHAPING THE EUROPEAN BANKING LANDSCAPE THROUGH FINTECH AND TECHNOLOGICAL INNOVATION

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ПЕРЕФОРМАТУВАННЯ ЄВРОПЕЙСЬКОГО БАНКІВСЬКОГО ЛАНДШАФТУ НА ОСНОВІ ФІНТЕХУ ТА ТЕХНОЛОГІЧНИХ ІННОВАЦІЙ

The article explores the transformative impact of financial technology (fintech) on the European banking landscape, focusing on the interplay between research and development (R&D) expenditure and fintech growth. It aims to address how innovation ecosystems and strategic investments drive fintech proliferation, posing challenges to traditional financial systems while offering unprecedented opportunities for efficiency and economic growth.

The research employs comparative analysis and Spearman correlation to examine the relationship between fintech density and R&D expenditure across European countries and the United States. Key performance indicators, including

fintech density, funding, workforce integration, and unicorn prevalence, are evaluated to identify regional strengths and challenges.

Top-performing nations, such as the United Kingdom, Sweden, and Malta, benefit from robust R&D ecosystems, skilled workforces, and strategic investments. Smaller economies like Estonia and Luxembourg demonstrate how targeted niche strategies can yield high-impact outcomes. Spearman correlation analysis reveals a weak, statistically non-significant association between R&D spending and fintech density, indicating that other factors, such as policy frameworks and venture capital ecosystems, significantly influence fintech growth.

The findings offer actionable insights for policymakers and industry leaders, emphasizing the need for targeted investments, workforce development, and supportive regulatory frameworks to foster fintech growth and competitiveness.

This article contributes to the literature by highlighting the nuanced relationship between R&D expenditure and fintech density, emphasizing the importance of diverse innovation strategies and offering a roadmap for enhancing the European banking landscape through fintech and technological innovation.

The study is limited by the cross-sectional nature of the data and the exclusion of variables such as digital literacy and regulatory environments. Future research should incorporate longitudinal data and broader metrics to provide a deeper understanding of fintech proliferation and its determinants.

Стаття досліджує трансформаційний вплив фінансових технологій (фінтех) на європейський банківський ландшафт, зосереджуючись на взаємозв'язку між витратами на науково-дослідні та дослідно-конструкторські роботи (НДДКР) і зростанням фінтеху. Мета полягає в тому, щоб визначити, як інноваційні екосистеми та стратегічні інвестиції стимулюють розвиток фінтеху, створюючи виклики для традиційних фінансових систем, але водночас відкриваючи безпрецедентні можливості для підвищення ефективності та економічного зростання.

У дослідженні використано порівняльний аналіз і кореляцію Спірмена для вивчення взаємозв'язку між щільністю фінтех-компаній і витратами на НДДКР у європейських країнах і США. Ключові показники ефективності,

такі як щільність фінтеху, фінансування, інтеграція робочої сили та поширення «єдинорогів», оцінюються для визначення регіональних сильних сторін і викликів.

Країни-лідери, серед яких Об'єднане Королівство Великої Британії та Північної Ірландії, Швеція та Мальта, отримують переваги завдяки розвиненим екосистемам, НДДКР, висококваліфікованій робочій силі та стратегічним інвестиціям. Менші економіки, Естонія та Люксембург, демонструють, як цільові ніші можуть давати значні результати. Аналіз кореляції Спірмена виявляє слабкий, статистично незначущий зв'язок між витратами на НДДКР і щільністю фінтеху, що свідчить про те, що інші чинники, такі як нормативно-правова база та екосистеми венчурного капіталу, мають істотний вплив на розвиток фінтеху.

Результати дослідження пропонують практичні висновки для політиків та лідерів індустрії, підкреслюючи важливість цільових інвестицій, розвитку робочої сили та регуляторних рамок підтримки для стимулювання зростання фінтеху та підвищення конкурентоспроможності.

Наукове значення статті полягає у висвітленні взаємозв'язку між витратами на НДДКР і щільністю фінтеху з акцентом на необхідності розробки інноваційних стратегій та формуванні алгоритму вдосконалення європейського банківського ландшафту через фінтех та технологічні інновації.

Дослідження обмежене перехресним характером даних і виключенням з аналізу таких змінних, як цифрова грамотність і нормативно-правове регулювання. Майбутні дослідження повинні враховувати довгострокові дані та розширений перелік показників для виявлення особливостей фінтеху та його детермінант.

Keywords: digital transformation, EU banking, financial system architecture, Fintech, modernization.

Ключові слова: цифрова трансформація, банківська система ЄС, архітектура фінансової системи, фінтех, модернізація.

General statement of the problem and its connection with important scientific or practical tasks. The rapid evolution of financial technology (fintech) has fundamentally transformed the global banking landscape, posing challenges to traditional financial systems while unlocking unprecedented opportunities for innovation, efficiency, and growth. This technological shift has disrupted long-established banking models, introducing agile, customer-focused solutions that cater to the demands of the digital economy. Across European countries, the fintech landscape is marked by significant diversity, shaped by a complex interplay of factors, including research and development (R&D) expenditure, workforce specialization, regulatory environments, and cultural attitudes toward innovation.

Analysis of recent studies and publications. The literature on fintech and technological innovation offers a robust exploration of how these advancements are transforming financial services globally. For example, Vakkapatla highlights the revolutionary impact of fintech through advanced technologies like blockchain, AI, and digital wallets, emphasizing enhanced efficiency, security, and accessibility. The work underscores how these innovations improve customer experience, reduce costs, and support sustainability. It also explores fintech's role in fostering global innovation, reshaping payments, and addressing challenges such as data security and regulatory compliance [1, p. 2059]. Although the study covers significant ground, it overlooks specific challenges and innovations relevant to European banking. The analysis misses the nuances of how banks in the region adapt to fintech under localized policies and diverse cultural contexts.

Sanyaolu, Adeleke, Azubuko, and Osundare examine fintech's role in democratizing financial services, enhancing inclusion, and improving operational efficiency. The text discusses automation and personalized interactions as critical benefits, while highlighting the balancing act required to align innovation with regulatory frameworks [2, p. 69-70]. Despite these strengths, the study does not delve into specific European regulations, such as PSD2 and GDPR, which play an essential role in shaping the region's fintech landscape. Furthermore, it fails to

account for cultural and economic variations that influence fintech adoption across the European Union.

Nwoke provides insights into the role of digital innovations like AI and blockchain in improving financial inclusion and operational efficiency. The research emphasizes how digital platforms expand access for underserved populations, fostering economic growth and competitiveness [3, p. 19-20]. That said, the analysis does not explore the increasing relevance of green fintech solutions that align with EU sustainability goals. Additionally, it neglects consumer protection standards, a vital aspect of the European banking framework.

Garškaitė-Milvydienė and Tvaronavičienė analyze the impact of financial technology on banking performance across EU countries. Their use of CRITIC and EDAS methods reveals how larger nations reap more significant benefits from fintech, while smaller countries show stronger correlations between technology and performance [4]. The study primarily focuses on traditional technologies like ATMs and internet banking, giving little attention to innovative trends like open banking or decentralized finance. Moreover, it lacks actionable strategies for banks to leverage these technologies to remain competitive within Europe's rapidly evolving banking landscape.

Tanvir and Manan explore digitalization's role in accessing financial resources, focusing on crowdfunding, ICOs, and fintech lending. The research identifies regulatory concerns and the complementarity of fintech and traditional banking in supporting startups and SMEs [5, p. 8]. While the study offers valuable insights, it does not highlight contributions from key European fintech hubs such as London, Berlin, or Amsterdam. Additionally, the text misses the opportunity to explore how regional investor behaviors and risk appetites influence the adoption of fintech-driven solutions.

Varalakshmi and Katta emphasize the transformative impact of financial innovation on banking, with advancements like mobile banking and digital wallets enhancing operational effectiveness and customer satisfaction [6, p. 1690]. While the study provides a broad overview of fintech's potential, it offers little discussion

on the unique implications for European banks. For example, the text does not address the influence of PSD2 on open banking or the significance of regulatory sandboxes in fostering innovation in Europe.

Kapoor, Soni, and Guruprasad discuss fintech's disruptive potential and the collaborative opportunities it offers traditional banks. They use comparative analysis and case studies to examine banks' adaptation strategies and highlight the importance of regulatory frameworks in fostering innovation [7, p. 2348]. Nevertheless, the research leaves out critical Europe-specific challenges such as cross-border banking and payment integration within the single market. It also does not address variations in digital literacy and trust levels across the continent, which significantly influence fintech adoption.

Iyelolu and Paul analyze fintech's disruption of traditional banking, focusing on the need for collaboration between banks and fintech startups. They stress customer-centric innovation and long-term sustainability in the digital era [8, p. 61]. Although their findings are informative, the strategies suggested are overly broad and fail to address specific issues faced by European banks, such as the adaptation to digital-only fintech models and navigating complex regulatory environments.

Muslimin, Suryathi, Kasiani, Felani, and Judijanto examine how fintech transforms financial services through innovations like AI and blockchain. Using case studies, they highlight fintech's role in fostering service transformation and inclusion [9, p. 311]. While the study provides valuable global insights, it does not reflect on the role of Europe's cultural diversity and consumer preferences in shaping fintech adoption. Moreover, the lack of focus on sustainable finance – a critical priority in the EU – detracts from its relevance to the region.

Faour and Al-Sowaidi explore fintech's convergence with traditional banking, emphasizing collaboration through open banking initiatives and EU regulatory frameworks like the European Data Strategy [10, p. 170-171]. Although the emphasis on partnerships is noteworthy, the text underrepresents the competitive dynamics between banks and fintech firms, which are pivotal in

Europe. Furthermore, the study does not sufficiently address the challenges posed by Europe's fragmented financial markets or the role of fintech in facilitating cross-border operations.

Kamuangu highlights advancements in AI and blockchain, emphasizing collaboration for ethical and transparent fintech adoption. The research outlines challenges like data privacy and regulation [11, p. 1674]. The analysis, however, lacks depth in addressing how these issues specifically manifest in Europe, where privacy regulations such as GDPR are particularly stringent. Additionally, the discussion of emerging technologies is generic and does not provide examples of region-specific implementations.

Anupa Baliga and Goveas examine how fintech drives innovation and profitability in banking. Their SWOC analysis highlights opportunities for collaboration and the technical complexities fintech introduces [12, p. 235]. Yet, the study remains too general, failing to explore how fintech addresses the needs of Europe's SMEs, a vital segment of the region's economy. Additionally, it does not include detailed examples of successful transformations within the European banking sector.

The reviewed literature underscores the transformative potential of fintech in reshaping the banking sector. Nevertheless, most studies fail to adequately address Europe-specific challenges and opportunities.

Formulation of the objectives of the article (task statement). The article aims to analyze the interplay between research and development expenditure and fintech opportunities in European countries, examining how these factors drive innovation in financial technologies while balancing economic potential with associated challenges.

Summary of the main research material. Table 1 offers a detailed comparison of fintech ecosystems across various countries, focusing on key performance indicators such as fintechs founded per million capita, funding per capita, deals per million capita, unicorns per million capita, workforce share in total employment, and an average ranking derived from these metrics.

**Table 1. Ranking fintech growth and performance
across European countries and U.S. in 2021**

Country	Fintechs founded per million capita	Fintech funding per capita	Deals per million capita	Unicorns per million capita	Workforce (fintech jobs) as share of total workforce	Average ranking
United Kingdom	6	3	4	4	3	4.0
Sweden	7	2	8	2	2	4.2
Malta	3	1	6	1	11	4.4
Luxembourg	1	12	2	n/a	4	4.8
Switzerland	5	8	3	8	7	6.2
Estonia	2	6	1	15	8	6.4
Ireland	4	9	7	7	5	6.4
Netherlands	11	7	14	5	6	8.6
Denmark	10	5	9	6	14	8.6
Germany	17	11	15	11	9	12.6
Cyprus	8	22	11	n/a	10	12.8
Lithuania	14	17	5	n/a	16	13.0
Finland	12	13	12	n/a	18	13.8
Austria	18	10	19	9	15	14.2
France	19	14	16	10	12	14.2
Latvia	13	24	13	n/a	13	15.8
Spain	20	16	18	12	19	17.0
Belgium	16	19	17	n/a	17	17.3
Portugal	21	15	20	n/a	26	20.5
Italy	26	20	22	13	22	20.6
Hungary	22	18	23	n/a	21	21.0
Slovenia	15	23	26	n/a	n/a	21.3
Czech Republic	23	21	21	n/a	24	22.3
Croatia	25	26	25	n/a	20	24.0
Poland	27	25	24	n/a	23	24.8
Greece	30	28	29	14	25	25.2
Bulgaria	24	27	28	n/a	28	26.8
Romania	29	29	27	n/a	28	28.3
Slovakia	28	30	30	n/a	28	29.0
United States	9	4	10	3	1	5.4

Source: elaborated by the author based on [13]

Top performers include the United Kingdom, Sweden, and Malta, which emerge as leading fintech hubs. The United Kingdom demonstrates a balanced performance across all indicators, achieving an average ranking of 4.0, thanks to its significant fintech workforce share and a high number of unicorns and deals per capita. Sweden stands out with the highest number of fintechs founded per capita

(7) and strong results in workforce share and unicorns, leading to an average ranking of 4.2. Malta, despite its small size, ranks exceptionally well in funding per capita and unicorns, securing an average ranking of 4.4.

Smaller countries such as Luxembourg, Estonia, and Switzerland showcase their ability to excel in niche markets. Luxembourg ranks highly in deals per capita (2) and workforce share (4), despite having no unicorns recorded. Estonia leads in deals per capita (1) and maintains competitive rankings in other categories, reflecting its focus on innovative startups and digital transformation. Switzerland performs strongly in metrics like unicorns and deals per capita, underlining its reputation as a fintech innovator.

The United States, often a leader in global fintech, ranks impressively in metrics like funding (4), unicorns (3), and workforce share (1). However, its performance in deals and fintechs per capita slightly lags behind smaller European countries, resulting in an average ranking of 5.4. This reflects its vast population diluting per-capita metrics but highlights its global leadership in absolute numbers.

Countries such as Ireland, the Netherlands, and Denmark occupy middle positions, with average rankings around 6 to 9. These nations show strengths in specific areas: Ireland in unicorns and funding, the Netherlands in deals and unicorns, and Denmark in workforce share. These metrics suggest these countries have vibrant fintech ecosystems but are still developing in comparison to top-tier players.

Eastern and Southern European countries, including Romania, Bulgaria, Poland, and Slovakia, rank lower on average. These nations generally exhibit weaker performance across all metrics, with fintech development being at a nascent stage. Poland, a larger market in Eastern Europe, ranks 24.8 due to limited per-capita funding and deals. Greece, despite some presence in unicorns, struggles with overall rankings (25.2), indicative of challenges in fostering a fintech-friendly environment.

Smaller countries like Malta and Luxembourg outperform larger economies in the density of unicorns, showcasing how targeted policies can lead to high-

impact outcomes despite limited scale. The United States leads in integrating fintech into its workforce, while Sweden and Estonia also perform exceptionally well. This suggests a direct correlation between workforce focus and broader ecosystem success.

The data underscores a diverse fintech landscape, where traditional powerhouses like the United Kingdom and the United States coexist with rising stars like Sweden and Estonia. Countries with strong policy frameworks, focused investments, and skilled workforces tend to dominate rankings, while others lag due to structural and economic constraints. The table serves as a roadmap for understanding the dynamics of fintech development and the factors driving success globally.

Table 2 presents research and development (R&D) expenditure as a percentage of GDP across European countries and the United States for the years 2018 to 2021.

Sweden leads with the highest average R&D expenditure at 3.40% of GDP, demonstrating consistent investment in innovation and technological development over the four years. This leadership reflects Sweden's robust policies and prioritization of R&D as a key driver of economic growth and competitiveness. Switzerland follows closely, despite incomplete data for 2018 and 2020, with a high average expenditure. This reflects Switzerland's reputation as a global leader in research, supported by its strong higher education institutions and innovative industries.

The United States has maintained consistent increases in its annual R&D expenditure, highlighting its sustained commitment to innovation. As the world's largest economy, it significantly invests in both public and private R&D sectors, maintaining its global leadership in technological advancements. Belgium, Austria, and Germany are also notable for their high and stable R&D spending, driven by their strong industrial bases and research-intensive sectors.

**Table 2. Research and development expenditure (% of GDP)
in European countries and U.S. in 2018-2021**

Country	2018	2019	2020	2021	Average	Ranking
United Kingdom	2.70	2.67	2.93	2.91	2.80	9
Sweden	3.32	3.39	3.49	3.42	3.40	1
Malta	0.58	0.56	0.65	0.67	0.62	29
Luxembourg	1.17	1.18	1.09	1.04	1.12	23
Switzerland	n/a	3.20	n/a	3.36	3.28	2
Estonia	1.41	1.63	1.75	1.75	1.64	14
Ireland	1.17	1.23	1.23	1.13	1.19	21
Netherlands	2.14	2.18	2.32	2.31	2.24	10
Denmark	2.97	2.90	2.97	2.81	2.91	7
Germany	3.11	3.17	3.13	3.14	3.14	6
Cyprus	0.61	0.71	0.84	0.83	0.75	27
Lithuania	0.94	0.99	1.13	1.11	1.04	24
Finland	2.76	2.80	2.91	2.99	2.86	8
Austria	3.09	3.13	3.20	3.26	3.17	5
France	2.20	2.19	2.28	2.22	2.22	11
Latvia	0.64	0.64	0.73	0.74	0.69	28
Spain	1.24	1.25	1.41	1.43	1.33	20
Belgium	2.86	3.16	3.40	3.43	3.21	4
Portugal	1.35	1.40	1.61	1.68	1.51	16
Italy	1.42	1.46	1.51	1.45	1.46	17
Hungary	1.51	1.47	1.59	1.64	1.55	15
Slovenia	1.95	2.04	2.14	2.13	2.07	12
Czech Republic	1.90	1.93	1.99	2.00	1.95	13
Croatia	0.95	1.08	1.24	1.24	1.13	22
Poland	1.21	1.32	1.39	1.44	1.34	19
Greece	1.21	1.27	1.51	1.46	1.36	18
Bulgaria	0.75	0.83	0.85	0.77	0.80	26
Romania	0.50	0.48	0.47	0.47	0.48	30
Slovakia	0.84	0.82	0.90	0.92	0.87	25
United States	3.01	3.17	3.47	3.46	3.28	3

Source: elaborated by the author based on [14]

Denmark, Finland, and the United Kingdom also demonstrate strong performance, with averages above 2.8%. Denmark and Finland are notable for their consistent annual investments, while the United Kingdom, despite slight fluctuations, maintains a solid position in R&D activities. These countries leverage their investments to foster innovation and sustain competitive economies.

The Netherlands, France, and Slovenia represent the middle tier, with average R&D expenditures ranging between 2.07% and 2.24%. The Netherlands

demonstrates incremental annual growth, indicating a steady trajectory toward higher innovation capacity. France remains a strong player in Europe, benefiting from its robust research infrastructure. Slovenia's moderate expenditure reflects its focus on gradually enhancing its R&D ecosystem.

Estonia and the Czech Republic also show promise in this group, with averages of 1.64% and 1.95%, respectively. These countries are making strides in their R&D investments, particularly Estonia, which saw a noticeable increase over the period.

Portugal, Hungary, and Greece display moderate levels of R&D investment. While not as competitive as higher-ranked countries, these nations are gradually increasing their expenditures, indicating a growing recognition of R&D's importance in economic development. Poland and Spain, with averages slightly above 1.3%, show positive trends in prioritizing research and innovation.

Several countries exhibit low levels of R&D expenditure, particularly in Eastern and Southern Europe. Croatia, Lithuania, and Slovakia have averages below 1.2%, reflecting limited resources and institutional support for research activities. These nations may face challenges in fostering competitive innovation environments due to lower investment levels. Romania ranks the lowest, with an average R&D expenditure of just 0.48% of GDP. This figure highlights significant underinvestment in research and innovation, which could hinder the country's ability to compete in the global knowledge economy.

There are clear regional disparities, with Western and Northern European countries, along with the U.S., leading the way in R&D expenditure, showcasing their advanced research ecosystems and strong policy support. Conversely, Eastern and Southern European nations generally lag, reflecting structural and economic challenges. While top-performing countries exhibit consistent investment levels, emerging economies display gradual growth, indicating efforts to enhance their R&D landscapes.

The relationship between the number of fintechs founded per million capita and research and development (R&D) expenditure as a percentage of GDP was

analyzed using the Spearman correlation coefficient. Results indicate a small, positive, but non-significant relationship between these variables (Table 3).

Table 3. Spearman's rank correlation between fintechs founded per million capita and R&D expenditures in European countries and U.S.

Parameter	Value	Parameter	Value
Spearman's rank correlation coefficient (r_s)	0.2463	Covariance	19.0862
r^2	0.06065	Sample size (n)	30
P-value	0.1894	Statistic	0.2463

Source: elaborated by the author

The Spearman's rank correlation coefficient suggests a slight positive association between fintech density and R&D investment. However, the analysis revealed that this relationship is not statistically significant, meaning the null hypothesis that no correlation exists could not be rejected. The coefficient of determination explains only a small percentage of the variance in fintech density by R&D expenditures.

The null hypothesis assumes no relationship between the variables. With the probability of incorrectly rejecting the null hypothesis being relatively high, the observed correlation is not statistically significant and could likely be attributed to random sampling variations rather than a true population effect. The test statistic falls within the region of acceptance, and the confidence interval for the correlation coefficient includes zero, further confirming the non-significance of the relationship.

Conclusions and prospects for further research in this area. Key insights from the analysis of fintech ecosystems and R&D expenditures across European countries and the U.S. reveal a strong performance by top-ranked nations such as the United Kingdom, Sweden, and Malta. These countries demonstrate the positive impact of robust innovation ecosystems, skilled workforces, and strategic investment in fintech infrastructure. Smaller economies like Estonia and Luxembourg illustrate how niche-focused strategies can yield significant results despite limited scale.

The relationship between fintech density and R&D expenditure, analyzed using the Spearman correlation coefficient, indicates a weak positive but statistically non-significant association. This finding underscores the need to explore beyond traditional metrics, considering additional factors like policy frameworks, cultural dynamics, and venture capital ecosystems, which might better explain fintech proliferation. While the current data suggests a limited direct correlation, the nuanced interplay of variables calls for a more detailed examination.

Future research should aim to address the limitations of this study by utilizing larger datasets and incorporating longitudinal designs to capture evolving trends. Expanding the scope to include variables such as digital literacy, regulatory environments, and global venture capital flows could provide deeper insights into the determinants of fintech growth. Comparative analyses between regions and countries with varying R&D intensities could also offer valuable lessons for emerging fintech ecosystems.

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