

The Paradox of Progress: Technological Advancements in Banking and the Dual Impact on SMEs Bank Borrowing & Performance

Julia Korosteleva (University College London)

(in co-authorship with)

Aneta Hryckiewicz (Kozminski University)

Lukasz Kozlowski (Kozminski University)

Malwina Rzepka (Kozminski University)

Ruomeng Wang (University College London)

OPUS research project funded via National Science Centre of Poland scheme (2020-23) “The Effect of New Technology of Banking Sector in the EU and SMEs lending”

Conference on European Economic Integration (CEEI 2025)

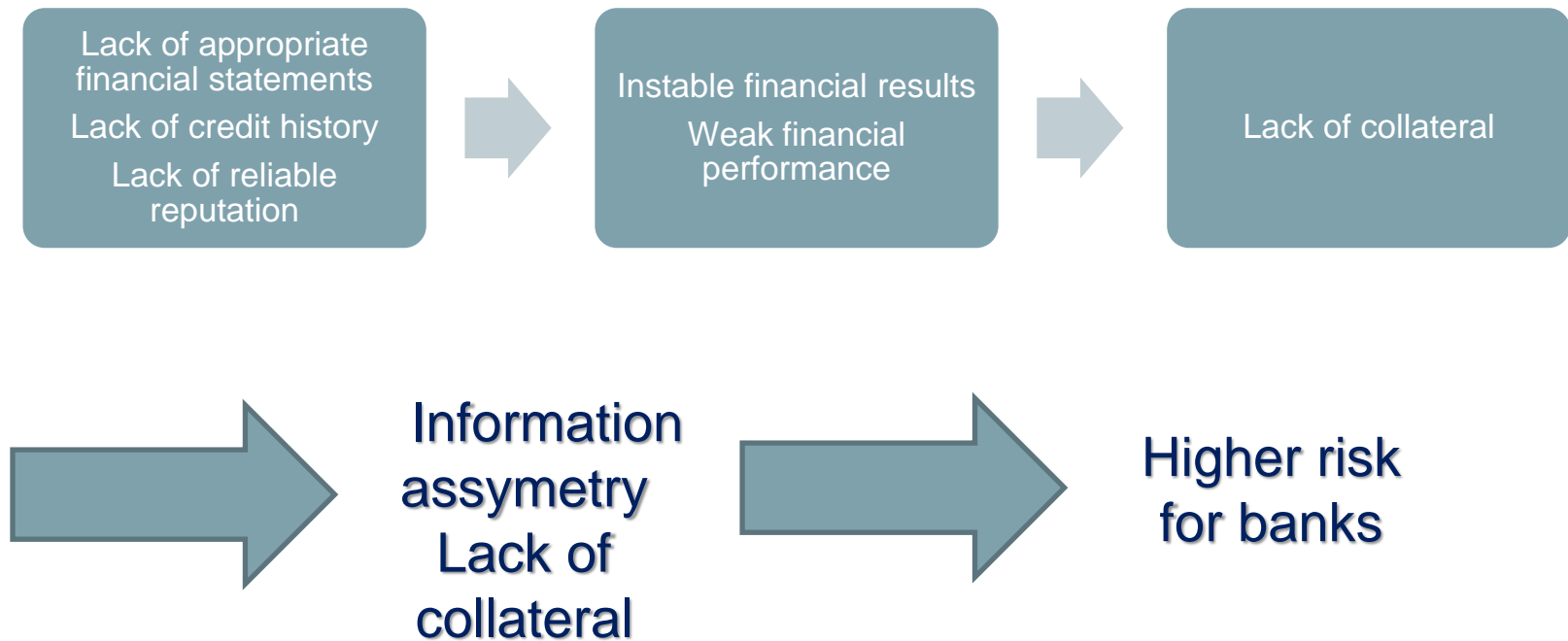
Hosted by the Oesterreichische Nationalbank (OeNB), Vienna

21 November 2025

Motivation

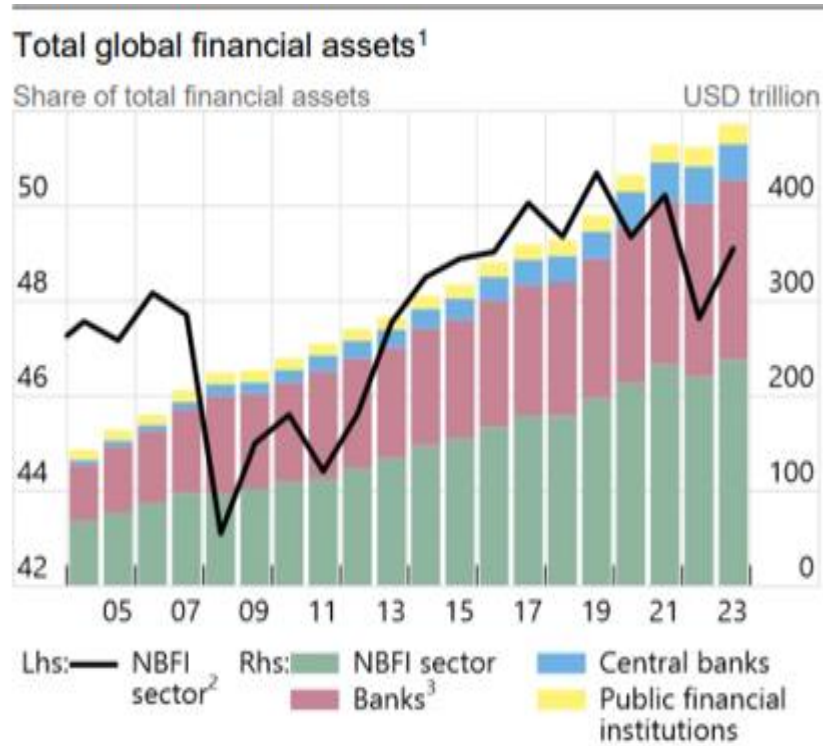
- We explore to what extent the advancements in bank digital technology help ease financial constraints for Small and Medium-sized enterprises (SMEs) with further implications for SMEs' performance
- Why focus on SMEs?
 - In Europe, SMEs account for **99% of the enterprise population**, and account for more than half of its GDP and employment.
 - The availability of lending and cost of finance have been well-documented in the literature as **a major constraint on growth opportunities for small and medium-sized enterprises** (Beck et al., 2006; Gorodnichenko and Schnitzer, 2010; Bottazzi et al., 2014; Berlingieri et al., 2020).
 - Almost 70% of SMEs do not use the external financing from banks, and another 15% are underfinanced (World Bank, 2017).

Why do SMEs exhibit higher financial constraints compared to larger firms?



Financial exclusion of SMEs

Financial Sector changes in the era of digital technology



- Share of NBFI assets has increased substantially over the past decades
- OFIs represent the largest share of NBFI (26.3% of total global financial assets vs. 38.8% for traditional banks)
- The role of banks ‘digitalisation is understudied, especially with focus on SMEs

Source: Assets of financial intermediaries globally, [FSB, 2024](#)

Theoretical Arguments & Empirical Evidence

- Financial technology reduces information frictions **via greater information availability and data sharing** (Ghosh et al., 2021; Ouyang, 2022)
- **More precise algorithms, data diversity & access to real-time transaction data** allow banks to compute the credit risks more precisely (Yang et al., 2023; Zheng et al., 2022); this **eases the collateral requirements** (Gambacorta et al., 2023).
- Technological digital solutions substitute for the relationship-based banking reliant on **physical branches** (Behr et al., 2020); **the application process is faster** (Fuster et. al., 2019).
- Digital solutions **optimize operational and regulatory costs** at banks, and improve banks' efficiency (Wang et. al., 2021; Lee et al., 2021).

But...the positive effects may not materialize (Philippon, 2017); lack of relationship with the borrowers observed in automated lending procedures **may push borrowers into moral hazard** (Di Maggio et al, 2021).

Sample

Year	Countries	Observations	% of observations
2009	10	7,395	0.7
2010	12	30,061	3.0
2011	12	74,473	7.4
2012	12	68,994	6.9
2013	13	103,770	10.3
2014	13	116,038	11.6
2015	13	119,877	11.9
2016	14	129,938	12.9
2017	14	133,456	13.3
2018	14	134,228	13.4
2019	15	85,178	8.5
All years	15	1,003,408	100.0

Banks affiliated with a firm	Observations	% of observations
1	717759	71.5
2	202319	20.2
3	63290	6.3
4	16677	1.7
5	3363	0.3
All observations	1,003,408	100.0

179,921 SMEs

54 European banks

Austria, Croatia, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Latvia, Poland, Portugal, Slovenia, Spain, and the UK.

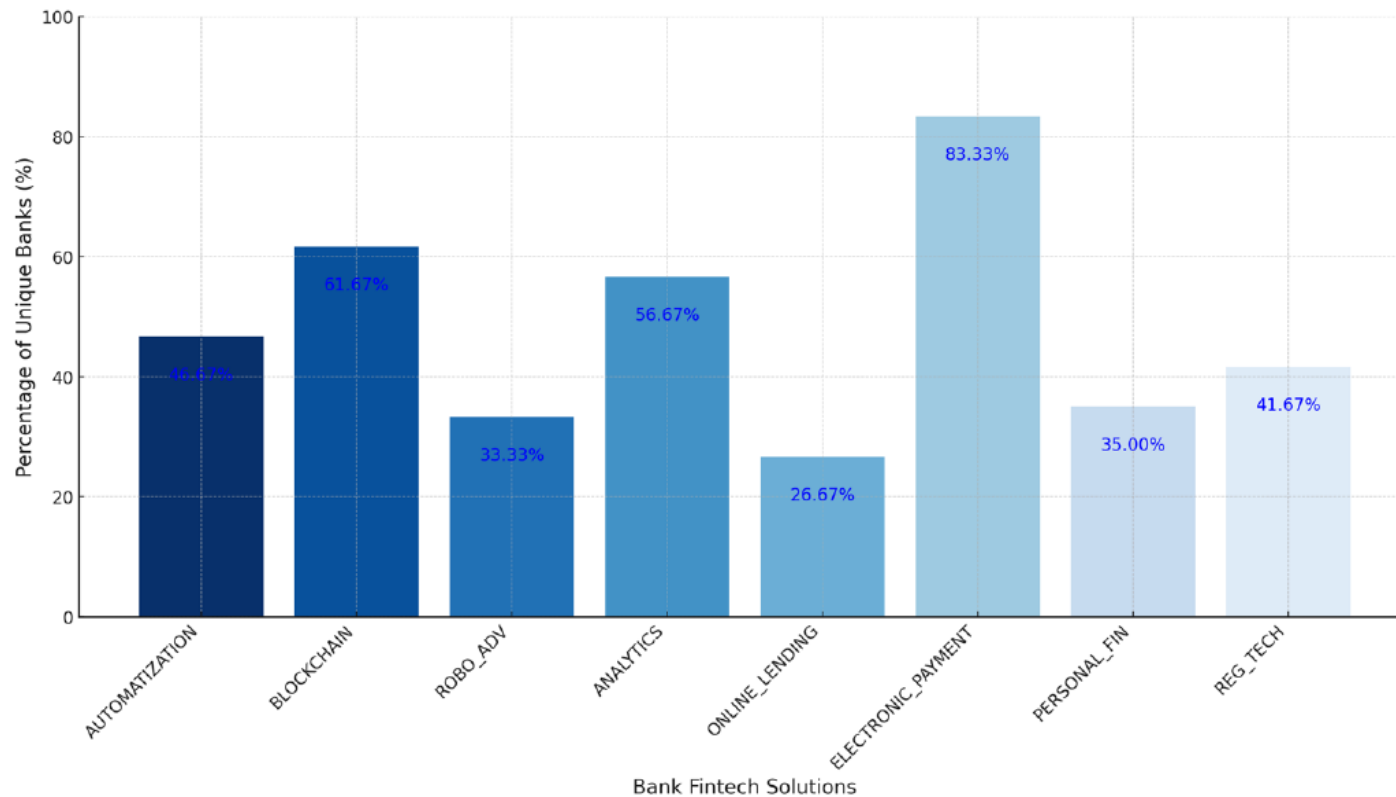
Period: 2009 - 2019

Banks' financial innovation

- automation software (AUT.SOFT)
- blockchain technology (BLOCKCHAIN)
- data analytics (ANALYTICS)
- lending solutions (LENDING)
- payments (PAYMENTS)
- personal finance (PERSON.FIN)
- regulatory technology (REGULAT)
- sum of the seven abovementioned variables (INNOV.ALL)

Sources: Crunchbase, CBInsights, banks' financial statements & public announcements

Percentage usage of individual technological solutions by banks



Methodology

- Address the issues of endogeneity due to unobserved heterogeneity of firms & possible bi-directional causality b/n SMEs' borrowing & bank innovation solutions
 - A two-way FEs model
 - Diff-in-Diff
- Robustness checks
 - Instrumental Variable approach
 - Using alternative measures of bank innovation from GlobalData database from Innovation Scoreboard
 - (i) a number of filed patents;
 - (ii) a number of granted patents by a bank; and
 - (iii) a number of deals a bank has been involved as a Venture Capitalist (VC)

Methodology (1/2): a two-way FE model

Dependent variables:

DEBT.GR
ST.DEBT.GR
LT.DEBT.GR
INT.COST

Control variables:

Firm's control variables:

- Profitability ratio (EBIT to sales ratio)
- FIXED.ASSET (value of fixed asset to total asset)
- EQUITY (Equity to firm total asset)
- ASSET.TURN (sales to total assets)
- FIRM.SIZE (ln firm's turnover)
- LN.FIRM.AGE (ln years in operation)

Bank control variables:

- BANK.SIZE (ln of assets)
- BANK.LOANS (loans to asset ratio)
- Bank equity ratio (BANK.EQUITY)
- Bank deposit growth (BANK.DEPO.GR)

Country's control variables:

- GDP.GROWTH (GDP growth rate)
- UNEMPL (unemployment rate)
- GDP.PC (GDP per capita)
- PRI.CREDIT (domestic credit to private sector by banks to a¹⁰ country's GDP)

$$\text{DEP}_{i,t} = f \left(\begin{array}{c} \text{FIRM}_{i,t-1} \\ \text{MAIN.BANK}_{j,t-1} \\ \text{COUNTRY}_{c,t} \\ \text{BANK.INNOV}_{j,t-1} \\ \text{firm fixed effects} \\ \text{year fixed effects} \end{array} \right),$$

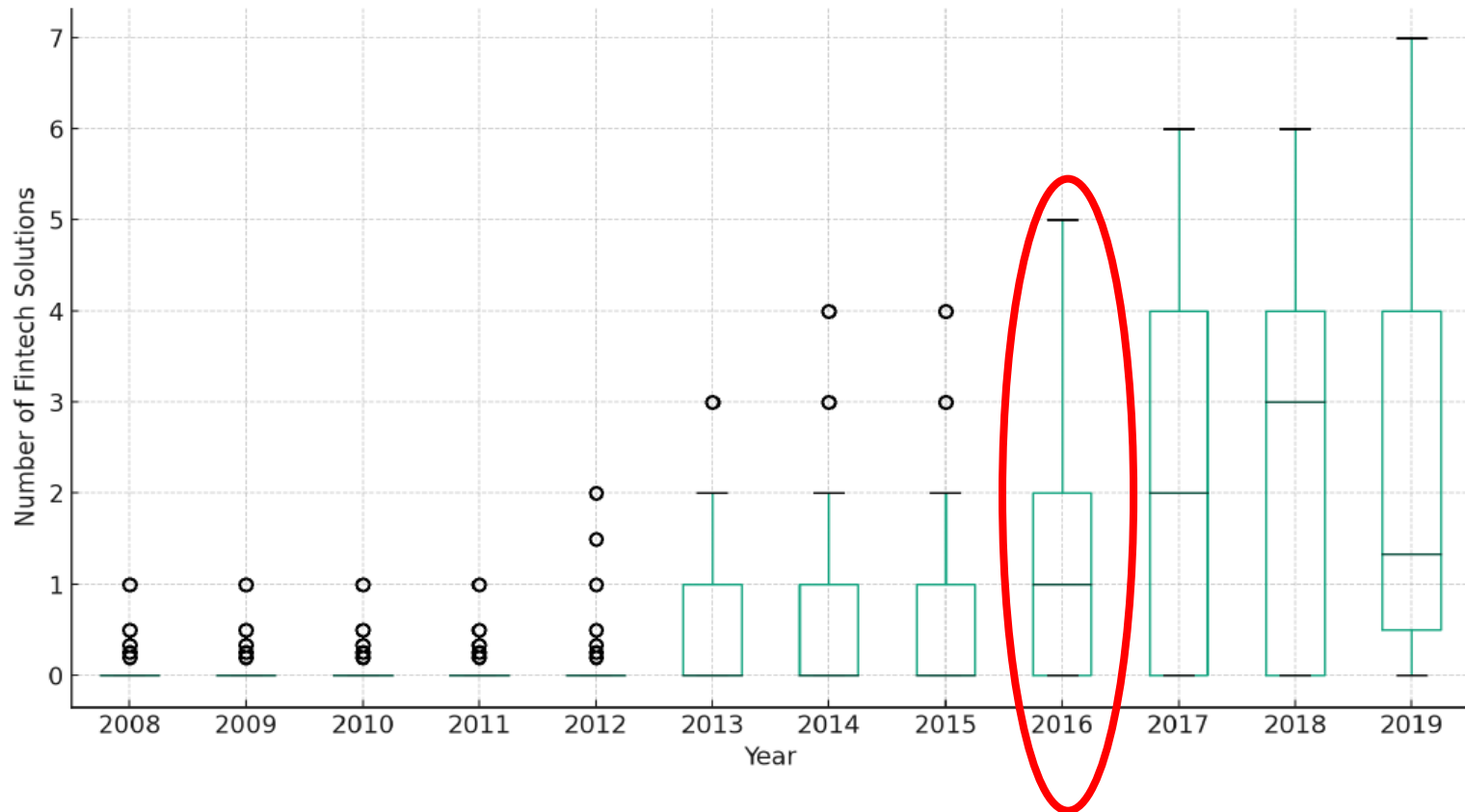
Methodology (2/2): DID

$$\text{DEP}_{i,t} = f \left(\begin{array}{l}
 \text{FIRM}_{i,t-1} \\
 \text{MAIN. BANK}_{j,t-1} \\
 \text{HIGH. DIGITAL}_{j,t} \\
 \text{COUNTRY}_{c,t} \\
 \text{HIGH. DIGITAL}_{j,t} * \text{TreatmentYear} \\
 \text{firm fixed effects} \\
 \text{year fixed effects}
 \end{array} \right)$$

Treatment Group & Year

- High Digital bank=1 if adopted at least 5 solutions in a given year (=95th centile of the distribution)
- Maximum Digital=1 if reached the maximum of solutions (i.e. 7 solutions)
- Treatment Year >= 2016
 - ✓ Adoption of the Payment Services Directive (PSD2) by the European Commission at the end of 2015

The Number of Bank Technology Solutions over time



- Bank digitalisation **increases SMEs' credit access** with effect being stronger for **long-term** credit growth
- But...Bank digitalisation **increases the borrowing costs for SMEs**
- **Collateral** becomes **less important** at financially innovative banks.
- A differentiated impact of bank technology solutions on credit provision
 - **Blockchain, automation and data analytics** play more important role in improving SMEs' access to credit
- Digital transformation in banking influences SMEs sales growth mainly through financing channels rather than directly. Bank digitalisation boosts both short- and long-term lending, strengthening SMEs' financial capacity, yet these gains are partially offset by higher intermediation costs

Policy recommendations

- Policy initiatives regarding the digitalisation of financial services are important to **increase the access to finance** in the context of Europe, though **they are not fully sufficient to impact the cost of financial services** which may still provide a hurdle for SMEs on average to access the bank credit.
- To foster financial inclusion and growth for SMEs, regulators should incentivize the adoption of specific technology solutions

THANK YOU

Any questions?



Additional slides for Q&A

Descriptive Stats

This table presents descriptive statistics for the sample.

Variable	Observations	Firms	Mean	Std.Dev.	Min.	1st Quart.	2nd Quart.	3rd Quart.	Max.
<i>A. Dependent variables</i>									
DEBT_GR	1,003,408	179,921	-0.004	0.116	-0.547	-0.042	-0.016	0.006	0.856
INT_COST	629,578	128,922	0.086	0.274	-0.057	0.007	0.029	0.064	4.003
LT_DEBT_GR	1,001,487	179,830	-0.008	0.098	-0.547	-0.036	-0.016	0.003	0.763
ST_DEBT_GR	1,002,321	179,867	-0.008	0.069	-0.536	-0.024	-0.012	0.003	0.756
<i>B. Other firm-level variables</i>									
PROFIT	1,003,408	179,921	0.026	0.159	-2.000	0.007	0.028	0.070	0.600
FIXED_ASSETS	1,003,408	179,921	0.299	0.259	0.000	0.075	0.231	0.473	1.000
LOW_COLLAT	977,667	176,325	0.499	0.500	0.000	0.000	0.000	1.000	1.000
EQUITY	1,003,408	179,921	0.466	0.264	0.000	0.246	0.450	0.679	1.000
ASSET_TURN	1,003,408	179,921	1.679	1.514	0.000	0.750	1.303	2.102	14.999
FIRM_SIZE	1,003,408	179,921	-0.268	1.688	-10.125	-1.392	-0.229	0.835	3.912
LN_FIRMAGE	1,003,408	179,921	2.724	0.818	0.000	2.398	2.890	3.219	5.541
DIGITAL_FIRM	1,731,608	173,161	0.030	0.171	0.000	0.000	0.000	0.000	1.000
HIGH_CAPITAL	1,731,608	173,161	0.014	0.117	0.000	0.000	0.000	0.000	1.000
<i>C. Country-level variables</i>									
PRLCREDIT	1,003,408	179,921	1.081	0.366	0.324	0.937	1.112	1.306	1.921
GDP_GROWTH	1,003,408	179,921	0.017	0.022	-0.143	0.007	0.020	0.029	0.084
GDP_PC	1,003,408	179,921	35.385	5.202	21.024	31.305	35.969	38.906	86.550
UNEMPL	1,003,408	179,921	0.155	0.067	0.031	0.097	0.153	0.214	0.275
<i>D. Bank fundamentals</i>									
BANK_SIZE	1,003,408	179,921	12.073	1.502	8.252	10.920	12.301	13.288	14.625
BANK_LOANS	1,003,408	179,921	0.597	0.093	0.131	0.561	0.595	0.655	0.863
BANK_EQUITY	1,003,408	179,921	0.080	0.031	0.011	0.063	0.070	0.081	0.224
BANK_DEPO_GR	1,003,408	179,921	0.055	0.105	-0.424	-0.003	0.034	0.085	1.311
<i>E. Financial innovations at a bank</i>									
AUT_SOFT	1,003,408	179,921	0.223	0.375	0.000	0.000	0.000	0.500	1.000
BLOCKCHAIN	1,003,408	179,921	0.153	0.338	0.000	0.000	0.000	0.000	1.000
ANALYTICS	1,003,408	179,921	0.134	0.301	0.000	0.000	0.000	0.000	1.000
LENDING	1,003,408	179,921	0.191	0.348	0.000	0.000	0.000	0.333	1.000
PAYMENTS	1,003,408	179,921	0.266	0.422	0.000	0.000	0.000	0.500	1.000
PERSON_FIN	1,003,408	179,921	0.089	0.260	0.000	0.000	0.000	0.000	1.000
REGULAT	1,003,408	179,921	0.238	0.387	0.000	0.000	0.000	0.500	1.000
BANK_INNOV	1,003,408	179,921	1.294	1.770	0.000	0.000	0.000	2.000	7.000
HIGH_DIGITAL	1,731,608	173,161	0.138	0.345	0.000	0.000	0.000	0.000	1.000
MAX_DIGITAL	1,643,512	164,351	2.750	2.096	0.000	1.000	3.000	4.000	7.000
<i>F. Alternative innovation measures at a bank</i>									
FILINGS	228,182	39,145	8.902	11.378	0.000	1.000	5.000	9.000	56.000
GRANTS	228,182	39,145	2.554	2.647	0.000	1.000	2.000	4.000	27.000
CVC_DEALS	228,182	39,145	1.850	1.790	0.000	1.000	1.000	3.000	10.000
SC_FILINGS	228,182	39,145	0.663	0.847	0.000	0.071	0.377	0.682	4.013
SC_GRANTS	228,182	39,145	0.190	0.197	0.000	0.071	0.150	0.301	1.935
SC_CVC_DEALS	228,182	39,145	0.137	0.127	0.000	0.071	0.075	0.207	0.694

Results (1/5): a FE model

VARIABLES	(1) DEBT.GR	(2) LT.DEBT.GR	(3) ST.DEBT.GR
L.BANK.INNOV	0.00109*** (0.000166)	0.000984*** (0.000137)	0.000240** (0.000101)
L.FIX_A	-0.0573*** (0.00171)	-0.0634*** (0.00145)	0.00627*** (0.000856)
L.EBIT_S	-0.00573*** (0.00120)	-0.00643*** (0.00104)	0.000909 (0.000639)
L.EQUITY	0.135*** (0.00144)	0.0909*** (0.00119)	0.0393*** (0.000747)
L.TAT	0.0140*** (0.000283)	0.00819*** (0.000213)	0.00508*** (0.000151)
L.LN_SALES	-0.0100*** (0.000461)	-0.00628*** (0.000375)	-0.00282*** (0.000252)
L.LN_FIRM_AGE	-0.0135*** (0.000958)	-0.00906*** (0.000757)	-0.00456*** (0.000516)
PRICREDIT	0.0165*** (0.00218)	0.0234*** (0.00179)	0.00394*** (0.00119)
GDPGROWTH	0.331*** (0.0150)	0.286*** (0.0120)	0.215*** (0.00939)
GDPPCPPP	-0.000544* (0.000324)	-0.000439* (0.000251)	-0.00167*** (0.000189)
UNEMPL	-0.223*** (0.0172)	-0.194*** (0.0137)	-0.177*** (0.00944)
L.BANK_LN_ASSETS	-0.00122 (0.00120)	-0.00176* (0.000990)	-0.00554*** (0.000698)
L.BANK_LOANS	-0.00919** (0.00436)	-0.00696* (0.00377)	-0.0140*** (0.00246)
L.BANK_EQUITY	-0.0299** (0.0129)	-0.000445 (0.0107)	-0.0289*** (0.00790)
L.BANK_DEPO_GR	0.00253* (0.00137)	0.00277** (0.00112)	0.00285*** (0.000880)
Constant	0.0335* (0.0175)	0.0384*** (0.0148)	0.142*** (0.00953)
Obs.	1,003,408	1,034,658	1,011,309
R-squared	0.043	0.036	0.041
Number of FIRM_ID	179,921	183,557	180,751
Time FE	YES	YES	YES
Firm FE	YES	YES	YES

Results (2/5): DID

VARIABLES	(1) DEBT.GR	(2) LT.DEBT.GR	(3) ST.DEBT.GR	(4) DEBT.GR	(5) LT.DEBT.GR	(6) ST.DEBT.GR
YEAR2016_DUMMY*HIGH.DIGITAL	0.00341*** (0.000578)	0.00273*** (0.000455)	0.00118*** (0.000364)			
YEAR2016_DUMMY *MAX.DIGITAL				0.00108*** (0.000137)	0.000918*** (0.000115)	0.000468*** (8.06e-05)
L.FIX_A	-0.0573*** (0.00171)	-0.0634*** (0.00145)	0.00626*** (0.000856)	-0.0572*** (0.00171)	-0.0633*** (0.00145)	0.00629*** (0.000856)
LEBIT_S	-0.00570*** (0.00120)	-0.00641*** (0.00104)	0.000914 (0.000639)	-0.00573*** (0.00120)	-0.00644*** (0.00104)	0.000900 (0.000639)
LEQUITY	0.135*** (0.00144)	0.0908*** (0.00118)	0.0393*** (0.000747)	0.135*** (0.00144)	0.0909*** (0.00119)	0.0394*** (0.000747)
L.TAT	0.0140*** (0.000283)	0.00819*** (0.000213)	0.00508*** (0.000151)	0.0140*** (0.000283)	0.00818*** (0.000213)	0.00508*** (0.000151)
LLN_SALES	-0.0100*** (0.000461)	-0.00629*** (0.000375)	-0.00282*** (0.000252)	-0.0101*** (0.000461)	-0.00631*** (0.000375)	-0.00283*** (0.000252)
LLN_FIRM_AGE	-0.0135*** (0.000957)	-0.00909*** (0.000757)	-0.00455*** (0.000516)	-0.0133*** (0.000959)	-0.00893*** (0.000758)	-0.00444*** (0.000517)
PRICREDIT	0.0153*** (0.00219)	0.0224*** (0.00180)	0.00358*** (0.00119)	0.0180*** (0.00220)	0.0247*** (0.00180)	0.00470*** (0.00121)
GDPGROWTH	0.325*** (0.0149)	0.280*** (0.0120)	0.215*** (0.00927)	0.339*** (0.0151)	0.293*** (0.0122)	0.222*** (0.00940)
GDPPCPPP	-0.000716** (0.000320)	-0.000600** (0.000247)	-0.00169*** (0.000187)	-0.000763** (0.000319)	-0.000645*** (0.000246)	-0.00170*** (0.000186)
UNEMPL	-0.235*** (0.0170)	-0.205*** (0.0135)	-0.179*** (0.00931)	-0.227*** (0.0170)	-0.199*** (0.0135)	-0.175*** (0.00941)
L.BANK_LN_ASSETS	-0.000302 (0.00119)	-0.000963 (0.000991)	-0.00532*** (0.000692)	-0.00180 (0.00120)	-0.00220** (0.000995)	-0.00597*** (0.000707)
L.BANK_LOANS	-0.00649 (0.00431)	-0.00450 (0.00373)	-0.0136*** (0.00243)	-0.0143*** (0.00449)	-0.0110*** (0.00390)	-0.0171*** (0.00257)
L.BANK_EQUITY	-0.0317** (0.0129)	-0.00205 (0.0107)	-0.0286*** (0.00790)	-0.0298** (0.0129)	-0.000674 (0.0107)	-0.0273*** (0.00789)
L.BANK_DEPO_GR	0.00140 (0.00135)	0.00167 (0.00110)	0.00272*** (0.000864)	0.00153 (0.00134)	0.00179 (0.00110)	0.00286*** (0.000860)
Constant	0.0305* (0.0175)	0.0361** (0.0149)	0.141*** (0.00954)	0.0499*** (0.0176)	0.0522*** (0.0148)	0.149*** (0.00965)
Observations	1,003,408	1,034,658	1,011,309	1,003,408	1,034,658	1,011,309
R-squared	0.043	0.036	0.041	0.043	0.036	0.041
Number of FIRM_ID	179,921	183,557	180,751	179,921	183,557	180,751
Time FE	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES

Results (3/5): Bank Digital Solutions

VARIABLES	(1) LT.DEBT.GR	(2) LT.DEBT.GR	(3) LT.DEBT.GR	(4) LT.DEBT.GR	(5) LT.DEBT.GR	(6) LT.DEBT.GR	(7) LT.DEBT.GR	(8) LT.DEBT.GR
L. ELECTRONIC.PAYMENTS	-0.00219*** (0.000691)							-0.000 (0.000677)
L. ONLINE.LENDING		-0.00309*** (0.000735)						-0.00179** (0.000897)
L. PERSONAL_FIN			0.000702 (0.000690)					-0.000635 (0.000858)
L. ANALYTICS				-0.000165 (0.000728)				0.00175** (0.000738)
L. REG_TECH					-0.000231 (0.000746)			0.00108 (0.000813)
L. BLOCKCHAIN						0.00309*** (0.000629)		0.00457*** (0.000648)
L. AUTOMATIZATION							0.000738 (0.000641)	0.00213*** (0.000663)
L.BANK.INNOV	0.00144*** (0.000195)	0.00146*** (0.000180)	0.000919*** (0.000151)	0.00100*** (0.000159)	0.00102*** (0.000191)	0.000491*** (0.000166)	0.000901*** (0.000156)	
Constant	0.0416*** (0.0149)	0.0349** (0.0149)	0.0379** (0.0149)	0.0383*** (0.0149)	0.0383*** (0.0148)	0.0321** (0.0150)	0.0402*** (0.0150)	0.0339** (0.0152)
Observations	1,034,658	1,034,658	1,034,658	1,034,658	1,034,658	1,034,658	1,034,658	1,034,658
R-squared	0.036	0.036	0.036	0.036	0.036	0.036	0.036	183.557
Number of FIRM_ID	183,557	183,557	183,557	183,557	183,557	183,557	183,557	0.036
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

VARIABLES	(1) ST.DEBT.GR	(2) ST.DEBT.GR	(3) ST.DEBT.GR	(4) ST.DEBT.GR	(5) ST.DEBT.GR	(6) ST.DEBT.GR	(7) ST.DEBT.GR	(8) ST.DEBT.GR
L. ELECTRONIC.PAYMENTS	-0.00493*** (0.000503)							-0.00400*** (0.000495)
L. ONLINE.LENDING		-0.00139** (0.000555)						0.00107 (0.000728)
L. PERSONAL_FIN			0.000702 (0.000690)					0.000712 (0.000629)
L. ANALYTICS				0.000928* (0.000542)				0.00253*** (0.000558)
L. REG_TECH					0.000732 (0.000711)			-0.000577 (0.000818)
L. BLOCKCHAIN						0.00209*** (0.000456)		0.00334*** (0.000497)
L. AUTOMATIZATION							0.00167*** (0.000474)	0.00131** (0.000520)
L.BANK.INNOV	0.00126*** (0.000141)	0.000456*** (0.000143)	0.000919*** (0.000151)	0.000145 (0.000123)	0.000115 (0.000165)	-9.26e-05 (0.000119)	5.16e-05 (0.000110)	
Constant	0.150*** (0.00960)	0.141*** (0.00955)	0.0379** (0.0149)	0.143*** (0.00953)	0.142*** (0.00953)	0.138*** (0.00959)	0.146*** (0.00971)	0.146*** (0.00978)
Observations	1,011,309	1,011,309	1,034,658	1,011,309	1,011,309	1,011,309	1,011,309	1,011,309
R-squared	0.041	0.041	0.036	0.041	0.041	0.041	0.041	180.751
Number of FIRM_ID	180,751	180,751	183,557	180,751	180,751	180,751	180,751	0.041
Time FE	YES	YES	YES	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES

Results (4/5): The role of collateral

VARIABLES	(1) DEBT.GR	(2) DEBT.GR	(3) LT.DEBT.GR	(4) ST.DEBT.GR
COLLATERAL*BANK.INNOV	0.00606*** (0.000406)			
LOW.COLLATERAL*BANK.INNOV		0.00177*** (0.000171)	0.00198*** (0.000136)	-3.80e-06 (0.000105)
L.LOW.COLLATERAL		-0.0263*** (0.000635)	-0.0267*** (0.000524)	0.000304 (0.000345)
BANK.INNOV	-5.04e-05 (0.000205)	0.000868*** (0.000197)	0.000432*** (0.000166)	0.000823*** (0.000117)
L.COLLATERAL	-0.0615*** (0.00177)	-0.0772*** (0.00192)	-0.0833*** (0.00163)	0.00656*** (0.000949)
L.EBIT_S	-0.00612*** (0.00120)	-0.00541*** (0.00120)	-0.00607*** (0.00104)	0.000867 (0.000639)
L.EQUITY	0.135*** (0.00144)	0.136*** (0.00144)	0.0914*** (0.00118)	0.0395*** (0.000747)
L.TAT	0.0140*** (0.000284)	0.0144*** (0.000284)	0.00860*** (0.000213)	0.00507*** (0.000151)
L.LN_SALES	-0.00997*** (0.000461)	-0.0107*** (0.000461)	-0.00702*** (0.000375)	-0.00280*** (0.000252)
L.LN_FIRM_AGE	-0.0127*** (0.000961)	-0.0136*** (0.000956)	-0.00929*** (0.000755)	-0.00436*** (0.000517)
PRICREDIT	0.0197*** (0.00219)	0.0190*** (0.00219)	0.0253*** (0.00179)	0.00521*** (0.00121)
GDPGROWTH	0.357*** (0.0155)	0.359*** (0.0155)	0.308*** (0.0124)	0.232*** (0.00978)
GDPCCPPP	-0.000545* (0.000322)	-0.000411 (0.000321)	-0.000316 (0.000248)	-0.00158*** (0.000187)
UNEMPL	-0.223*** (0.0170)	-0.234*** (0.0169)	-0.204*** (0.0134)	-0.177*** (0.00930)
L.BANK_LN_ASSETS	-0.00306** (0.00121)	-0.00216* (0.00121)	-0.00241** (0.000996)	-0.00635*** (0.000707)
L.BANK_LOANS	-0.0141*** (0.00445)	-0.0140*** (0.00443)	-0.0104*** (0.00384)	-0.0175*** (0.00254)
L.BANK_EQUITY	-0.0286** (0.0129)	-0.0324** (0.0129)	-0.00272 (0.0106)	-0.0272*** (0.00788)
L.BANK_DEPO_GR	0.00259* (0.00135)	0.00263* (0.00135)	0.00266** (0.00110)	0.00344*** (0.000864)
Constant	0.0543*** (0.0175)	0.0603*** (0.0175)	0.0621*** (0.0148)	0.149*** (0.00958)
Observations	1,003,165	1,003,408	1,034,658	1,011,309
R-squared	0.043	0.046	0.041	0.041
Number of FIRM_ID	179,904	179,921	183,557	180,751
Time FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES

Results (5/5): Cost of Intermediation

VARIABLES	(1) INT.COST	(2) INT.COST	(3) INT.COST	(4) INT.COST
YEAR2016_DUMMY*BANK.INNOV		0.00150** (0.000657)		
BANK.INNOV	0.000441 (0.000468)	-0.00185** (0.000851)		
YEAR2016_DUMMY*HIGH.DIGITAL			0.00342** (0.00156)	
YEAR2016_DUMMY*MAX.DIGITAL				0.000834** (0.000406)
L.FIX_A	-0.0541*** (0.00437)	-0.0541*** (0.00437)	-0.0541*** (0.00437)	-0.0540*** (0.00437)
L.EBIT_S	0.00262 (0.00300)	0.00263 (0.00300)	0.00263 (0.00300)	0.00261 (0.00300)
L.EQUITY	0.0832*** (0.00450)	0.0831*** (0.00450)	0.0832*** (0.00449)	0.0832*** (0.00449)
L.TAT	0.0148*** (0.00105)	0.0148*** (0.00105)	0.0148*** (0.00105)	0.0148*** (0.00105)
L.LN_SALES	-0.0101*** (0.00128)	-0.0101*** (0.00128)	-0.0101*** (0.00128)	-0.0101*** (0.00128)
L.LN_FIRM_AGE	-0.0209*** (0.00325)	-0.0210*** (0.00325)	-0.0208*** (0.00325)	-0.0208*** (0.00325)
PRICREDIT	-0.0179* (0.0100)	-0.0167* (0.00991)	-0.0194* (0.00990)	-0.0179* (0.00984)
GDPGROWTH	0.231*** (0.0453)	0.230*** (0.0458)	0.233*** (0.0453)	0.242*** (0.0458)
GDPPCPPP	0.00488*** (0.00120)	0.00481*** (0.00119)	0.00490*** (0.00118)	0.00475*** (0.00118)
UNEMPL	0.492*** (0.0667)	0.494*** (0.0653)	0.490*** (0.0649)	0.492*** (0.0651)
L.BANK_LN_ASSETS	-0.00493 (0.00381)	-0.00337 (0.00389)	-0.00442 (0.00373)	-0.00529 (0.00379)
L.BANK_LOANS	-0.00890 (0.0119)	-0.00572 (0.0117)	-0.00673 (0.0120)	-0.00973 (0.0119)
L.BANK_EQUITY	0.0677* (0.0379)	0.0739* (0.0381)	0.0743** (0.0378)	0.0796** (0.0379)
L.BANK_DEPO_GR	-0.000584 (0.00368)	-0.00122 (0.00359)	-0.000603 (0.00351)	-0.000923 (0.00350)
Constant	0.00303 (0.0570)	-0.0174 (0.0575)	-0.00316 (0.0570)	0.0122 (0.0574)
Observations	634,770	634,770	634,770	634,770
R-squared	0.012	0.012	0.012	0.012
Number of FIRM_ID	129,387	129,387	129,387	129,387
Time FE	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES

SME's specific characteristics (digital intensity)

The Table presents the regression results for firm- and year-fixed-effect panel models examining the impact of bank technological innovation on SMEs' borrowing. DEBT.GR represents the growth of an SME's combined short-term and long-term bank debt at time t , divided by the previous year's total assets (inflation-adjusted). LT.DEBT.GR indicates the growth of an SME's long-term credit at time t , while ST.DEBT.GR denotes the growth of the SME's short-term credit. BANK.INNOV is defined as the number of technological solutions adopted by bank i at time t . DIGITAL.FIRM denotes all firms operating in the digital sector, classified according to NACE codes. This category includes codes such as Computer programming activities (NACE: 6201), Computer consultancy activities (NACE: 6202), Computer facilities management activities (NACE: 6203), Other information technology and computer service activities (NACE: 6209), Data processing, hosting, and related activities (NACE: 6311), Web portals (NACE: 6312), Publishing of computer games (NACE: 5821), Other software publishing (NACE: 5829), and Retail sale via mail order houses or via the Internet (NACE: 4791). For brevity, coefficients for the year dummy variables are not presented. Standard errors, clustered at the firm level, are shown in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	(1) DEBT.GR	(2) LT.DEBT.GR	(3) ST.DEBT.GR
YEAR2016_DUMMY*DIGITAL.FIRM	0.000238 (0.00161)	-0.00212* (0.00127)	0.00142 (0.000900)
L.BANK.INNOV	0.00109*** (0.000166)	0.000982*** (0.000138)	0.000242** (0.000101)

The table presents the regression results for firm- and year-fixed-effect panel models examining the impact of bank technological innovation on SMEs' borrowing. DEBT.GR represents the growth of an SME's combined short-term and long-term bank debt at time t , divided by the previous year's total assets (inflation-adjusted). LT.DEBT.GR indicates the growth of an SME's long-term credit at time t , while ST.DEBT.GR denotes the growth of the SME's short-term credit. BANK.INNOV is defined as the number of technological solutions adopted by bank i at time t . DIGITAL.FIRM refers to all firms operating in the digital sector, classified according to NACE codes. This category includes Computer programming activities (NACE: 6201), Computer consultancy activities (NACE: 6202), Computer facilities management activities (NACE: 6203), Other information technology and computer service activities (NACE: 6209), Data processing, hosting, and related activities (NACE: 6311), Web portals (NACE: 6312), Publishing of computer games (NACE: 5821), Other software publishing (NACE: 5829), and Retail sale via mail order houses or via the Internet (NACE: 4791). HIGH.DIGITAL denotes highly digitalized banks, defined as those exceeding four technological solutions adopted. For brevity, coefficients for the year dummy variables are not presented. Standard errors, clustered at the firm level, are shown in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

VARIABLES	(1) DEBT.GR	(2) LT.DEBT.GR	(3) ST.DEBT.GR
HIGH.DIGITAL	0.00341*** (0.000582)	0.00284*** (0.000459)	0.00110*** (0.000365)
HIGH.DIGITAL *DIGITAL.FIRM	0.000217 (0.00360)	-0.00400 (0.00249)	0.00309 (0.00260)

IV approach

This panel presents the results of the second-stage regressions of the instrumental variable of bank technological innovation on SMEs access to bank credit. We instrumentalize BANK.INNOV with yearly IT spendings of the firm's main bank divided by the bank's total assets. For brevity, we do not present coefficients for firm- (PROFIT, FIXED.ASSETS, EQUITY, ASSET.TURN, LN.FIRM.AGE, and FIRM.SIZE), country- (PRI.CREDIT, GDP.GROWTH, GDP.PC, and UNEMPL), and bank-level control variables (BANK.SIZE, BANK.LOANS, BANK.EQUITY, and BANK.DEPO.GR), the constant term, and year dummy variables. Robust standard errors are shown in parentheses. *, **, *** refer to significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)
Dependent variable:	DEBT.GR	LT.DEBT.GR	ST.DEBT.GR	INT.COST
BANK.INNOV _{t-1}	0.00742*** (0.00224)	0.00984*** (0.00213)	0.00442*** (0.00147)	-0.000951 (0.00358)
Observations	712,380	740,726	716,827	527,096
Kleibergen–Paap rk LM (underidentification test)	2205	1599	2065	3593
Kleibergen–Paap rk LM, p-value	0	0	0	0
Kleibergen–Paap rk Wald F (weak identification test)	1976	1443	1858	3112
Cragg–Donald Wald F (weak identification test)	2353	1807	2186	4089

alternative measures of bank innovation

This panel presents the results of the second-stage regressions of the instrumental variable of bank technological innovation on SMEs access to bank credit. DEBT.GR is a SME growth of total sum of short-term and long-term bank debt in time t divided by the previous year's total assets (inflation-adjusted). For brevity, we do not present coefficients for firm- (PROFIT, FIXED.ASSETS, EQUITY, ASSET.TURN, LN.FIRMAGE, and FIRM.SIZE), country- (PRI.CREDIT, GDP.GROWTH, GDP.PC, and UNEMPL), and bank-level control variables (BANK.SIZE, BANK.LOANS, BANK.EQUITY, and BANK.DEPO.GR), the constant term, and year dummy variables. Standard errors clustered at the firm-level are shown in parentheses. *, **, *** refer to significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Impact on debt growth

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable:	DEBT.GR _{<i>t</i>}	DEBT.GR _{<i>t</i>}	DEBT.GR _{<i>t</i>}	DEBT.GR _{<i>t</i>}	DEBT.GR _{<i>t</i>}	DEBT.GR _{<i>t</i>}
Regressor used as BANK.INNOV:	FILINGS _{<i>t</i>}	GRANTS _{<i>t</i>}	CVC.DEALS _{<i>t</i>}	SC.FILINGS _{<i>t</i>}	SC.GRANTS _{<i>t</i>}	SC.CVC.DEALS _{<i>t</i>}
BANK.INNOV _{<i>t</i>}	8.61e-05** (4.03e-05)	0.000465*** (0.000177)	0.000787** (0.000352)	0.00112** (0.000537)	0.00583** (0.00234)	0.0109** (0.00482)
Observations	228,182	228,182	228,182	228,182	228,182	228,182
Firms	39,145	39,145	39,145	39,145	39,145	39,145

Panel B. Impact on cost of debt

	(9)	(10)	(11)	(12)	(13)	(14)
Dependent variable:	INT.COST _{<i>t</i>}	INT.COST _{<i>t</i>}	INT.COST _{<i>t</i>}	INT.COST _{<i>t</i>}	INT.COST _{<i>t</i>}	INT.COST _{<i>t</i>}
Regressor used as BANK.INNOV:	FILINGS _{<i>t</i>}	GRANTS _{<i>t</i>}	CVC.DEALS _{<i>t</i>}	SC.FILINGS _{<i>t</i>}	SC.GRANTS _{<i>t</i>}	SC.CVC.DEALS _{<i>t</i>}
BANK.INNOV _{<i>t</i>}	-9.94e-05 (0.000135)	0.000103 (0.000393)	-0.00107 (0.00116)	-0.00136 (0.00180)	0.00110 (0.00537)	-0.0136 (0.0161)
Observations	176,249	176,249	176,249	176,249	176,249	176,249
Firms	34,126	34,126	34,126	34,126	34,126	34,126

Extending the analysis to the performance of SMEs using an instrumental variable (IV) approach

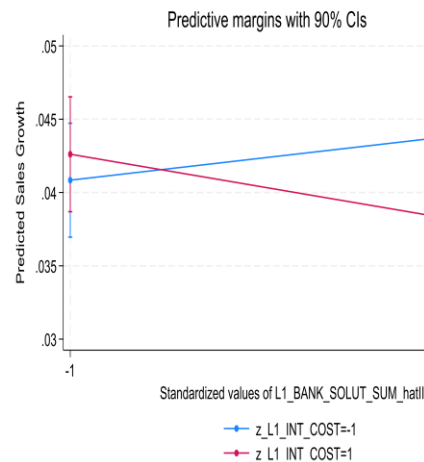
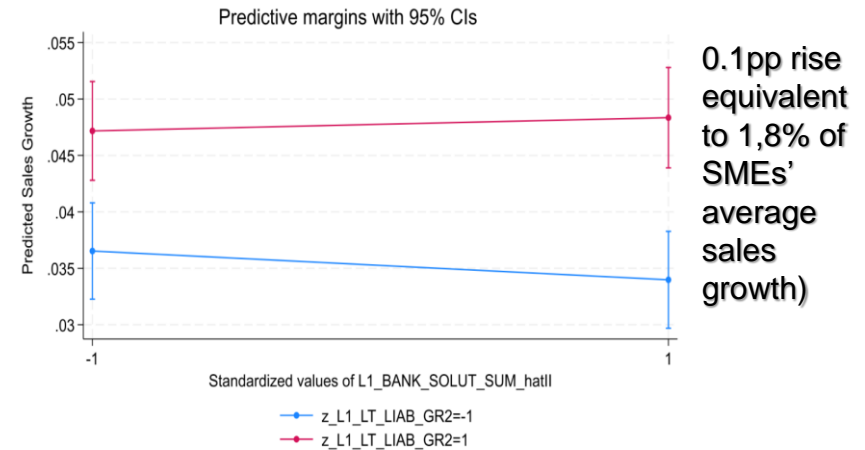
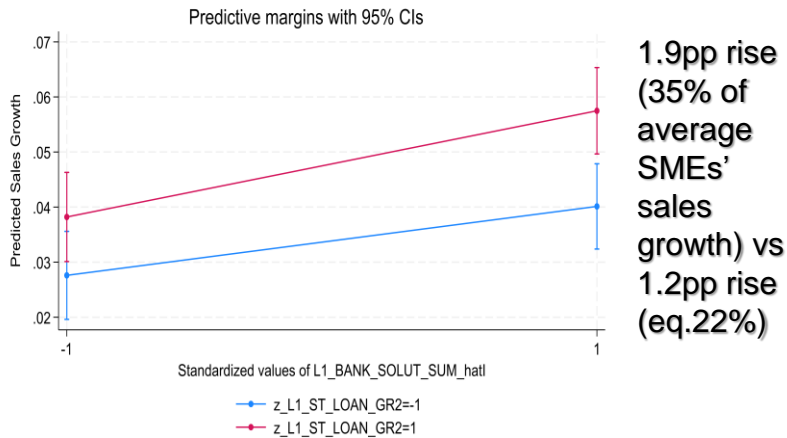
VARIABLES	(1) ST LOAN GR	(2) LT LIAB GR	(3) INT COST	(4) SALES GR
BANK_SOLUT_SUM_hatST	0.000* (0.000)			
BANK_SOLUT_SUM_hatLT		0.001*** (0.000)		
BANK_SOLUT_SUM_hatCOST			0.002* (0.001)	
BANK_SOLUT_SUM_hatSALES				-0.000 (0.001)
LEBIT_S	0.000 (0.001)	-0.004*** (0.002)	0.005 (0.003)	-0.046*** (0.009)
L.FIX_A	-0.000 (0.001)	-0.056*** (0.002)	-0.068*** (0.005)	-0.082*** (0.007)
LEQUITY	0.054*** (0.001)	0.130*** (0.002)	0.093*** (0.005)	-0.191*** (0.006)
L.TAT	0.012*** (0.000)	0.015*** (0.001)	0.018*** (0.001)	-0.039*** (0.002)
LLN_SALES	-0.003*** (0.000)	-0.010*** (0.001)	-0.012*** (0.001)	-0.352*** (0.003)
LLN_FIRM_AGE	-0.002** (0.001)	-0.015*** (0.002)	-0.012*** (0.003)	-0.045*** (0.005)
L.ST_LOANS	-0.090*** (0.001)	0.087*** (0.001)	0.002 (0.003)	0.005** (0.002)
L.BANK_BRANCHES	0.000 (0.000)	0.000*** (0.000)	-0.000 (0.000)	-0.000 (0.000)
L.BANK_LN_ASSETS	-0.001 (0.001)	0.002* (0.001)	0.003 (0.003)	-0.000 (0.004)
L.BANK_LOANS	-0.001 (0.002)	-0.010** (0.004)	-0.006 (0.010)	0.009 (0.012)
L.FINTECH_CREDIT_USD_PC	-0.000** (0.000)	-0.001*** (0.000)	-0.001 (0.001)	-0.002*** (0.001)
L.GDPGROWTH	0.161*** (0.037)	0.258*** (0.084)	0.181** (0.090)	0.538*** (0.131)
iq1	0.034*** (0.002)	0.046*** (0.004)	0.048*** (0.007)	0.081*** (0.008)
iq2	0.015*** (0.001)	0.024*** (0.003)	0.033*** (0.005)	0.034*** (0.006)
iq3	0.003** (0.001)	0.008*** (0.002)	0.017*** (0.004)	0.008* (0.005)
iq4	0.001 (0.001)	-0.006** (0.002)	0.005 (0.004)	0.006 (0.004)
Constant	-0.003 (0.010)	-0.107*** (0.018)	0.027 (0.040)	0.452*** (0.050)
Observations	594,446	492,629	532,531	588,296
R-squared	0.123	0.085	0.013	0.199
Number of FIRM_ID	104,349	96,933	98,432	104,418
FIRM FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) SALES_GR via BANK_SOLUT _hatII
z_L1_BANK_SOLUT_SUM_hatII	-0.000 (0.002)
z_L1_ST_LOAN_GR2	0.007*** (0.001)
c.z_L1_BANK_SOLUT_SUM_hatII#c.z_L1_ST_LOAN_GR2	0.001 (0.001)
z_L1_LT_LIAB_GR2	0.006*** (0.001)
c.z_L1_BANK_SOLUT_SUM_hatII#c.z_L1_LT_LIAB_GR2	0.001 (0.001)
z_L1_INT_COST	-0.001 (0.001)
c.z_L1_BANK_SOLUT_SUM_hatII#c.z_L1_INT_COST	-0.002*** (0.001)
LEBIT_S	-0.032** (0.014)
L.FIX_A	-0.076*** (0.009)
LEQUITY	-0.198*** (0.009)
L.TAT	-0.030*** (0.002)
LLN_SALES	-0.439*** (0.005)
LLN_FIRM_AGE	0.087*** (0.008)
L.ST_LOANS	0.004 (0.003)
Constant	0.019 (0.096)
Observations	338,451
R-squared	0.219
Number of FIRM_ID	77,562
FIRM FE	YES
Year FE	YES

Robust standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The impact of instrumented Bank Technology solutions on SMEs' sales growth



The magnitude in the divergence in sales growth associated with the rise of cost of intermediation is about 0.6pp (eq. 11% of growth)