
Digital transformation and bank profitability

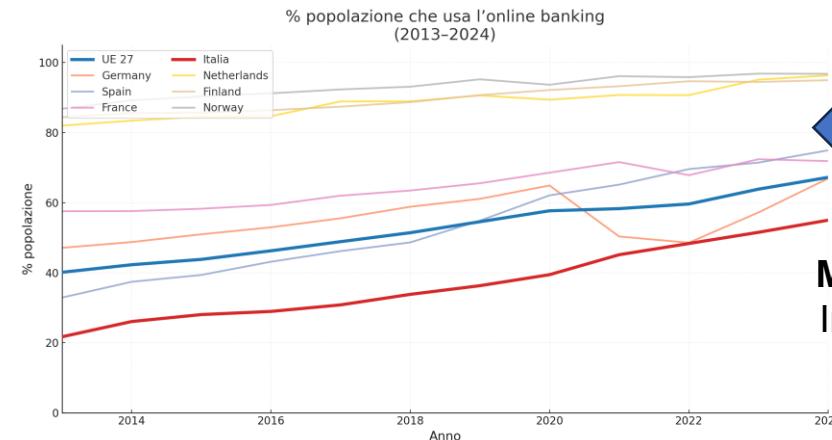
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MSCA Training – History and prospects of Digital Finance
12/12/2025

Overview

- The **disruptive digitalisation wave** in the financial industry that has occurred around 2010 has among its outcomes the **diffusion of new business models** and the **arrival of a new players**, born in a fully digital environment, i.e. fintech and neobanks.
- The **coronavirus pandemic** had a significant impact on the digital transformation, creating a direct need for banks to **communicate** with their customers **through digital channels**, such as platforms and apps.
- **Digital channels have become the preferred means for online banking activities**, including checking account balances, viewing transactions, and transferring money. Despite a reduction in customer branch visits, partly driven by the pandemic, branches remain important for many customers who seek more complex assistance and advisory services

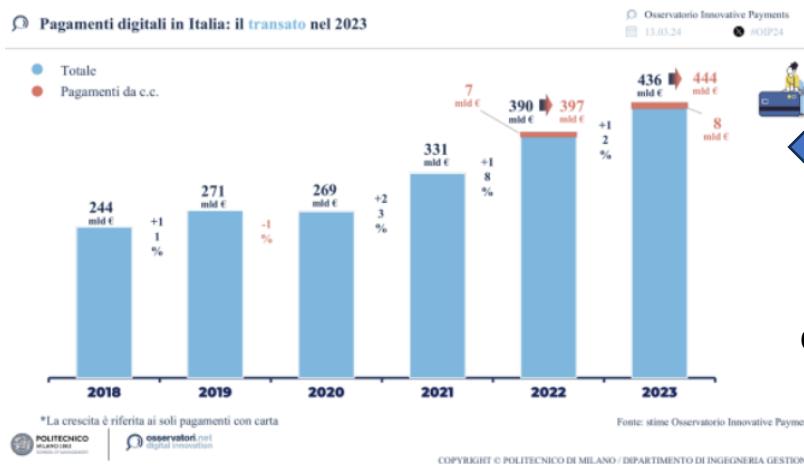
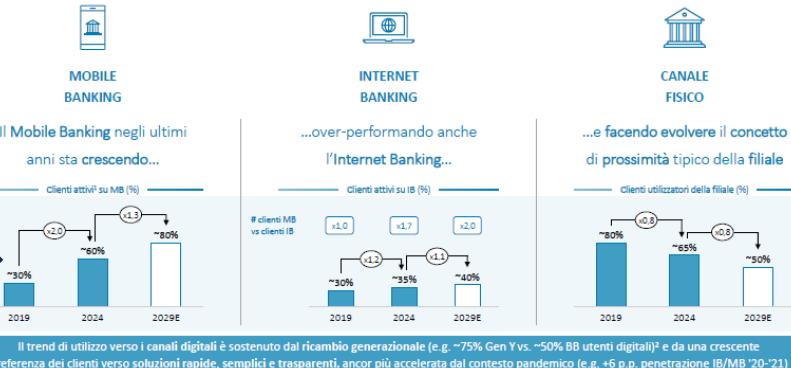
Digital Behavioural Patterns of Bank Customers



In recent years, consumers have increasingly moved to digital channels.

In Italy, **about 55% of individuals use online banking** – still below the EU average, but on a clear upward path.

Mobile banking is the main driver of this shift.
In 2024, around 60% of Italian users accessed banking services via mobile apps, while branch visits keep declining.



Digital payments have expanded rapidly.

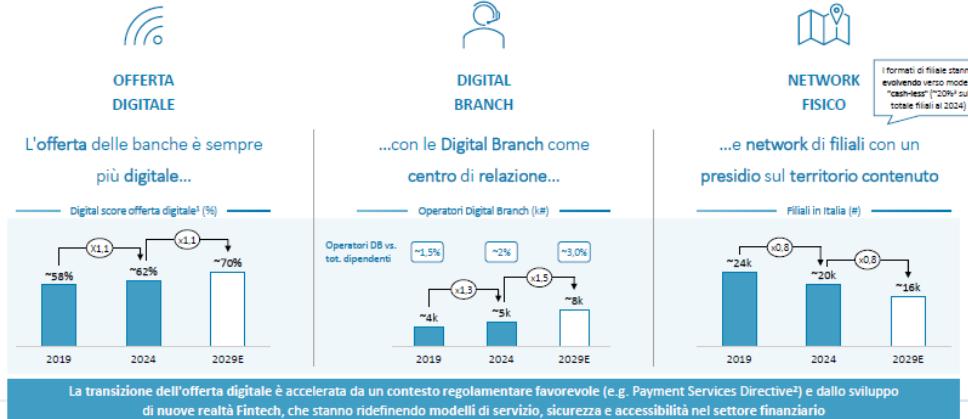
In 2023, **cashless payments in Italy reached €444 billion (+12% YoY)**, close to total cash transactions, yet the country still ranks **24th out of 27** in the EU for digital payment intensity.

In brick-and-mortar retail, **contactless now dominates**: in 2023, almost **80% of digital POS transactions were tap-and-go**.

Payments via smartphones and wearables reached **€29 billion**, a 73% increase vs. 2022.

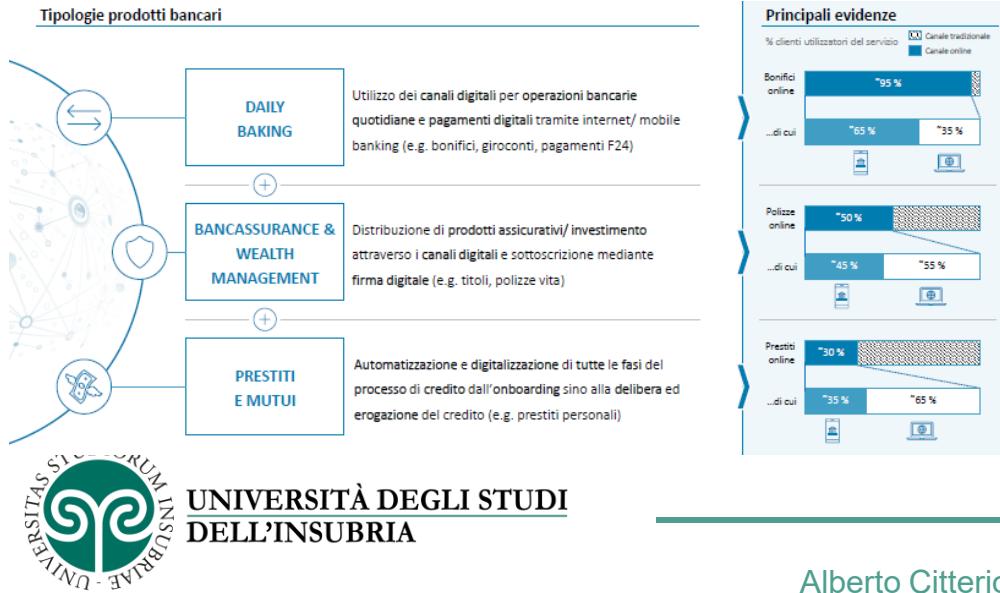


Evolution of Banking Service Supply and Demand



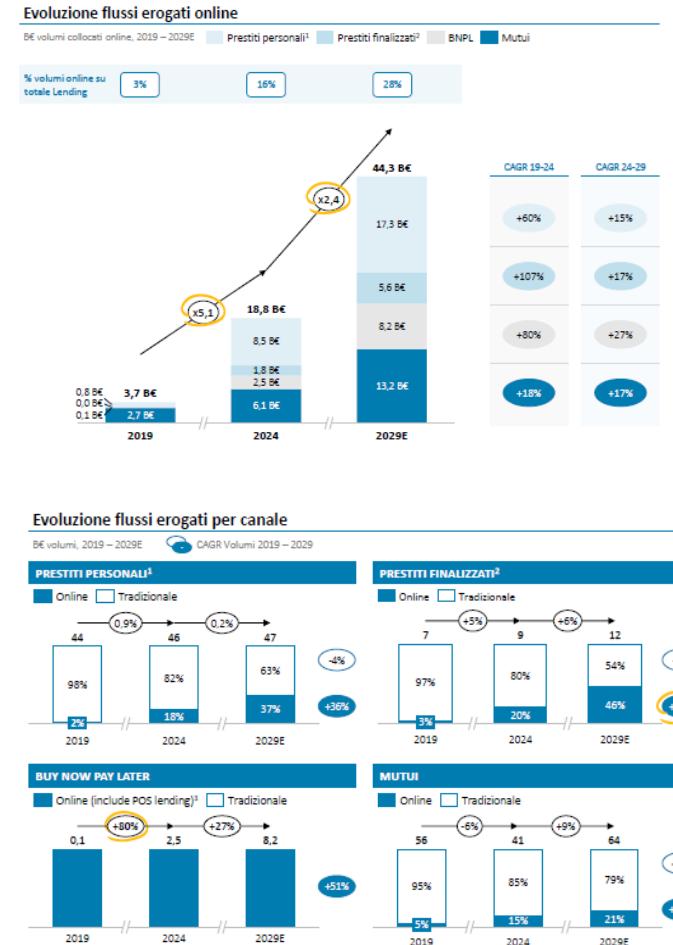
As a result, banks have significantly expanded and improved their **digital offering**, while **sharply reducing the size of their physical branch networks**.

Almost all **routine operations** are now carried out through digital channels: around **95% of bank transfers and basic payment instructions** are initiated online or via mobile.



More complex services are also moving online, though to a lesser extent: roughly **50% of insurance policies** are now acquired digitally, and about **30% of loans** are originated through remote channels.

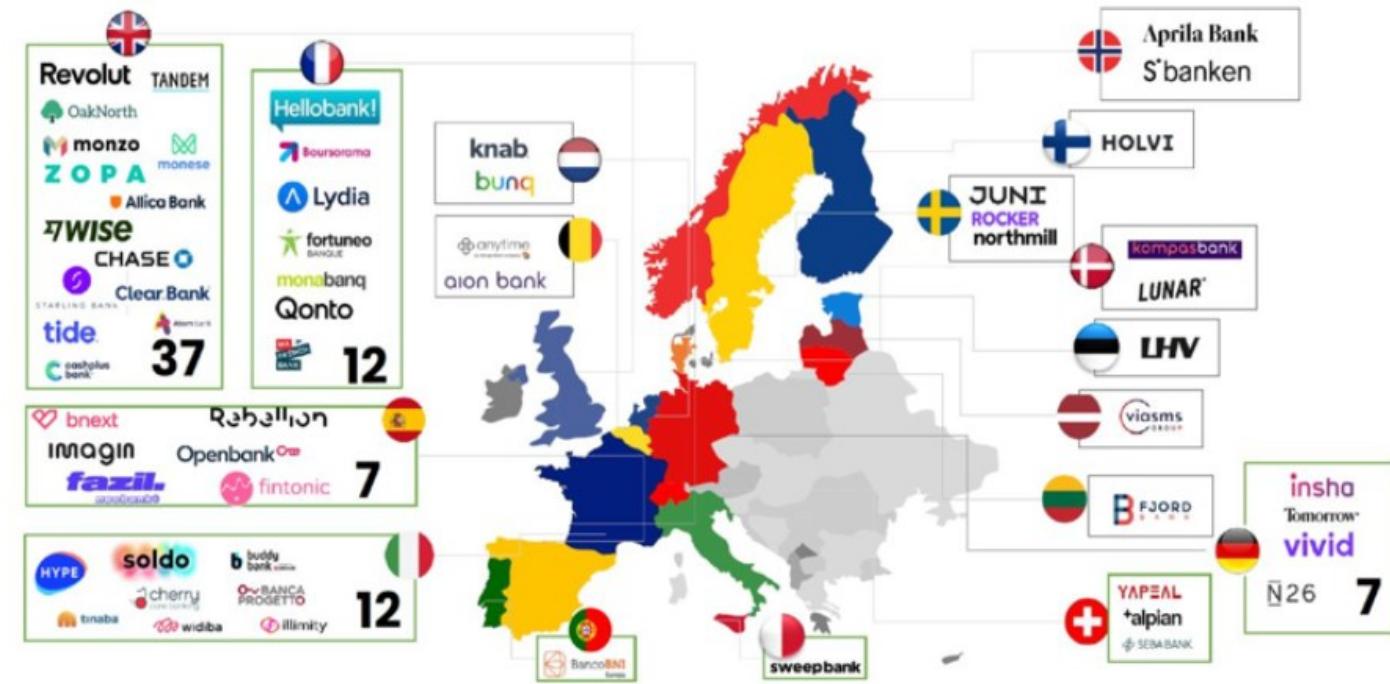
By contrast, the **digital penetration of high-complexity products** (such as mortgages) remains relatively limited, with growth prospects that are more gradual and constrained.



Growth of Fintech, Neobanks, and BigTech in the Banking Sector

Neobanks (digital-native banks)

- **Digital-only, licensed banks**, typically operating with no (or a very light) physical branch network.
- Offer standard retail banking services – current accounts, payment cards, consumer loans, basic investments – **exclusively through digital channels** (mobile apps, web platforms, chatbots, fully remote onboarding).
- Compete mainly through **low operating costs**, highly automated processes, simple pricing and a **frictionless customer experience**, often with rapid cross-border customer acquisition.
- However, despite strong growth in users, **profitability remains limited** for most neobanks, and their aggregate balance-sheet size is still small relative to incumbent banks (which helps explain why incumbents remain central in credit intermediation).



Growth of Fintech, Neobanks, and BigTech in the Banking Sector

FinTech firms

- **Technology-driven non-bank intermediaries** (often start-ups or specialised platforms) that use digital tools to deliver **innovative financial services**.
- Operate across a wide range of verticals: **digital payments, P2P and marketplace lending, robo-advisory and wealth management, insurtech, crowdfunding, personal finance management, etc.**
- Typically follow a **narrow, product-focused business model**: they “unbundle” traditional banking services, targeting specific segments with specialised, user-friendly solutions.
- Their scale in terms of balance sheet is still modest relative to banks, but they have been important in **setting new standards for user experience, pricing transparency and speed**.



Growth of Fintech, Neobanks, and BigTech in the Banking Sector

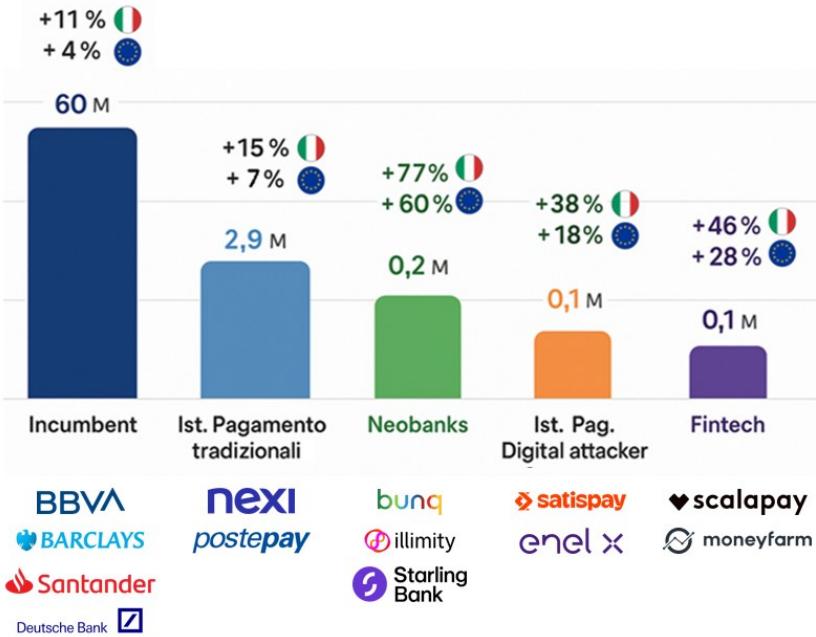
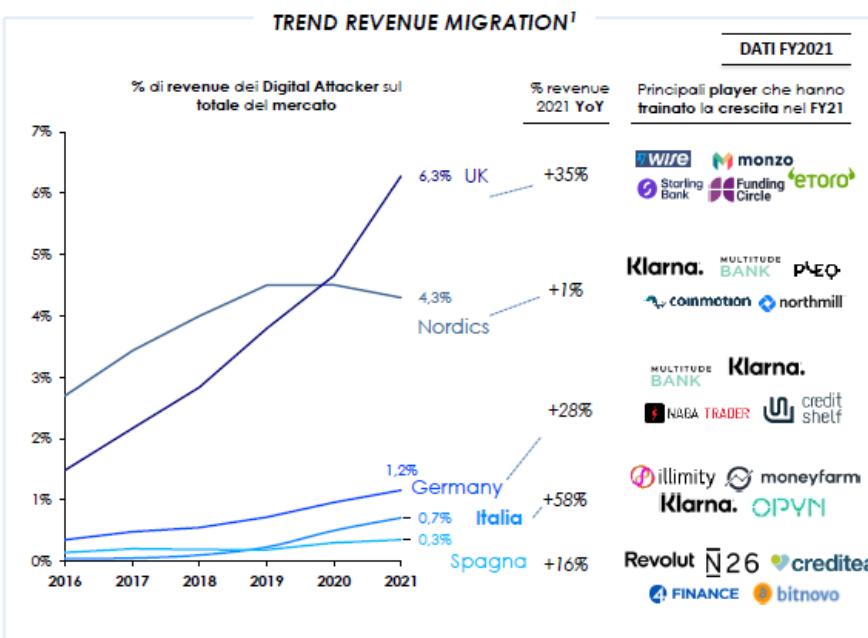
BigTech firms

- Large digital platforms (e.g. Apple, Google, Amazon, Meta, Alibaba) that were **not originally financial institutions**, but have progressively entered financial services.
- Typically offer **payments and wallets** (Apple Pay, Google Pay, Amazon Pay), digital wallets, instalment/consumer credit, small-business lending, and sometimes insurance or savings products.
- Leverage their **massive user base, data advantage and ecosystem integration** (e-commerce, app stores, social networks, devices) to embed financial services into non-financial activities ("embedded finance").
- In most jurisdictions they operate via **partnerships with licensed banks or as regulated payment institutions**, so their **direct role in credit intermediation is still limited**, but they exert strong competitive pressure on banks in terms of **user experience, data analytics and customer ownership**.



Growth of Fintech, Neobanks, and BigTech in the Banking Sector

In the last decade, **digital attackers** – neobanks, digital payment institutions and specialised FinTech platforms – have grown **much faster** than traditional intermediaries in terms of customers, transaction volumes and brand visibility.



Despite this expansion, their **impact on the aggregate revenue pool remains limited**. In Italy, for instance, digital attackers still account for a **small share of banking and payment revenues**, even though a few players (such as **Satispay**, **Illimity**, **Moneyfarm**) have built successful niche positions. This helps explain why **incumbent banks remain central in credit intermediation**, while facing mainly *competitive pressure on pricing and customer experience* rather than a large-scale displacement.

Competitive pressure from digital attackers

In summary:

Who are the “digital attackers”? Neobanks, specialised FinTech platforms and BigTech-affiliated payment institutions operating with lean, digital-first models.

What do they change? They set new benchmarks in terms of:

- user experience (frictionless onboarding, real-time apps)
- **pricing transparency** and low fees
- **speed** of execution and remote accessibility.

How do they affect incumbents? → Even with a **small balance-sheet footprint**, they reshape **customer expectations** about how banking services should be delivered → Banks are pushed to **accelerate their own digital transformation** (channels, processes, IT architecture) to avoid losing relevance at the interface with clients.

Where is the competitive pressure strongest?

- Less on the **core credit intermediation** (where attackers' market share remains modest),
- More on **payments, basic transactional services and daily banking**, where convenience and UX are key.

Implication for our study → Digital attackers help explain **why incumbent banks invest heavily in digitalisation**, even when direct revenue erosion is still limited: the competition is primarily on **customer relationship and service quality**, not (yet) on full displacement of traditional banks.

Theoretical framework

Theoretical and empirical work points to several mechanisms through which IT and digital tools can affect banks' business models and performance:

- 🔍 **Improved monitoring and screening** - Use of digital footprints and alternative data to predict default and refine credit scoring (Berg et al., 2020)
- ✅ **More accurate lending decisions** - IT-intensive banks allocate credit more efficiently and sustain lending in stressed regions (Pierr & Timmer, 2020)
- 🌐 **Virtual geographic expansion (“spatial capture”)** - Digital channels allow banks to reach and serve distant customers without a dense physical branch network (Boot et al., 2021)
- 😊 **Stronger customer satisfaction and retention** - Higher service quality and responsiveness through digital interfaces translate into competitive advantage (Mithas et al., 2012).
- 📈 **Larger effective customer base** - Lower access costs and simplified onboarding broaden the pool of potential clients (Kwan et al., 2021).
- 🔄 **Enhanced cross-selling opportunities** - Data-driven profiling supports targeted offers to existing customers (Pierr & Timmer, 2020).
- ⌚ **Faster decision-making and process execution** - Digital workflows shorten response times and increase operational agility (Boot et al., 2021)

Theoretical framework

Several studies warn that digital **technologies do not automatically translate into higher profitability**:

-  **Commoditisation of IT** - When technologies are widely available, they improve operational efficiency but do not necessarily yield sustained profit advantages (Carr, 2003; Aral & Weill, 2007).
-  **Persistent role of the branch network** - Physical branches have historically been crucial to overcome information frictions and build relationship lending with customers (Boot et al., 2021).
-  **Fee-intensive activities remain branch-based** - Many high-margin services – such as securities custody and personalised advisory – still rely heavily on in-branch interaction (Chiorazzo et al., 2018; Dandapani et al., 2018).

Literature review

Literature dealing with effect of IT development on performance is scant and offers mixed results:

- **Beccalli (2007), Berger (2003) and Hernandez Murillo et al. (2010)** do not find a positive impact of IT investments on profitability (profitability paradox), suggesting the presence of a “profitability paradox”.
- **DeYoung et al. (2007)** examine the impact of internet banking adoption on performance for a large set of US community banks, finding that internet adoption positively affects performance.
- **Humprey et al. (2006)** study the effect of new payment technology (such as ATMs and online banking) on banks’ operating costs, and find a strong reduction effect.
- **Pierrri and Timmer (2020)** study IT adoption and bank risk, finding that banks with higher IT adoption are more resilient in times of crisis.
- Similarly, **Dadoukis et al. (2021)** show that high IT adopters performed better during the initial stages of the Covid-19 pandemic.

Motivations

- Over the last decade, IT and digital technologies have reshaped the banking industry, and the Covid-19 shock has acted as a further accelerator, making digital transformation a core strategic issue for banks.
- Despite this, the empirical literature on the **digitalisation–performance nexus** is still relatively thin, partly because of the lack of structured, bank-level measures of digitalisation (see Beccalli, 2007).

Our contribution

- We build a **novel digitalisation index** on the basis of an original dataset that combines:
 - **IT investment** (technology-related intangibles)
 - **Process and channel digitalisation** (internal and customer-facing)
 - **Customer engagement and satisfaction with digital channels**

This allows us to study the link between digital maturity and bank performance in a much more systematic way.

Digitalization index

Variable (acronym)	Description	Source
IT investments (R1_inv)	Intangible assets (excluding goodwill)/total assets	BankFocus
Network efficiency – branches (R2_bra)	Total assets/Number of branches	BankFocus
Network efficiency – employees (R3_emp)	Total assets/Number of employees	BankFocus
Use of digital channels: Mobile app (R4_appuse)	Number of ratings/total assets	Androidrank.org, Appbrain.com
Use of digital channels: Mobile app (R5_apprat)	Average rating	Androidrank.org, Appbrain.com
Use of digital channels: Website (R6_webuse)	Average monthly visits/total assets	Similarweb.com

Sample composition

- We collect consolidated data for EU-27 banks from 2017 to 2022
 - We only consider banks with the following characteristics:
 - Availability of data on branches and employees (BankFocus or manually-collected data)
 - Availability of financial data for at least two consecutive years
 - We exclude banks that share their digital infrastructure with other banks. For example, many German cooperative and savings banks sharing the same mobile application are excluded
- An unbalanced panel of 279 banks headquartered in the EU-27 member states during the period 2017-2022, resulting in a total of 1,516 observations.

Methodology

$$Y_{i,t} = \alpha_0 + \beta DI_{i,t-1} + \gamma BC_{i,t-1} + \delta CL_{j,t-1} + \mu_i + \varepsilon_{i,t-1}$$

- **Y:** Return on Assets
- **DI:** Digitalization index.
- **BC:** control variables (size, income, diversification, gross loans customers, liquid assets, customer deposits, total equity, NPL, number of products line).
- **CL:** country-level controls (GDP growth, GDP per capita, concentration ratio).
- The indices i, j, t , represent, respectively, the bank, country, and fiscal year
- One-year lagged independent variables to reduce the risk of endogeneity cause by potential reverse causality or simultaneity bias

Dependent variables and control variables

Category	Variable (acronym)	Description	Source
Variabile dipendente	ROA	Return on assets	BankFocus
	Total equity	Capitale proprio / totale attivo *100	BankFocus
	Non-performing loans	Prestiti deteriorati / prestiti lordi alla clientela *100	
	Customer deposits	Depositi della clientela / totale attivo *100	BankFocus
	Liquid assets	Liquid assets to total assets*100	BankFocus
Variabili di controllo	Gross loans	Attività liquide / totale attivo *100	BankFocus
	Income diversification	Calcolata come indice di Herfindahl-Hirschman (HHI), considerando il valore assoluto di ciascuna componente dei ricavi operativi totali (TOR): reddito da interessi (INT), commissioni nette (NFC), redditi da negoziazione (NTI), altri ricavi (OTH). Formula: (Elsas et al., 2010)[1 - ((INT/TOR) ² + (NFC/TOR) ² + (NTI/TOR) ² + (OTH/TOR) ²)]	BankFocus
	Cost-to-income	Costi operativi / ricavi operativi	BankFocus
	Total assets	Logaritmo naturale del totale attivo	BankFocus
Variabili di contesto Paese	Gdp per capita	PIL / popolazione media	World Bank
	Gdp growth	Tasso annuo di crescita del PIL reale a prezzi di mercato in valuta locale costante	World Bank
	Bank concentration	Attività delle tre maggiori banche come quota del totale delle attività bancarie commerciali	World Bank

Results – Digitalization index

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.572	0.036	0.260	0.260
Comp2	1.536	0.531	0.258	0.518
Comp3	1.005	0.148	0.168	0.686
Comp4	0.857	0.252	0.143	0.828
Comp5	0.605	0.179	0.101	0.929
Comp6	0.425	0.000	0.071	1

Test	Value
KMO	0.661
Bartlett	1401.32***
Cronbach's alpha	0.615

To characterise banks' digitalisation in a tractable way, we apply **Principal Component Analysis (PCA)** to the six underlying indicators and use the resulting latent factors as synthetic measures of digital maturity.

Main steps

- **Single-index specification** - First, we retain **one principal component** and use it as an overall digitalisation index at the bank-year level.
- **Multi-dimensional specification** - Then, we keep all components with **eigenvalues greater than 1**, i.e. those accounting for a non-trivial share of total variance (Guttman–Kaiser criterion) → This yields a small set of economically interpretable factors that capture different dimensions of digitalisation and are used in the subsequent analysis.
- To assess the validity of the PCA approach, we use the **Kaiser-Meyer-Olkin (KMO)** measure of sampling adequacy, conduct the **Bartlett test** for equal variance, and employ **Cronbach's alpha** as a measure of internal consistency

Results – Digitalization index

Variable	Comp1
R1_inv	0.242
R2_bra	0.432
R3_emp	0.264
R4_appuse	0.486
R5_apprat	0.495
R6_webuse	0.512

Variable	Comp1	Comp2	Comp3
R1_inv	-0.000	0.002	0.982
R2_bra	0.084	0.709	-0.049
R3_emp	-0.099	0.678	0.049
R4_appuse	0.629	-0.090	-0.017
R5_apprat	0.577	0.007	0.111
R6_webuse	0.501	0.170	-0.134

Higher loadings indicate that a given variable is more representative of the corresponding **latent component**.

- In the **upper panel**, we retain only **one component (Comp1)**, which aggregates all six indicators into a **single, global digitalisation index**.
- In the **lower panel**, we keep **three principal components** (according to the criterion shown in the previous slide), which allows us to disentangle distinct dimensions of digitalisation:

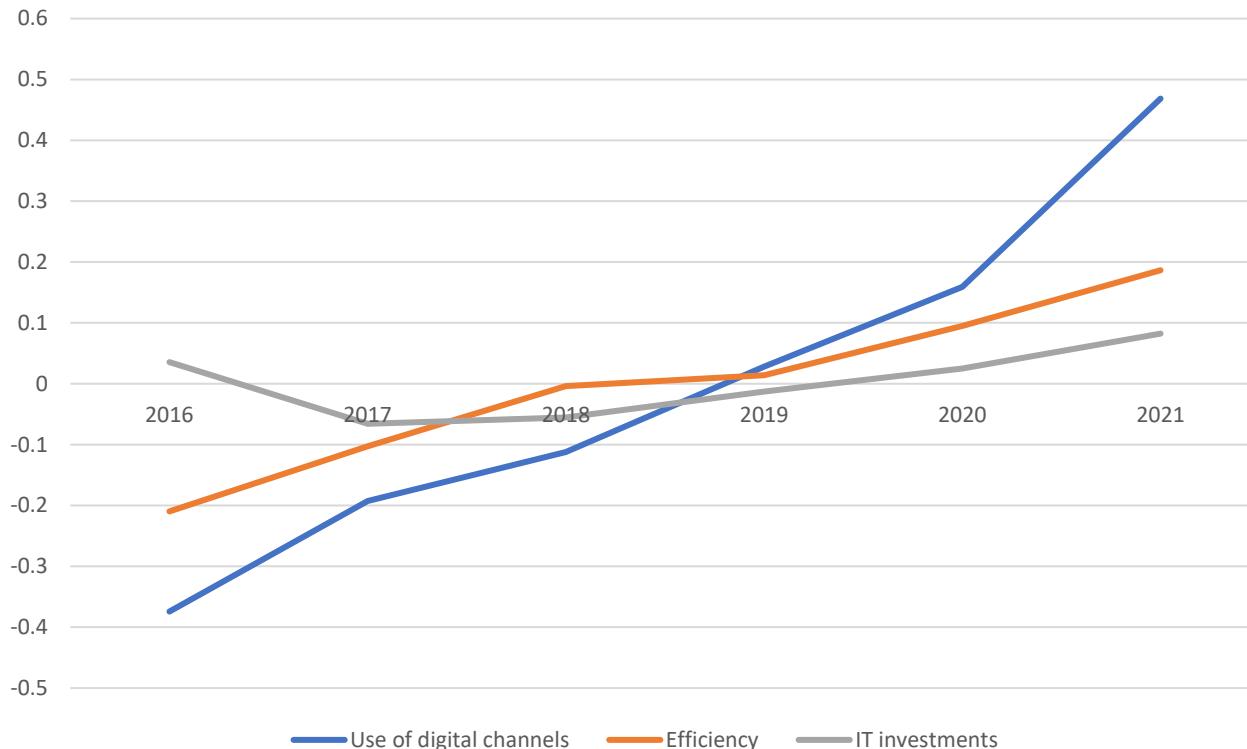
Comp1 – Digital channels - high loadings on app usage (R4), app rating (R5) and web traffic (R6)

Comp2 – Network efficiency - high loadings on branch efficiency (R2) and staff efficiency (R3)

Comp3 – IT investment - high loading on IT-related intangibles (R1)

These components form the basis for our **composite index** and for the **dimension-specific analyses** that follow.

Results – Digitalization trends



- All factors show an increasing trend within the analyzed period
- Factor 1 (use of digital channels) exhibits the most significant increase
- The Covid-19 pandemic appears to have further accelerated these trends.

Results – Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) ROA	1.000											
(2) Digitalization	0.146*	1.000										
(3) Digital channels	0.198*	0.863*	1.000									
(4) Efficiency	0.040*	0.536*	0.036*	1.000								
(5) IT investment	0.063*	-0.005	-0.016	0.023*	1.000							
(6) Non-performing loans	-0.195*	-0.168*	-0.065*	-0.224*	0.018*	1.000						
(7) Total equity	0.218*	-0.125*	-0.017	-0.214*	-0.073*	0.093*	1.000					
(8) Customer deposits	0.080*	-0.217*	0.027*	-0.473*	-0.030*	0.087*	-0.104*	1.000				
(9) Liquid asset	-0.042*	-0.125*	-0.121*	-0.044*	-0.012	0.087*	0.171*	0.002	1.000			
(10) Gross loans	0.005	-0.014	0.085*	-0.171*	0.019*	0.120*	-0.059*	0.070*	-0.693*	1.000		
(11) Income diversification	-0.164*	-0.047*	0.019*	-0.129*	0.097*	0.063*	-0.200*	-0.100*	0.113*	-0.097*	1.000	
(12) Size	0.001	0.399*	0.308*	0.269*	0.136*	-0.125*	-0.392*	-0.301*	-0.226*	0.077*	0.248*	1.000

*** p<0.01, ** p<0.05, * p<0.1

The correlation matrix suggests a **positive relationship** between profitability and digitalization indices.

Results – Descriptive statistics

Variable	Observations	Mean	Std. Deviation	Min	Max
ROA	1516	0.57	1.13	-11.43	7.67
Digitalization index	1516	27.08	20.80	0.00	100.00
Digital channel development	1516	26.40	21.33	0.00	100.00
Network efficiency	1516	15.75	16.34	0.00	100.00
IT investment	1516	72.51	13.67	0.00	100.00
Non-perfoming loans	1516	7.58	9.24	0.00	46.52
Total equity	1516	9.98	4.88	3.24	33.40
Customer deposits	1516	68.07	17.38	6.44	92.51
Liquid assets	1516	29.02	16.45	3.20	86.75
Cost-to-income ratio	1516	72.24	23.86	31.00	187.03
Gross loans	1516	58.92	19.40	5.04	94.56
Income diversification	1516	49.81	14.75	5.98	71.13
Size	1516	15.15	2.20	10.95	20.63
Gdp Growth	1516	10.40	0.52	8.93	11.80
Gdp per capita	1516	1.57	4.22	-11.32	13.58
Bank concentration	1516	82.75	9.79	44.75	100.00

Results – High vs Low IT banks

	High-IT	Low-IT	Diff.
ROA	0.890	0.322	-0.568***
Interest income	2.236	1.779	-0.457***
Net fees and commissions	0.784	1.577	0.793***
Other non-interest income	0.145	0.398	0.253***
Staff expenses	1.012	1.864	0.853***
Non-staff expenses	1.170	1.357	0.186*
Cost-to-income ratio	63.260	82.858	19.598***
Customer Deposits	64.140	73.258	9.118***
Gross loans	58.756	56.279	-2.477
Non-performing loans	5.129	9.214	4.085***
Liquid assets	27.945	32.636	4.691***
Total equity	9.856	10.981	1.126***
Size	16.181	13.392	-2.789***

Comparison between high- and low-digitalisation banks

We compare banks in the **top quartile** of our IT-digitalisation index with those in the **bottom quartile**.

High-digitalisation banks are characterised by:

- **Higher profitability** - Significantly higher ROA on average.
- **Stronger interest income** - Digital capabilities allow them to intermediate larger volumes and reach clients beyond the traditional branch footprint.
- **Lower fee and commission income** - Activities that remain strongly branch-based (e.g. advisory, custody, some wealth management services) are relatively less developed in highly digital banks.
- **Greater cost efficiency** - Lower cost-to-income ratios, reflecting leaner operating structures and higher assets per employee/branch.
- **Better asset quality** - Lower NPL ratios, consistent with enhanced screening and monitoring through data-driven credit processes.
- **Lower customer deposit funding** - More traditional, deposit-intensive business models tend to be less digitalised and remain anchored to a physical-branch paradigm.

Results – Baseline regressions

	Dependent variable: ROA				
	(1)	(2)	(3)	(4)	(5)
Digitalization index	0.017**				
Digital channel development		0.009			0.010
Network efficiency			0.026**		0.028**
IT investments				0.035***	0.035***
Non-performing loans	-0.022*	-0.022*	-0.021*	-0.020	-0.020
Total equity	-0.091***	-0.089***	-0.090***	-0.086***	-0.089***
Customer Deposits	-0.008	-0.008	-0.007	-0.008	-0.007
Liquid assets	0.001	0.001	-0.001	-0.001	-0.001
Gross loans	0.008	0.008	0.007	0.007	0.007
Cost-to-income ratio	-0.012**	-0.012**	-0.012**	-0.012**	-0.011**
Income diversification	-0.006*	-0.006*	-0.006*	-0.006*	-0.006*
Size	-0.601**	-0.546*	-0.642**	-0.522*	-0.655**
GDP per capita	-0.678	-0.560	-0.360	-0.331	-0.576
GDP growth	-0.004	-0.005	-0.006	-0.006	-0.005
Concentration	0.022**	0.021**	0.021**	0.020**	0.021**
Number of observations	1516	1516	1516	1516	1516
R-squared	0.100	0.097	0.099	0.105	0.111

The regression table reports the association between our **Digitalisation Index** and banks' profitability (ROA).

The **composite digitalisation index is positive and statistically significant** - This challenges the “IT profitability paradox”, indicating that, in our setting, digital transformation is on average associated with higher bank performance.

The improvement is mainly driven by:

- **Network efficiency** (leaner branch networks and higher assets per employee)
- **IT investment** (higher IT-related intangibles)

By contrast, the **digital channels factor** (apps and website usage) is positively signed but **not statistically significant**.

On its own, front-end digital adoption does not translate into a robust, measurable effect on profitability.

Results – Pre vs post Covid period

	Dependent variable: ROA			
	(1)	(2)	(3)	(4)
<i>Panel A. Covid-19</i>				
Post-Covid Dummy		0.226***	0.240***	0.363***
Digitalization index		0.010*		
PCD*DI		0.006*		
Digital channel development			0.008	
PCD*DCD			0.046*	
Network efficiency				0.039**
PCD*NE				-0.013**
IT investments				
PCD*II				0.025***
Number of observations	1516	1516	1516	1516
Bank controls	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes
R-squared	0.106	0.106	0.108	0.111

N.B. PCD = Post-Covid Dummy; DI = Digitalization index, DCD = Digital channels development; NE = Network efficiency; II = IT investments

We re-estimate the models allowing for a **post-Covid shift**, to test whether the digitalisation–performance link changed after 2020.

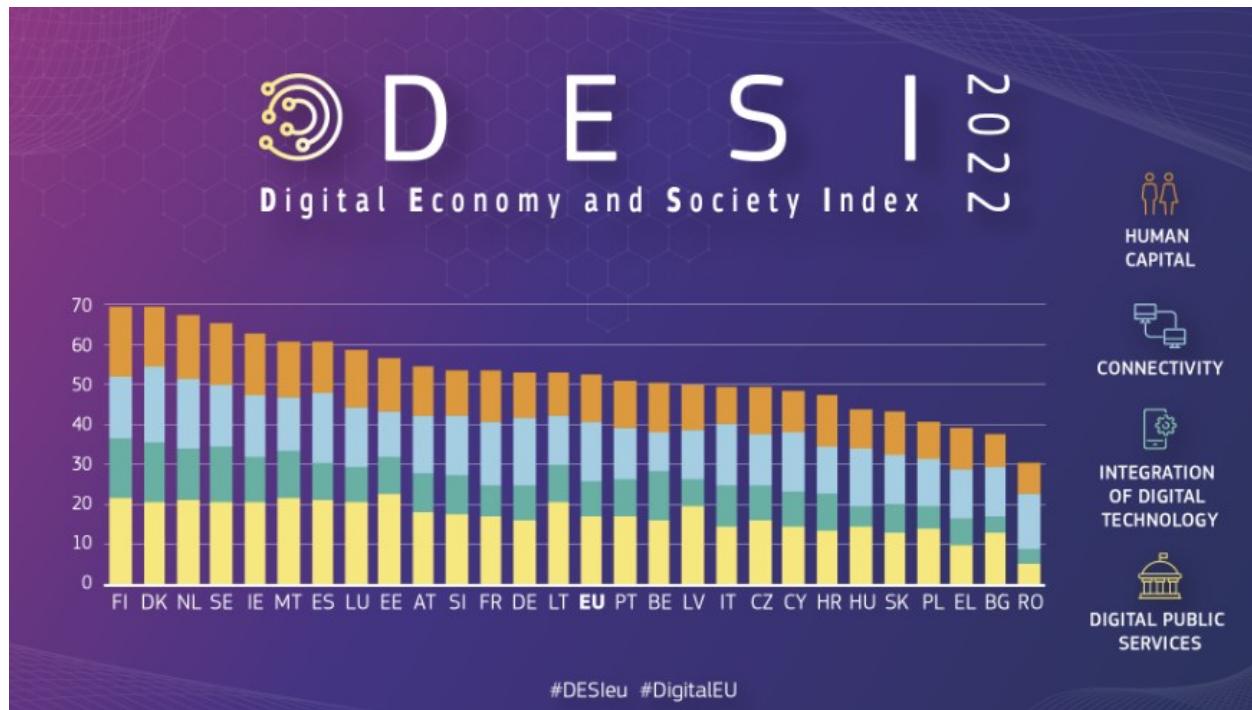
Stronger overall effect of digitalisation after 2020 - In the post-Covid years, more digital banks exhibit **significantly higher profitability**, suggesting that digital capabilities helped absorb the operational and economic shock.

Digital channels become performance-relevant only after Covid - Before 2020, apps and online platforms had no clear impact on performance; in the post-Covid period, their coefficient turns positive and significant, in line with the surge in customer adoption.

IT investment–performance link intensifies - The payoff to IT capital deepening is stronger after Covid, consistent with greater reliance on technology-intensive processes.

Network efficiency remains positive, but with weaker marginal gains - Branch and staff rationalisation still supports performance, although the incremental benefit of further downsizing is smaller in the post-Covid years.

DESI Index



What is the DESI Index and why do we use it?

DESI (Digital Economy and Society Index) is a composite indicator developed by the European Commission to track the **digital maturity of EU countries**. It summarises four main pillars:

- **Human capital** – basic and advanced digital skills in the population
- **Connectivity** – coverage and quality of fixed and mobile broadband networks
- **Integration of digital technology** – adoption of digital tools and processes by firms
- **Digital public services** – availability and effective use of e-government services

Why is DESI relevant for our analysis?

- It provides a **standardised, EU-wide measure of the digital environment**, allowing us to control for cross-country differences in digital maturity.
- Using DESI, we can test whether the **payoff of bank-level digitalisation depends on the surrounding ecosystem** (infrastructure, skills, firm adoption, public services).
- Its four pillars help us interpret which dimensions of the national digital context are more closely associated with banks' performance.

Results – Country IT levels

	Dependent variable: ROA			
	(5)	(6)	(7)	(8)
<i>Panel B. Country IT level</i>				
High-tech country Dummy	0.121	0.094	0.124	0.077
Digitalization index	0.014*			
HTD*DI	0.008			
Digital channel development		0.006		
HTD*DCD		0.011**		
Network efficiency			0.024**	
HTD*NE			0.008	
IT investments				0.032***
HTD*II				0.012**
Number of observations	1516	1516	1516	1516
Bank controls	Yes	Yes	Yes	Yes
Country controls	Yes	Yes	Yes	Yes
R-squared	0.130	0.128	0.130	0.136

N.B. DI = Digitalization index, DCD = Digital channels development ; NE = Network efficiency; II = IT investments. HTD = High-tech country variable. HTD equals 1 for countries in the top 25% of the DESI index distribution, 0 otherwise

To examine whether the impact of digitalisation depends on the broader technological environment, we split countries according to their position in the **DESI** distribution. We distinguish between:

- **High-tech digital economies (HTD):** countries in the top 25% of the DESI distribution

- **Lower-tech digital economies:** all remaining countries

This allows us to assess whether national digital maturity amplifies or dampens banks' own digital efforts.

Key Findings

Stronger performance effects in HTD countries - The marginal impact of bank-level digitalisation on profitability is clearly larger where the surrounding economy is already highly digitalised.

Digital channels benefit from digitally mature customers - Apps and online platforms are more effective in contexts with high digital literacy and widespread use of online financial services.

IT investments are more productive in favourable ecosystems

- When infrastructures and skills are in place, banks are better able to translate IT spending into efficiency gains and higher returns.

Results – Non-linear relationship

	Dependent variable: ROA			
	(1)	(2)	(3)	(4)
Digitalization index	0.019**			
Digitalization index^2	-0.000			
Digital channel development		0.010		
Digital channel development^2		-0.000		
Network efficiency			0.053**	
Network efficiency^2			-0.005**	
IT investments				-0.050**
IT investments^2				0.008***
Non-performing loans	-0.022*	-0.021*	-0.021	-0.020
Total equity	-0.090***	-0.089***	-0.090***	-0.087***
Customer Deposits	-0.008	-0.008	-0.006	-0.008
Liquid assets	0.001	0.001	-0.001	-0.001
Gross loans	0.008	0.008	0.007	0.007
Cost-to-income ratio	-0.012**	-0.012**	-0.012**	-0.011**
Income diversification	-0.006*	-0.006*	-0.006*	-0.006
Size	-0.601**	-0.547*	-0.683**	-0.485
GDP per capita	-0.696	-0.569	-0.380	-0.407
GDP growth	-0.004	-0.005	-0.006	-0.006
Concentration	0.022**	0.021**	0.021**	0.020**
Number of observations	1516	1516	1516	1516
R-squared	0.100	0.097	0.101	0.109

Exploring Non-Linear Effects of Digitalisation

To assess whether the impact of digitalisation on bank performance is linear or varies across different levels of digital maturity, we augment the baseline specification by including the squared terms of our digitalisation measures. This allows us to test for **non-linearities**, such as diminishing marginal returns or threshold effects, in a standard flexible functional form.

Composite Digitalisation Index - The overall index exhibits a **stable and positive marginal effect** across the distribution. Banks that increase their digital maturity continue to experience performance gains, with no evidence of saturation or reversal at higher levels of digitalisation.

Network Efficiency - For network efficiency, the squared term indicates **diminishing returns**. Once physical networks have already been substantially downsized, further reductions contribute little to additional performance improvements—and may, in some cases, start constraining business capacity or service quality.

IT Investment - The non-linear specification confirms the well-known **J-shaped pattern** of IT investment. Initial increases in IT capital tend to depress efficiency because of implementation costs, organisational adjustment, and temporary disruptions. Over time, however, as systems stabilise and complementary processes adapt, the marginal effect turns positive, reflecting productivity gains.

Additional tests

Two-step GMM model

	Dependent variable: ROA			
	(1)	(2)	(3)	(4)
L.ROA	1.014*** (0.362)	0.846*** (0.301)	0.701** (0.329)	0.304** (0.146)
Digitalisation index	0.065* (0.035)			
Digital channel development		0.015 (0.032)		
Network efficiency			0.053** (0.098)	
IT investments				0.021** (0.010)
Observations	1,237	1,237	1,237	1,237
Number of bvd	279	279	279	279
Year FE	Yes	Yes	Yes	Yes
Cluster SE Bank	Yes	Yes	Yes	Yes
AR(2) P-value	0.640	0.513	0.531	0.484
Hansen p-value	0.699	0.406	0.492	0.448

Granger causality test

Variable	Coef.	Std.Err	Z	P> z	[95% Conf. Interval]
Digitalization index	0.28	0.005	6.16	0.000	0.190 0.037
L.ROA					
HPJ Wald test	38.002				
P-value	0.000				

Endogeneity issues

- We employ a dynamic **system GMM** estimator (two-step) with Windmeijer-corrected standard errors.
- Second-order lags and differences of the dependent variable are used as instruments, while the remaining explanatory variables are treated as strictly exogenous.

Granger-causality check

- We run **Granger-style causality tests** between digitalisation and bank performance.
- Results indicate that changes in digitalisation **precede and help predict** subsequent profitability, whereas the reverse link is weaker.

Robustness check

- We use **ROE** as an alternative performance measure, obtaining qualitatively similar results.

Conclusions

- **Digitalisation can enhance bank performance**, but having an app or a website is not enough. Meaningful gains require **substantial IT investment**, organisational simplification, and the ability to embed technology into core processes.
 - **Digital channels alone do not generate competitive advantages** unless they are aligned with a broader strategic transformation—governance, processes, incentives, and delivery models need to evolve together.
 - **Effects are non-linear:**
 - IT investments increase costs in the short run, but their benefits materialise gradually through efficiency, scale, and data-driven decision-making.
 - Excessive downsizing of the physical network may weaken customer relationships and limit service capacity.
 - **Post-Covid dynamics have amplified digital gaps.** Banks that were technologically prepared weathered the shock better and strengthened their market position.
 - **Country-level technological readiness matters.** In more digitalised economies, the returns to digital transformation are **stronger, more persistent, and more evenly distributed across banks**.
- 👉 **Digitalisation works — but only when supported by a coherent vision, sustained investment, and an enabling environment.**

Thank you!
