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EXPLORING THE IMPACT OF ICT DIFFUSION IN THE EUROPEAN BANKING INDUSTRY: EVIDENCE IN THE PRE- AND POST-COVID-19

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Based on daily data from Thomson Reuter's Refinitiv, we investigate the effect of information and communication technology (ICT) on the profitability and risk of the European banking industry during the COVID-19 pandemic. Specifically, we empirically examine whether and how ICT diffusion affects banks' stock return, credit default swaps (CDS) spreads and market volatility over the period spanning from January 1, 2020, to March 31, 2020. Our evidence demonstrates that ICT improves banks' performance measures and reduces risks. These effects are more significant in the post-COVID-19 period.

Keywords: Stock markets; COVID-19 outbreak; banks; ICT.

JEL Classifications: E52, E58, G14, G21

1. Introduction

Advances in Information and Communication Technology (ICT) over recent decades have profoundly reshaped the operation of the financial industry, facilitating complete information and data dissemination, reducing information asymmetries, and furthering the rapid diffusion of financial innovations worldwide (Marszk &

Lechman 2021). The recent COVID-19 pandemic — that swept the world causing unprecedented effects — brought to light the importance of ICT diffusion to resolving the challenges caused by the pandemic and responding to restrictions due to lockdown measures. Like most industries, the financial sector has been hit hard by the coronavirus. Banks have been forced to adopt new and digitalized ways of working, migrating their workers to remote setups, deal with an unprecedented influx in the demand of digital financial services, navigate cybersecurity and compliance issues, and manage high deferral rates among customers. ICT solutions have represented the key to banks' strategy in fighting back against the COVID-19 crisis in such complex circumstances. Despite ICT adoption and its effects on the banking industry have received remarkable attention in academia (Beccalli 2007, Casolaro & Gobbi 2007, Scott *et al.* 2017), to date, empirical evidence on how ICT access and use affect banks' performance and risk profiles is quite fragmented and lacking in robustness.

This study aims to fill this gap in the literature by investigating the effect of ICT on the profitability and risk of the European banking industry during the COVID-19 pandemic. Specifically, we empirically examine whether and how ICT diffusion affects banks' stock return, credit default swaps (CDS) spreads and market volatility pre and post the COVID-19 outbreak. To this end, we use daily data from Thomson Reuter's Refinitiv on European listed banks. We performed event studies on banks' returns and risks inside the period spanning from January 1, 2020, to March 31, 2020. As discussed in detail below, results reveal that the diffusion of ICT in terms of the internet exerts a twofold positive impact on the European banking sector. Indeed, although in the post-COVID-19 periods, there is a decline in stock returns, banks operating in countries with greater internet diffusion recorded a 3.4% increase in absolute returns (p-value < 0.01) and a 3.5% increase in abnormal returns (p-value < 0.05). When we consider the relationship between ICT diffusion and banking risk, the results show a positive association between ICT diffusion and bank stability. Specifically, ICT diffusion reduces market volatility (Volatility $\beta = -0.080$, p-value < 0.01; Idiosyncratic Volatility $\beta = -0.067$, p-value < 0.01) and default risk (CDS spread $\beta = -0.022$, p-value < 0.01).

The findings support the theory that better dissemination of information may limit bank insolvency risk and improve stability, especially in times of extreme uncertainty created by the COVID-19 pandemic. Results related to the IT payment channel (i.e. the ATM ratio) show that banking profitability — both in the pre- and post-COVID period — is not significantly associated with the level of employed automated teller machines. Therefore, ATM penetration does not significantly affect the potential market recovery after the COVID crisis, and investors do not consider it an added value. Although there is no doubt about the importance of ATMs for the further developments of the banking industry, some researchers have found a lack of proportionality between the increase in the scale of technology utilization and the increase in banks' profitability (Le & Ngo 2020). Finally, overall results reveal that the diffusion of automated teller machines reduces stock market volatility, but this effect does not persist in the post-COVID-19 period.

This study offers a twofold contribution to the literature. First, it adds to the ongoing debate on the economic impact of ICT in the banking industry. The scant research conducted to date has produced mixed results on whether and how significantly ICT affects banking performance and risk (Scott *et al.* 2017). No consensus has been reached yet, and the results on the economic effects of ICT in the banking industry are still controversial. Here, research is urgently needed, especially with the current fourth wave of FinTech innovation led by new technological developments and implementations and embedded finance. Second, this paper contributes to the literature on the effects of the COVID-19 crisis by investigating the impact of ICT diffusion on the banking industry in the pre- and post-pandemic periods.

The rest of the paper is organized as follows. Section 2 discusses the related literature and the development of our hypotheses. In Sec. 3, we describe our data set, summary statistics, and methodology. In Sec. 4, we report our results. Finally, in Sec. 5, we report our conclusions.

2. Related Literature and Testable Hypotheses

Innovations in information processing, telecommunications, and related technologies have played a significant role in developing and consolidating the banking industry over the years (Berger 2003). The heated debates of the 1980s and 1990s on the ambiguity of the economic impact of ICT adoption and on what has been defined as the *productivity paradox*[a] (Roach 1991, Brynjolfsson 1993) seem to have ultimately confirmed positive results from ICT investments on a range of measures relating to banks' performance (Beccalli 2007, DeYoung *et al.* 2007).

In their seminal paper on disruptive technologies, Bower & Christensen (1995) noted that "one of the most consistent patterns in business is the failure of leading companies to stay at the top of their industries when technologies or markets change". The advent of disruptive technologies has changed the structure and the competitive landscape of the banking industry. In such a dynamic scenario, ICT adoption has been essential for banks' competitiveness since it enables quick responses to a dynamic market and helps the banks improve their business productivity. In the modern global world, there are not the largest banks that the competitive advantages get but the ones that are the most adapted to changes. The existing literature highlights how ICT has made the banking sector more innovative and competitive because of the advancements in information and communications technologies. ICT adoption has enabled banks to improve information processing on customer deposits and loans and collect and sort borrowers more efficiently, reducing banking insolvency risk and ameliorating its stability (Berger & Mester 2003).

[a] The productivity paradox, also referred to as the Solow paradox, has been defined as a perceived discrepancy between investment measures in information technology and measures of output at the national level. This perceived paradox was characterized by Robert Solow's famous quote that "*you can see the computer age everywhere but in the productivity statistics*" (Solow 1987).

By embracing ICT, banks have enhanced their ability to store and manage semi-structured and unstructured data in real-time and process payments more quickly and with fewer resources. At the same time, banks have exploited economies of scale and scope that derive from standardized IT-supported processes by reducing operational costs and efforts to provide customized products and value-added services (Marinč 2013). Technological progress has also helped banks increase overall productivity in terms of improved quality and variety of banking services (Berger 2003). Scott *et al.* (2017) showed that the adoption and diffusion of ICT facilitate the business processes and transactions commonly used in banking (e.g. payments, confirmations, financial reporting, pre-trade, trade, and post-trade activities) and help us to increase sales and reduce long-term operating costs, which, in turn, positively affect banking profitability.

Several studies have documented the positive impact of Internet technologies' adoption on bank performance (Furst *et al.* 2002, DeYoung *et al.* 2007, Hernando & Nieto 2007, Ciciretti *et al.* 2009). By influencing the nature of the relationships between banks and their customers, the widespread availability of information technologies in general and the Internet in particular as a delivery channel has affected the mix of financial services produced by banks, how banks produce those services, and the resulting financial performances of those banks (DeYoung *et al.* 2007). In a recent study, Le & Ngo (2020) revealed that the IT-based methods of products and services delivery (i.e. bank cards, automated teller machines (ATMs) and point of sale (POS) terminals) enhance bank profitability. Therefore, the expansions of these channels in providing banking products and services should be further promoted. These findings are consistent with Schumpeter's Creative Destruction Theory (Schumpeter 1942), according to which technological advances and innovation are key drivers of economic growth and firm performance.

Despite supporting evidence that ICT enhances bank growth and boosts their performance, some studies have identified financial innovations as a source of systemic risks to bank financial stability and credibility and new risks associated with cybersecurity, fraud, and ethical issues. Specifically, financial innovations can be associated with lower bank stability. Several authors have pointed to distortions introduced by financial innovations, such as securitization and new derivative securities, and how they have contributed to aggressive risk-taking and reduction in lending standards, as the root cause of the 2007–2008 Global Financial Crisis (Instefjord 2005, Brunnermeier 2009, Diaz-Rainey & Ibikunle 2012, Fostel & Geanakoplos 2012, Gennaioli *et al.* 2012). Following the "innovation-fragility" hypothesis presented by Beck *et al.* (2016), financial innovation can also be associated with higher bank fragility through higher volatility of their profitability, especially in countries with larger securities markets and more restrictive regulatory frameworks. The widespread digitalization of operations and financial services delivery has exposed banks and other financial institutions to security threats resulting from cyber-attacks or data breaches (Uddin *et al.* 2020). Cybersecurity risk makes the global financial industry vulnerable and has a twofold adverse impact for direct losses from cybersecurity breaches and additional cyber overhead costs (Kopp *et al.* 2017, Aldasoro *et al.* 2020).

Given the active academic and policy debate on the effect of technology diffusion, there is a striking paucity of empirical studies of the real and financial implications of ICT in the banking sector (Beck *et al.* 2016). The need to clarify the relationship between ICT diffusion and banks' performances and risk has become even more urgent in light of the COVID-19 pandemic that has accelerated the diffusion of online banking and digital payments, reducing many consumers' dependence on cash traditional brick-and-mortar banks. There is still a lot to learn about the exact shape of this relationship, the contingencies and dynamic components that alter it, and the moderating and mediating factors that may affect its direction and strength. To address this, we empirically examine whether and how ICT diffusion affects banks' profitability and risks pre and post the COVID-19 pandemic. In capital markets, access to information is essential. ICT provides the opportunity to have accurate and timely information on the stock market that can be very sensitive to various changes resulting from the ICT diffusion. The previous literature review has reported positive results from ICT diffusion on a range of measures relating to bank performance. Since fluctuations in stock prices reflect investors' expectations on banks' future profitability (Fama 1990, Fama & French 1988) and are primarily driven by informational trades (Lee & Rui 2001), we hypothesize the following:

- **H1:** ICT diffusion positively influences the performance of European banks measured in terms of market returns after the COVID outbreak.

Measuring the total return variation explained by shocks to expected cash flows, time-varying expected returns, and shocks to expected returns are one way to judge the rationality of stock prices (Fama 1990). Furthermore, in this paper, we investigate the impact of ICT on banks' risk profiles. Specifically, we empirically examine the movement of bank CDS (Fiordelisi *et al.* 2020) and stock returns volatility (Albuquerque *et al.* 2020) in relation to the ICT diffusion over two different phases: pre- and post-COVID-19. We hypothesize that the COVID-19 outbreak had the effect of significantly reducing banks' credit risk and market volatility by amplifying the positive effect of ICT diffusion. Accordingly, we developed the following hypothesis:

- **H2:** ICT diffusion negatively affects European banks' risk (measured by return volatility and credit default spread (CDS)) after the COVID outbreak.

3. Data and Methodology

3.1. *Data and sample representativeness*

We collect data from different sources. Bank stock prices and the MSCI Europe index are from Datastream, and we consider the period from January 1, 2020, to March 31, 2020. Data on CDS spreads are from Markit. In line with previous empirical research (Fiordelisi *et al.* 2020, Hasan *et al.* 2016, Black *et al.* 2016, Acharya *et al.* 2014), we use the 5-year CDS contracts on senior debt securities because they are typically more liquid than other maturities as our additional risk measure in our analysis. The sample selection process consists of the following steps. First, we consider the universe of publicly listed banks in the European Union both on Datastream and Markit. Second, we focus only on those financial institutions classified as bank holding companies. Finally, we filter out banks for which the information on prices and CDS spreads is missing. This final step leads to a final sample of 38 banks from 14 European countries. The information related to ICT is gathered from the World Development Indicators published by the World Bank in 2020.

Table 1, Panel A, reports the sample of banks. Panel B shows the sample representativeness relative to the population of banks in the EU-14 over the sample period in terms of total assets. The sample accounts for more than 86% of the total assets of all banks in EU-14.[b]

Table 2 presents variable definitions and summary statistics. In terms of ICT indicators, the individual usage of Internet in percentage of total population (*Internet*) and ATM ratio (*ATM ratio*) average is, respectively, 0.878, and 0.053.[c] The bank stock return (*Returns*) equals −0.008 (−0.8%), and the MSCI Europe index returns (*Return MSCI Europe*) equals −0.004 (−0.4%). The abnormal return (*Abnormal return*) is estimated as the difference between the logarithm return (*Return*) of a bank and the CAPM beta times the logarithm return of the market. The CAPM beta is estimated using the daily returns during 2019 and the MSCI Europe as the market index. The abnormal returns average is −0.003 (−0.3%). Furthermore, we calculate the volatility of stock returns, both for raw (*Volatility*) and abnormal returns (*Idi. Volatility*) that equals, respectively, 0.031 and 0.023. Finally, the CDS spreads averages 1.334%.

Figure 1 evidences the geographical distribution of Internet usage (Panel A) and ATM ratio (Panel B) across the EU-14 during 2020. The figure presents five categories obtained using boxplot methodology, with green color representing more use of the Internet or higher level of ATM ratio. The highest *Internet* usage is observed in Northern European countries (i.e. Denmark, Norway, and Sweden). Most of the countries in Continental Europe (i.e. Belgium and Germany) are either second or third. The smallest Internet usage appears in the Southern European Countries (with the exclusion of Spain). In contrast, the highest value is observed in Continental Europe regarding the ATM ratio, followed by Northern European countries (except Sweden).

3.2. *Methodology and empirical design*

Using a panel estimation technique, we assess the link between bank market performance, risk, and ICT diffusion in the EU-14. Specifically, we regress our

[b] The EU-14 Countries are Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Greece (GR), Ireland (IE), Italy (IT), the Netherlands (NL), Norway (NO), Portugal (PT), Spain (ES), and Sweden (SE).

[c] It would be interesting to use the time of Internet usage and the number of innovative ATMs (ATM 2.0). Unfortunately, there are no data available for those variables.

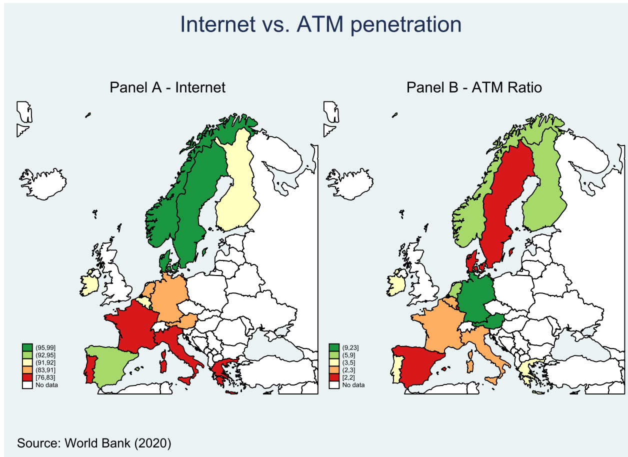
Table 1. Sample composition and representativeness.

Banks' name	Country code
Panel A — Sample composition	
ABN AMRO BANK NV	NL
AIB GROUP PUBLIC LIMITED COMPANY	IE
ALPHA BANK	GR
BANCA MONTE DEI PASCHI DI SIENA SPA	IT
BANCO BILBAO VIZCAYA ARGENTARIA SA	ES
BANCO BPM SPA	IT
BANCO COMERCIAL PORTUGUES, SA	PT
BANCO DE SABADELL SA	ES
BANCO SANTANDER SA	ES
BANKIA, SA	ES
BANKINTER SA	ES
BAWAG GROUP AG	AT
BNP PARIBAS	FR
CAIXABANK, S.A.	ES
COMMERZBANK AG	DE
CREDIT AGRICOLE SA	FR
DANSKE BANK A/S	DK
DEUTSCHE BANK AG	DE
ERSTE GROUP BANK AG	AT
ING GROEP NV	NL
INTESA SANPAOLO	IT
JYSKE BANK A/S	DK
KBC GROEP NV/ KBC GROUPE SA	BE
MEDIOBANCA — BANCA DI CREDITO FINANZI..	IT
NATIXIS SA	FR
NIBC HOLDING NV	NL
NORDEA BANK ABP	FI
PERMANENT TSB GROUP HOLDINGS P.L.C	IE
PIRAEUS FINANCIAL HOLDINGS SA	GR
RAIFFEISEN BANK INTERNATIONAL AG	AT
SKANDINAVISKA ENSKILDA BANKEN AB	SE
SOCIETE GENERALE	FR
STOREBRAND ASA	NO
SVENSKA HANDELSBANKEN AB	SE
SWEDBANK AB	SE
SYDBANK A/S	DK
UNICREDIT SPA	IT
UNIONE DI BANCHE ITALIANE SPA	IT
Panel B — Representativeness	
Sample: Total asset (billion euro)	26,880
EU-14: Total asset (billion euro)	31,084
Representativeness in %	86%

Notes: This table shows the composition and representativeness of the sample. Panel A reports the sample of banks. Panel B reports the representativeness of our sample in terms of total assets.

Table 2. Variables, definitions, and summary statistics.

Variables	Definitions	Obs.	Mean	Median	SD	p25	p75	Min	Max
Internet	Individuals using the Internet (% of population)	2470	0.878	0.913	0.071	0.833	0.932	0.761	0.970
ATM ratio	Ratio of ATMs to bank branches (automated teller machines (ATMs) per 100,000 adults; mobile cellular subscriptions (per 100 people))	2470	0.053	0.027	0.058	0.023	0.052	0.021	0.226
COVID	Dummy variable that equals one from February 24, 2020 to March 31, 2020, and zero from January 1, 2020 to February 23, 2020 (Albuquerque *et al.* 2020, Ramelli & Wagner 2020)	2470	0.415	0.000	0.493	0.000	1.000	0.000	1.000
Return	Bank stock return.	2470	−0.008	−0.003	0.048	−0.020	0.010	−0.274	0.270
Return MSCI Europe	The MSCI Europe index stock return.	2470	−0.004	0.000	0.027	−0.008	0.007	−0.141	0.085
Abnormal return	The abnormal daily return is the difference between the daily logarithm return (i.e. the logarithm of return) of a stock and the CAPM beta times the daily logarithm return of the market, expressed as a percentage. The CAPM beta is estimated using daily returns during 2019, where the market index is MSCI Europe.	2470	−0.003	−0.001	0.034	−0.015	0.010	−0.316	0.244
Volatility	Volatility of daily logarithm returns (15 days moving average)	2470	0.031	0.020	0.026	0.013	0.041	0.005	0.146
Idi. volatility	Volatility of daily abnormal return (15 days moving average)	2470	0.023	0.016	0.018	0.011	0.030	0.004	0.124
CDS spreads (in %)	The five-year CDS spreads contracts on senior debt securities.	2469	1.334	0.605	2.113	0.388	1.202	0.191	10.346



Notes: The figure presents the geographical distribution of the individuals using the Internet (Panel A) and ATM Ratio (Panel B) across the European countries analyzed. The distribution is based on the value of individuals using the Internet (in terms of the total populations) during 2020 (source: World Bank). The figure presents five categories based on boxplot methodology. Green colors represent a high level of individuals who use the Internet (Panel A) and ATM ratio (Panel B).

Fig. 1. The use of Internet and ATM ratio across European countries analyzed.

dependent variables of market performance and risk on two different measures of ICT diffusion. The baseline regression model is specified as follows:

$$y_{i,t} = \beta_0 + \beta_1 COVID_t + \beta_2 ICT_{i,t} + \beta_3 ICT_{i,t} \times COVID_t + \sum_{k=j}^{n} \beta_j x_{i,t} + \epsilon_{i,t}, \qquad (1)$$

where i denotes a bank, t is the time dimension representing the period from January 1, 2020 to March 31, 2020. $y_{i,t}$ refers to both market profitability (i.e. *Return* and *Abnormal return*) and bank risk (i.e. *Volatility*, *Idi. Volatility*, and *CDS Spreads*). $COVID_t$ equals one from February 24, 2020 to March 31, 2020, and zero before this period. For the choice of events window ($COVID_t$), we follow Albuquerque *et al.* (2020) and Ramelli & Wagner (2020). The authors identify February 24 as the start of the "fever period" and also the first trading day after the first lock-down in Europe (11 municipalities in Northern Italy). $ICT_{i,t}$ is a vector of information and communication technology variables. Specifically, the ICT variables are *Internet*, which is the percentage of Internet users in relation to the country population, and ATM ratio, which is the ratio between the number of ATMs and the total number of branches. The ATM ratio is a sort of proxy of investment in IT (Del Gaudio *et al.* 2021). $ICT_{i,t} \times COVID_t$ is our variable of interest that captures the effect of the $ICT_{i,t}$ on bank market profitability and bank risk. The key coefficient is β_3. If the coefficient of β_3 is positive (negative) on bank market performance (bank risk), then we assume that $ICT_{i,t}$ have contributed positively to increase (decrease) bank performance (bank risk). $x_{i,t}$ are a set of fixed effects to control for any omitted variable bias due to unobserved heterogeneity. More precisely, this set is represented by *Bank* FE_t and *Time* FE_c. $\epsilon_{i,t}$ represents an error term. Finally, we clustered the standard errors at the bank-level to adjust for within-bank correlation in the error term.

4. Results

4.1. *Stock return*

Table 3, Panel A presents results of stock return (*Return*) and abnormal stock return (*Abnormal return*). In columns 1-2-7-8 omit fixed effects, in columns 3-4-9-10 include bank fixed effects, and in columns 5-6-11-12 include bank and day fixed effects. Standard errors are clustered by bank and day.

The results show that the coefficient associated with the interaction between *COVID* and *Internet* is positive and significant at the 5% level. Banks located in countries where the diffusion of *Internet* is higher earn an average (abnormal) return of 3.4% (3.5%) relative to other banks from February 24 to March 31. The diffusion of *Internet* seems not to affect bank stock (abnormal) return (columns 1 and 2). The results also show that the *Covid* dummy is negative and significant at the 5% level after the COVID-19 outbreak, banks lose an average (abnormal) return range of 1.7%–5.3% (3%–4.1%).

In contrast, when we consider the interaction between *COVID* and *ATM Ratio*, the associated coefficient is not statistically significant. Similarly, the related coefficient of the *ATM Ratio* is not statistically significant. We do not find evidence that countries with a higher ATM penetration are associated with higher stock (abnormal) returns pre and post the COVID-19 outbreak.

4.2. *Volatility of stock returns*

As with the stock returns, we conduct a panel regression analysis to better tie the variation in volatility of stock returns, diffusion of the ICT and the COVID-19 pandemic. For this analysis, we repeat the regression in Panel A of Table 3 using two different proxies of Volatility: (1) the Volatility of daily returns (*Volatility*); the Volatility of daily abnormal returns (*Idi. Volatility*).

Panel B of Table 3 presents the results. The regressions show that the change in Volatility increased during the COVID-19 outbreak. The *Volatility* (*Idi. Volatility*) of bank stock return is lower for banks located in countries where the diffusion of *Internet* is high. This is particularly true, during the COVID-19 outbreak, the coefficient associated with the interaction between *COVID* and *Internet* is negative and significant at the 1% level. Banks located in countries where the diffusion of *Internet* is higher experience a decrease in *Volatility* (*Idi. Volatility*) of 8.00% (6.70%) relative to other banks from February 24 to March 31.

Similarly, when we consider the relation between stock return volatility and the *ATM Ratio*, we find evidence that banks located in countries where the *ATM Ratio* is

Table 3. The impact of ICT on bank market performance and risk.

Panel A	(1) Return	(2) Abnormal return	(3) Return	(4) Abnormal return	(5) Return	(6) Abnormal return	(7) Return	(8) Abnormal return	(9) Return	(10) Abnormal return	(11) Return	(12) Abnormal return
COVID	−0.053*	−0.041**	−0.053***	−0.041***	−0.017*	−0.030**	−0.022***	−0.010***	−0.022***	−0.010***	0.014**	0.001
	(−1.935)	(−2.170)	(−6.652)	(−3.570)	(−2.017)	(−2.402)	(−7.498)	(−4.791)	(−21.139)	(−7.271)	(2.492)	(0.235)
Internet	−0.008	−0.008										
	(−0.957)	(−1.015)										
Internet*COVID	0.034	0.035*	0.034***	0.035**	0.034***	0.035**						
	(1.133)	(1.661)	(3.899)	(2.677)	(3.849)	(2.643)						
ATM ratio							0.006	0.006				
							(0.754)	(0.820)				
ATM ratio*COVID							−0.009	−0.010	−0.009	−0.010	−0.009	−0.010
							(−0.272)	(−0.427)	(−0.709)	(−0.747)	(−0.700)	(−0.738)
Constant	0.008	0.008	0.001***	0.001***	0.000	0.000	0.001	0.001	0.001***	0.001***	−0.000	−0.000
	(1.074)	(1.174)	(3.986)	(3.575)	(0.000)	(0.000)	(1.081)	(1.570)	(3.384)	(3.258)	(−0.000)	(−0.000)
Observations	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470
R-squared	0.054	0.024	0.054	0.024	0.598	0.215	0.053	0.023	0.054	0.023	0.598	0.214
Day FE	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	YES	YES
Bank FE	NO	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES	YES
N. of banks	38	38	38	38	38	38	38	38	38	38	38	38
Panel B	**(1) Volatility**	**(2) Idi. volatility**	**(3) Volatility**	**(4) Idi. volatility**	**(5) Volatility**	**(6) Idi. volatility**	**(7) Volatility**	**(8) Idi. volatility**	**(9) Volatility**	**(10) Idi. volatility**	**(11) Volatility**	**(12) Idi. volatility**
Covid	0.107***	0.080***	0.107***	0.080***	0.139***	0.100***	0.037***	0.021***	0.037***	0.021***	0.070***	0.042***
	(10.311)	(10.530)	(4.364)	(3.878)	(5.636)	(4.946)	(30.474)	(22.904)	(14.846)	(8.904)	(17.173)	(10.480)
Internet	−0.013***	−0.015***										
	(−3.780)	(−4.241)										
Internet*COVID	−0.080***	−0.067***	−0.080***	−0.067***	−0.080***	−0.067***						
	(−6.866)	(−7.805)	(−2.976)	(−2.900)	(−2.938)	(−2.863)						

Table 3. (*Continued*)

Panel B	(1) Volatility	(2) Idi. volatility	(3) Volatility	(4) Idi. volatility	(5) Volatility	(6) Idi. volatility	(7) Volatility	(8) Idi. volatility	(9) Volatility	(10) Idi. volatility	(11) Volatility	(12) Idi. volatility
ATM ratio							−0.011***	−0.011***				
							(−3.979)	(−3.930)				
ATM ratio*COVID							−0.019	−0.013	−0.019	−0.013	−0.019	−0.013
							(−1.342)	(−1.346)	(−0.872)	(−0.716)	(−0.861)	(−0.707)
Constant	0.027***	0.027***	0.016***	0.015***	0.012***	0.012***	0.016***	0.015***	0.016***	0.015***	0.012***	0.012***
	(8.768)	(8.846)	(23.669)	(21.002)	(13.516)	(11.969)	(59.587)	(54.080)	(20.592)	(19.062)	(11.200)	(10.823)
Observations	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470	2,470
R-squared	0.489	0.352	0.509	0.409	0.875	0.690	0.464	0.312	0.497	0.389	0.863	0.669
Day FE	NO	NO	NO	NO	YES	YES	NO	NO	NO	NO	YES	YES
Bank FE	NO	NO	YES	YES	YES	YES	NO	NO	YES	YES	YES	YES
N. of banks	38	38	38	38	38	38	38	38	38	38	38	38

Notes: This table reports the results of a regression of daily bank stock return and volatility of the return. $COVID_t$ equals one from February 24, 2020 to March 31, 2020, and zero before this period. *Internet* is the percentage of internet users in relation to the country population. *ATM ratio* is the ratio between the number of ATMs and the total number of branches. In columns 1-2-7-8, the specification does not include bank and day fixed effects. In columns 3-4-9-10, the specification includes bank fixed effects. In columns 5-6-11-12, the specification includes bank and day fixed effects. In Panel A, we estimate the baseline model of equation (1) for the period from January 1, 2020 to March 31, 2020 using as dependent variables *Return* and *Abnormal return*. In contrast, in Panel B, we estimate the model of equation (1) using as dependent variables the *Volatility* and *Idi. Volatility*. Standard errors are clustered at the bank level. The numbers in parenthesis are t-statistics. All variables are defined in Table 2. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

higher experience an average decrease in *Volatility* (*Idi. Volatility*) of about 1.00%. In contrast, when we consider the interaction between *COVID* and *ATM Ratio*, the associated coefficient is not statistically significant. We do not find evidence that banks located in countries with a higher ATM penetration are associated with a decrease in *Volatility* (*Idi. Volatility*) after the COVID-19 outbreak.

4.3. *CDS spreads*

As an alternative proxy of bank risk, we use the CDS spreads, and we repeat the regression in Panel B of Table 3, coherently with the empirical literature on this topic (Fiordelisi *et al.* 2020, Hasan *et al.* 2016, Black *et al.* 2016, Acharya *et al.* 2014). Table 4 shows the results. The diffusion of *Internet* seems to decrease the bank *CDS Spreads* (column 1). Furthermore, the coefficient associated with the interaction between *COVID* and *Internet* is negative and significant at the 1% level (columns 2 and 3). Countries where the diffusion of *Internet* is higher experience an average decrease in *CDS Spreads* relative to other banks from February 24 to March 31. Similarly, when we consider the relation between bank *CDS Spreads* and the *ATM Ratio*, we find evidence that banks located in countries where the *ATM Ratio* is

Table 4. The impact of ICT on bank CDS spreads.

	(1) CDS Spreads	(2) CDS Spreads	(3) CDS Spreads	(4) CDS Spreads	(5) CDS Spreads	(6) CDS Spreads
Covid	2.114	2.234***	2.337***	0.319***	0.329***	0.427***
	(1.574)	(4.345)	(4.457)	(2.879)	(5.703)	(5.865)
Internet	−0.116***					
	(−11.932)					
Internet*Covid	−0.021	−0.022***	−0.022***			
	(−1.436)	(−3.931)	(−3.895)			
ATM Ratio				−0.018***		
				(−4.463)		
ATM Ratio*Covid				−0.007	−0.007	−0.007
				(−1.068)	(−1.538)	(−1.520)
Constant	11.399***	1.212***	1.270***	1.313***	1.212***	1.270***
	(12.665)	(83.231)	(58.005)	(18.216)	(67.769)	(62.826)
Observations	2,469	2,469	2,469	2,469	2,469	2,469
R-squared	0.181	0.346	0.574	0.008	0.273	0.502
Day FE	NO	YES	YES	NO	YES	YES
Bank FE	NO	NO	YES	NO	NO	YES
N. of Banks	38	38	38	38	38	38

Notes: This table reports the results of a regression of daily bank CDS spreads. $COVID_t$ equals one from February 24, 2020 to March 31, 2020, and zero before this period. *Internet* is the percentage of internet users in relation to the country population. *ATMratio* is the ratio between the number of ATMs and the total number of branches. In columns 1-2, the specification does not include bank and day fixed effects. In columns 3-4, the specification includes bank fixed effects. In columns 5-6, the specification includes bank and day fixed effects. Standard errors are clustered at the bank level. The numbers in parenthesis are *t*-statistics. All variables are defined in Table 2. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

higher experience a lower *CDS Spreads*. As in the previous results, when we consider the interaction between *COVID* and *ATM Ratio*, the associated coefficient is not statistically significant.

Overall, our results support both *H1* and *H2*. Banks located in countries with a higher Internet diffusion displayed higher resilience in terms of market (abnormal) returns, volatility of returns, and CDS spreads.

5. Conclusions

Recent advances in information and communications technology have improved the global banking market, its structure and services. Through the diffusion of ICT, banks now can provide more innovative services to customers (e.g. internet banking, electronic payments, and security investments), reducing their associated costs. Following this pattern, it is clear that ICT can make a beneficial contribution to banks' profitability (Berger 2003). The recent COVID-19 outbreak and the resulting health and economic crisis have sparked renewed debates on the effects of ICT diffusion in the banking sector. Research is crucial here since practitioners and policymakers have scarce resources to base their response actions, and scholars have the unique opportunity, perhaps an obligation, to revisit the foundational knowledge about the diffusion of financial innovation in the banking industry to draw up agendas for future research. In this paper, we investigate the role ICT diffusion plays in the European banking industry in the unprecedented scenario of the COVID-19 pandemic. More precisely, we test whether and how ICT diffusion affects banks' profitability and risk profiles over the period spanning from January 1, 2020, to March 31, 2020. We find that the investors are very sensitive to changes induced by the ICT diffusion, especially after the COVID-19 outbreak. Our results highlight a significant increase in the (abnormal) returns of banks in countries where Internet diffusion is higher from February 24 to March 31.

This result could be attributed to the technology endowment allowing greater information availability and its more rapid dissemination to a broad base of investors in real-time and at low cost, thus expanding the universe of investors with access to information. Furthermore, ICT improves banks' processes, facilitates customer relationships, and allows a more straightforward assessment of their creditworthiness. During the COVID-19 pandemic, when people are instructed to stay at home, ICT tools make a difference, allowing banks to adapt offerings to support clients' needs and changing behavior and introduce fast, flexible and effective measures to keep operations and services stable. These factors are appreciated by financial markets and investors who favor banks operating in countries with high ICT levels. We do not find evidence that countries with a higher ATM penetration are associated with higher stock (abnormal) returns after the COVID-19 outbreak. Therefore, ATM penetration does not seem to impact the potential market recovery after the COVID crisis significantly. Investors do not consider it as an added value. Our findings also reveal a positive association between ICT diffusion and bank stability.

Specifically, ICT diffusion reduces market volatility and default risk for banks in countries with a high Internet diffusion. This is particularly true after the COVID-19 outbreak.

We do not find evidence that countries with a higher ATM penetration are associated with higher stock (abnormal) returns after the COVID-19 outbreak. Therefore, ATM penetration does not seem to impact the potential market recovery after the COVID crisis significantly. Investors do not consider it as an added value. Our findings also reveal a positive association between ICT diffusion and bank stability. Specifically, ICT diffusion reduces market volatility and default risk for banks in countries with a high Internet diffusion. This is particularly true after the COVID-19 outbreak. These findings support the theory that better dissemination of information may limit bank insolvency risk and improve stability, especially in times of extreme uncertainty such as the COVID-19 pandemic. Finally, our findings suggest that the diffusion of automated teller machines reduces stock market volatility, but this effect does not persist in the post-COVID-19 period. This paper has several implications. First, the findings of this study can be of interest to the Capital Markets Authority to determine the impact of ICT on stock returns and hence keep abreast with the information technologies by fostering their potential benefits and mitigating risks. A second implication is that banks in countries with higher ICT diffusion performed better in the post-COVID-19 period.

Our findings should enable policymakers and regulators to understand why some parts of the banking sector are underperforming and what can be done to enhance their performance. The Bali Fintech Agenda — developed in 2018 by the World Bank and IMF (International Monetary Fund) staff — has recognized "*the need to adapt regulatory frameworks and supervisory practices to facilitate the safe entry of new products, activities, and intermediaries while maintaining financial stability and sustaining trust, confidence, and the ability to respond to risks.*" Furthermore, on July 21, 2020, the European Commission announced the EUR 1.8 trillion European Recovery Plan (ERP) to boost economic resilience and recovery across Europe in the wake of the devastating effects of the COVID-19 pandemic. The ERP includes the Recovery and Resilience Facility (RRF), which makes EUR 312.5 billion and EUR 360 billion in grants and loans, respectively, available to finance reforms and investments undertaken by the Member States to promote the green transition and digital transformation. Finally, our analysis paves the way for future research on the long-term consequences of ICT diffusion in banking in the post-COVID-19 era.

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