UNIMORE UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA CEFIN Centro Studi Banca e Finanza

ISSN 2282-8168

CEFIN Working Papers No 86

Climate Stress Test: bad (or good) news for the market? An Event Study Analysis on Euro Zone Banks

by Costanza Torricelli, Chiara Pederzoli, Fabio Ferrari

November 2023

CEFIN – Centro Studi di Banca e Finanza www.cefin.unimore.it
Dipartimento di Economia Marco Biagi – Università di Modena e Reggio Emilia
Viale Jacopo Berengario 51, 41121 MODENA (Italy) tel. 39-059.2056711 (Centralino) fax 39-059 205 6927

CLIMATE STRESS TEST: BAD (OR GOOD) NEWS FOR THE MARKET? AN EVENT STUDY ANALISYS ON EURO ZONE BANKS*

Costanza Torricelli, University of Modena and Reggio Emilia
and CEFIN – Center for Studies in Banking and Finance§
Chiara Pederzoli, University of Milano Bicocca and CEFIN– Center for Studies in Banking and Finance
Fabio Ferrari, University of Modena and Reggio Emilia

Abstract

This paper investigates how the 2021 ECB Climate stress test affected the market view on the climate risk exposure of the banking sector. To this end, we set up an event study analysis on stock returns of the banks included in the exercise, whereby at the relevant dates we test for the existence of abnormal returns. The potential hypothesis is that bad/good news on climate risks exposure of banks may negatively/positively impacts their profitability and hence stock returns. Three main results emerge from our analyses. First, the stress test announcement had no significant impact on banks stock returns, a result that can be explained by the type of information given, i.e. only the methodology and some preliminary mainly qualitative evidence. Second, and by contrast, the publication of the final results with quantitative details determined a positive significant reaction, since the market possibly expected banks' exposure to climate risks to be greater. Third, an event related to the worldwide consensus on the need to manage climate change (COP26), yet not strictly related to the climate stress test, had no significant market impact. Our results, which are robust to various checks, may have policy implications for future climate stress tests and institutional initiatives needed to manage climate risk.

Keywords: banks climate stress test, physical risk, transition risk, abnormal returns, event study

JEL : G14, G28, F55

Revised version, November 2023

* The authors thank the Editor, the referee, Giuseppe Marotta and Dimitrios Tsomocos for helpful comments and suggestions on a previous version of the present paper. Usual caveat applies.

§ Corresponding author: costanza.torricelli@unimore.it

1. Introduction

Climate change is likely the most challenging issue the world has to face this century and, among policy reactions, the most cited is perhaps the Paris Agreement reached in December 2015 setting the ambitious aim of limiting climate change through a global response, by "keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius".[1]

Climate concerns have been receiving increasing attention in finance fostered, among other things, by the Sustainable Development Goals (SDGs) set in the 2030 Agenda by UN (2015), and the recent action plan to contrast climate change in the European Union known as Fit for 55 (European Commission, 2021a,b).

Negative impacts for all economies round the world and all economic sectors, non-financial and financial ones, are coming from both physical risks and transition risks. The definition of these two types of risk can be found e.g. in BCBS (2021a). Physical risks are represented by economic costs and financial losses resulting from the increasing severity and frequency of extreme climate change-related weather events (e.g. heatwaves, landslides, floods, wildfires, storms), longer-term gradual shifts of the climate (e.g. changes in precipitation, extreme weather variability, ocean acidification, and rising sea levels and average temperatures), and indirect effects of climate change such as loss of ecosystem services (e.g. desertification, water shortage, degradation of soil quality or marine ecology). Transition risks are related to the process of adjustment towards a low-carbon economy and include changes in public sector policies, legislation and regulation, changes in technology and changes in market and customer sentiment.

Banks are affected by climate risks via manyfold channels, whereby the two most relevant ones are the traditional risk categories, i.e. credit and market risk. In fact, banks' assets are affected in value and subject to fluctuations in connection with climate risks in the form of physical risks and/or transition risks, which are also intertwined (BCBS, 2021b). Specifically, climate risks can impact credit risk via the probability of default (PD), the loss given default (LGD) and hence the expected loss (EL), whereas market risk is mainly affected via the sensitivity of the price of securities to movements in market-risk factors due to climate risks.

Although bank regulation can in principle tackle the issue based on a prudential regulation by requiring an adequate level of capital against climate risks, the approach taken so far by supervisors and central banks to quantify exposure to climate risk has been based on climate stress tests (e.g. Bank of England, Banque de France).[2] At the moment, this is the approach taken also by the European

[1] https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[2] Consideration of climate risks could enter in the first Pillar by means of a "green supporting factor" or "brown penalty factor" in the calculation of Risk Weighted Assets, in the second Pillar with "ad hoc" capital requirements based on KPI

Central Bank in its first economy-wide climate stress test performed in 2021.

The scope of this paper is to assess how the 2021 ECB Climate stress test affected the market view on the climate risk exposure of the banking sector.[3] The potential hypothesis is that knowledge of the climate risks affecting banks and resulting from the ECB stress test may negatively impact their profitability and hence stock returns, also in consideration of a possible future impact in terms of regulatory requirements. Specifically, we aim to answer a set of related research questions: have market investors reacted to ECB climate stress test? If so, have bank quotes anticipated and/or reflected (expected) outcomes of this first test? Are other climate related international initiatives such as COP26 able to affect the information on banks' climate risk exposure? To answer these questions, we set up an event study analysis, whereby at the relevant dates - i.e. announcement, final results and COP26 - we have used market data in order to test for the existence of abnormal returns. As far as we know we are the first to address these issues.

A few main results emerge from our research. First, the announcement of the methodology of the ECB climate stress test and some preliminary mainly qualitative evidence had no impact on the stock prices of the banks included in the exercise. Second, on the date of publication of the final results, the evidence shows a significant positive reaction from market participants with positive cumulative average abnormal returns ranging from +2.2% (+/-3 days window) to +4.6% (+/-10 days window). This positive reaction can be interpreted as a positive surprise with respect to the announcement, as the market expected the banks' exposure to climate risks to be greater than the one emerging from final results. Third, on the starting date of COP26, there is no significant effect on banks' quotes, which can be explained by the event being much related to climate policy but only indirectly related to climate stress test. Finally, robustness tests including small banks not directly supervised by the ECB and banks with a business model not focused on credit intermediation, indicate that the market consider them exposed to climate risks as well.

The paper is organized as follows. Section 2 briefly recalls the main features of the ECB climate stress test and the results that motivate the research in this paper. In Section 3 the event study methodology is illustrated in terms of main steps and choices taken in the present study. While Section 4 describes the set-up of the sample, Section 5 discusses results and Section 6 presents robustness checks. Final Section concludes.

---

such as the Green Asset Ratio proposed by EBA, or in the third Pillar requiring disclosure on the exposure to physical and transition risks (Bolton et al., 2020).

[3] Since 2011 the European Banking Authority has been conducting stress tests on the European banking system, to check resilience to adverse macroeconomic scenarios and a strand of literature investigated the informative/predictive content of market based risk measures with respect to regulatory stress test (e.g. Pederzoli and Torricelli, 2017).

2. The 2021 ECB climate stress test

In order to assess whether the results of the 2021 ECB climate stress test affected the market performance of the banks subject to it, it is worth recalling the main features and the results for banks of this climate stress test. It goes beyond the scope of this paper to provide a detailed description of the methodology and the results, for which we refer to Alogoskoufis et al. (2021). Rather, we focus to the main point explaining how this test may have informed participants in the stock market over the climate risk impact on banks.

The 2021 ECB climate stress test is based on a top-down approach, i.e. data, assumptions and models are developed by ECB staff, thus ensuring comparability.[4] The subjects tested are both non-financial companies and banks in the Euro area, and the impacts of physical and transition risks are jointly analysed. The time horizon is thirty years and a static budget hypothesis is adopted.[5] The dataset is very granular and it contains information on more than four million companies and over 1600 banking groups in the euro area. The model also takes into account climate risk mitigators and amplifiers, but only through assumptions regarding insurance coverage. The scenarios used are based on the Network for Greening the Financial System (NGFS), specifically on the three representative Phase I scenarios (NGFS, 2020): the ordered transition path (OT) is the baseline scenario taken as a reference for the other two, i.e the disorderly transition (DT) and the hot house world (HHW). The effects of these projections are mapped to bank exposures, making it possible to measure the impact of climate risks on credit institutions.

The results of the ECB's economy-wide climate stress test show that there are clear benefits in acting early and that the short-term costs of the transition are more than compensated in the medium to long term. The results also show that although the effects of climate risks would increase moderately on average until 2050 if climate change was not mitigated, they would be concentrated in certain geographical areas and sectors, especially in the mining and electricity and gas sectors, with a consequent increase in their probability of default in the short to medium term. The increase in default probabilities is also true for firms located in geographical areas that are most exposed to physical risk.

As for banks, results, which are published in aggregate form with no detail on single banks, show that for banks most exposed to climate risks the impact is potentially very significant, especially in the absence of further climate policies, and thus climate change represents a major source of systemic

[4] By contrast, bottom-up exercises are based on the self-assessments conducted internally by each bank and the results are then put together by the promoter of the climate exercise.

[5] The static balance sheet hypothesis, which in many cases is used as a simplifying hypothesis, is therefore not realistic, and will in future have to be replaced by a dynamic balance sheet hypothesis, as shown in the Banque De France climate stress test, which allows the composition of banks' assets to be changed over the time horizon of the year (Clerc et al., 2021).

risk, particularly for banks with portfolios concentrated in certain economic sectors and, even more importantly, in specific geographical areas. Finally, the impact on banks' expected losses is mostly driven by physical risk and it is potentially severe. These results motivate the aim of this paper.

3. Event study methodology

The objective of the event study analysis performed in this paper is to detect the effect of the ECB 2021 climate stress test on stock returns of the EU banks, i.e. to test for the presence of abnormal returns. To this end, we follow Loipersberger (2018) event study aimed to test the effect of supranational banking supervision (SSM) on the financial sector. Main steps are the choice of a "normal return" model and the events' dates.

The "normal return" model is used to estimate the theoretical returns the stocks would have had in the absence of the event. Once the normal model has been estimated over an appropriate estimation window, abnormal returns $AR_{i,t}$ are defined as:

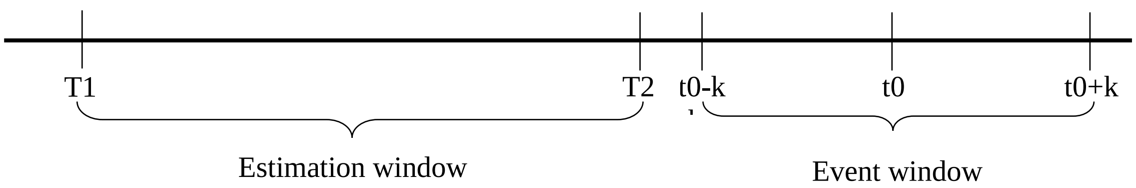
$$AR_{i,t} = R_{i,t} - NR_{i,t} \tag{1}$$

where:

$R_{i,t}$ are market returns,

$NR_{i,t}$ are normal returns.

The latter are calculated on the event window of length ± k around the event day t0, based on the market model coefficient estimated on the estimation window [T1,T2].



The normal returns are defined by the model chosen for returns. The one-factor market model is a standard in the literature on financial data (see e.g. Loipersberger 2018, Kruger 2015). In general, the model used for normal returns can be expressed as in equation (2). Thus, we estimate over the estimation window the equation:

$$R_{i,t} = \alpha_i + \sum_j \beta_{ij} R_{j,t} + \varepsilon_{i,t} \tag{2}$$

where R_j are the factors influencing stock returns.

The residuals of equation (2) represent the abnormal returns, $AR_{i,t}$. Among the various models proposed in the literature (see e.g. Kolari and Pynnonen 2010), we base our analysis on a two-factor model, namely for each bank we take a common industry specific index (Euro Stoxx Banks) and a country-specific stock index[6]. This choice is motivated by the aim to reduce the residual cross correlation to a minimum[7]. As highlighted by Petrella and Resti (2013), the bank specific factor allows to control for industry-wide effects and the use of country specific factors prevents residuals to be influenced by national shocks.

As for the estimation window we take a 6-month length, since it allows to have sufficiently stable estimates and is in line with the comparable work by Loipersberger (2018). Taking into account the event days to be considered in the present study, as specified below, a longer period would be affected by the Covid pandemic negative effects on financial markets.[8]

In relation to the ECB 2021 climate stress test three are the days that we assume being relevant: the first two characterized by official information revealed by the ECB to the market, the latter is connected to the climate concerns. Specifically, as summarized in Figure 1:

- **18.03.2021**: Luis de Guindos, Vicepresident of the ECB, communicated the framework for the economy-wide climate stress the ECB was conducting and preliminary (mainly qualitative) results showing that, in the absence of further climate policies, the costs to companies arising from extreme weather events rise substantially, and greatly increase their probability of default. Results also show that there are clear benefits in acting early.[9]
- **22.09.2021**: ECB published final results of its economy-wide climate stress test. Results are overall in line with preliminary ones, but they are more quantitative and detailed (e.g. over the increase in banks' default probability, expected losses, reduction in collaterals, differences by geographical areas and sectors) although they are published in aggregate form and no detail on single banks is available.[10]
- **01.11.2021**: it is the starting date of COP26 in Glasgow, with China and India pushing for the language on coal to change from "phase out" to "phase down" in the deal in contrast to those who wanted a much more ambitious outcome at the conference. Although this date is not directly linked with the ECB climate stress test, the COP26 final agreement pointed to a climate risk (especially physical) level higher than expected, with a possible negative impact on banks' stocks in the Event Study Analysis. However, it has to be stressed that, since climate risks have impact not only on banks but on the economy in general, it could well be that the

[6] DAX (Germany), CAC 40 (France), IBEX 35 (Spain), FTSEMIB (Italy), BEL 20 (Belgium), ATX (Austria), CSE General (Cyprus), OMX (Finland), AEX (Netherlands), PSI (Portugal), ISEQ (Ireland), FTSE Greece (Greece).

[7] We estimated other alternative models for return (one-factor standard market model based on Euro Stoxx 50, one factor model based on country specific index - in line with Petrella and Resti 2013-, three factor Fama-French) but they all resulted in worse fit and higher residual cross correlation.

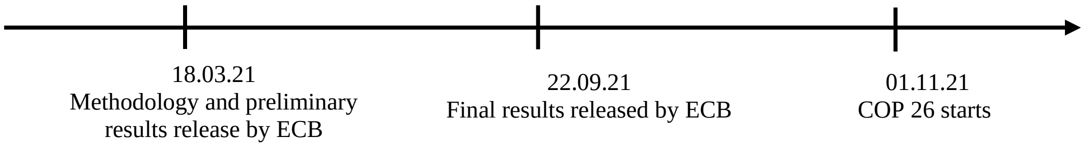
[8] In Section 6.3 we consider a three years estimation window as a robustness check: the results are qualitatively similar even including the Covid period in the estimation window.

[9] https://www.ecb.europa.eu/home/search/html/stress_tests.en.html

[10] https://www.ecb.europa.eu/press/pr/date/2021/html/ecb.pr210922~59ade4710b.en.html

whole stock market has a negative performance and hence banks would not record abnormal returns.

Figure 1- Event days



4. The sample

Since the objective is to test the effect of the ECB climate stress test, only banks of the Euro area are considered. Restrictions are then set according to liquidity so as to have reliable estimates of the abnormal returns, and to exclude those with missing information along the estimation window.[11] The resulting sample consists of 48 banks: Table1 reports their denomination, the country of residence, the total assets and the business model.

Since the business model may impact the abnormal returns, the main analysis will be performed on a more homogeneous sample in terms of exposure to climate risks, which is obtained by dropping banks with business model "asset managers and custodians" and "development/promotional lenders", and those with total asset lower than €30 billion so as to have only those banks under the direct SSM supervision.[12] Robustness analyses based on the extended sample are provided in Section 5.

Table 1 – Banks in the main and in the extended samples
(Main sample in Bold)

Name	*Country*	*Total Assets*	*Business model*
BAWAG Group AG	**AUT**	**54,370**	**Diversified lender**
Erste Bank	**AUT**	**309,240**	**Diversified lender**
Raiffeisen Bank International AG	**AUT**	**190,610**	**Diversified lender**
KBC Groep NV	**BEL**	**354,336**	**Diversified lender**
Bank Of Cyprus Holdings PCL	CYP	24,551	Diversified lender
Hellenic Bank	CYP	18,675	Diversified lender
Aktia Bank Abp	FIN	11,374	Asset manager and custodian
Nordea Bank Abp	**FIN**	**614,509**	**Universal and investment bank**
Bank of Aland PLC	FIN	6,353	Universal and investment bank
Evli Pankki Oyi	FIN	752	Asset manager and custodian
BNP Paribas SA	**FRA**	**2,725,667**	**G-sib**
Credit Agricole SA	**FRA**	**2,090,500**	**G-sib**

[11] As for liquidity restrictions, the minimum daily threshold is set to 5,000 units over the estimation window. As for banks with missing information they are only two: Oma Saastopankki Oyj and Nova Ljubljanska Banka dd Ljubljana).

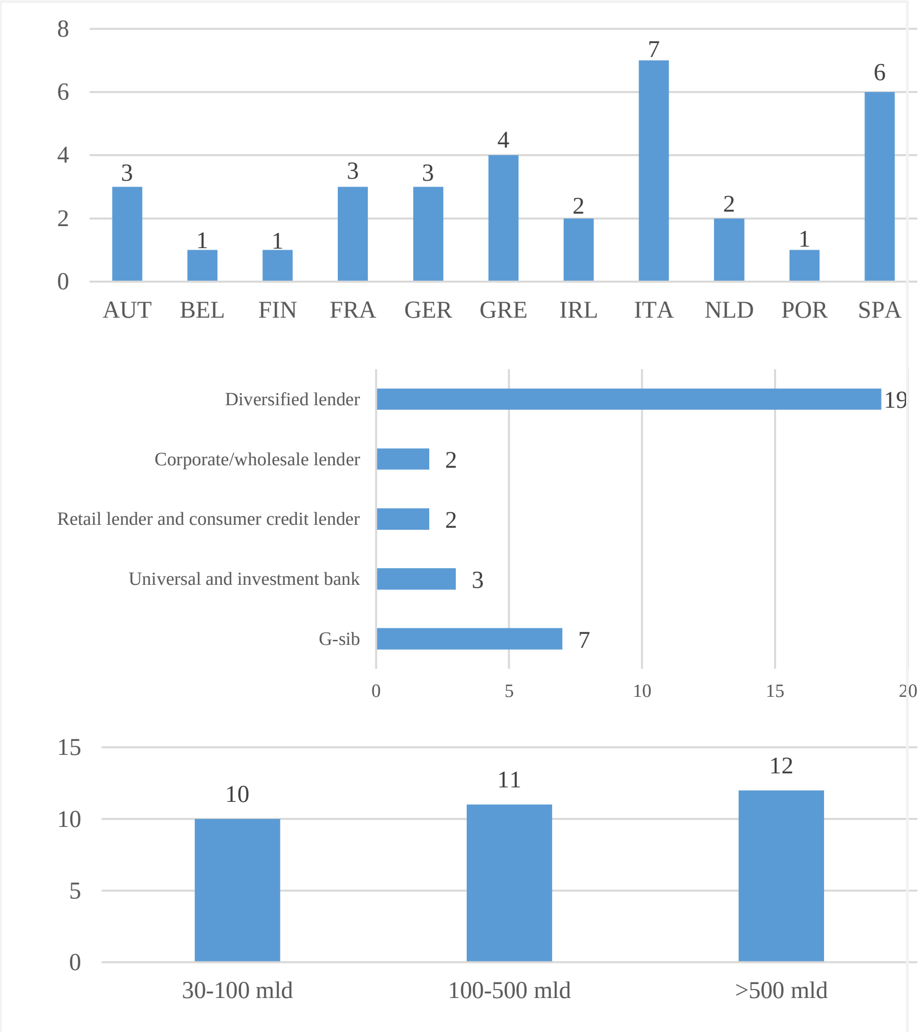
[12] Although this is not the only criterion used to classify banks for SSM supervision, we use it as a good proxy to distinguish between Significant and Less Significant banks. The issue is discussed when testing robustness to the sample in relation to banks' asset in Section 6.2.

Societe Generale SA	**FRA**	**1,526,354**	**G-sib**
Commerzbank AG	**GER**	**541,258**	**Diversified lender**
Deutsche Bank AG	**GER**	**1,326,058**	**G-sib**
Deutsche Pfandbriefbank AG	GER	58,833	Development/promotional lender
Aareal Bank	**GER**	**46,751**	**Corporate/wholesale lender**
Umweltbank AG	GER	4,944	Corporate/wholesale lender
Alpha Bank SA	**GRE**	**73,075**	**Diversified lender**
Attica Bank SA	GRE	3,504	Corporate/wholesale lender
EFG Eurobank Ergasias	**GRE**	**73,374**	**Diversified lender**
National Bank of Greece SA	**GRE**	**81,610**	**Diversified lender**
Piraeus Bank SA	**GRE**	**75,421**	**Corporate/wholesale lender**
AIB Group PLC	**IRL**	**122,888**	**Diversified lender**
Bank of Ireland Group PLC	**IRL**	**149,932**	**Retail lender and consumer credit lender**
Permanent TSB Group Holdings PLC	IRL	21,504	Retail lender and consumer credit lender
Banca Popolare di Sondrio ScpA	**ITA**	**53,334**	**Diversified lender**
Banco Bpm SpA	**ITA**	**196,781**	**Diversified lender**
Banco Desio SpA	ITA	17,699	Diversified lender
Bper Banca SpA	**ITA**	**134,174**	**Diversified lender**
Credito Emiliano SpA	**ITA**	**66,793**	**Universal and investment bank**
Illimity Bank SpA	ITA	4,331	Corporate/wholesale lender
Intesa Sanpaolo SpA	**ITA**	**1,071,418**	**Universal and investment bank**
Mediobanca Banca di Credito Finanziario SpA	**ITA**	**85,555**	**Diversified lender**
UniCredit SpA	**ITA**	**948,584**	**G-sib**
Banca Mediolanum SpA	ITA	67,554	Asset manager and custodian
FinecoBank Banca Fineco SpA	ITA	33,534	Asset manager and custodian
Banca Generali	ITA	15,579	Asset manager and custodian
Banca IFIS SpA	ITA	12,769	Corporate/wholesale lender
ABN AMRO Group NV	**NLD**	**417,026**	**Diversified lender**
ING Groep NV	**NLD**	**988,751**	**G-sib**
Banco Comercial Portugues SA	**POR**	**91,463**	**Diversified lender**
Banco Bilbao Vizcaya Argentaria SA	**SPA**	**651,834**	**Diversified lender**
Banco de Sabadell SA	**SPA**	**249,922**	**Diversified lender**
Banco Santander	**SPA**	**1,578,295**	**G-sib**
Bankinter	**SPA**	**102,469**	**Diversified lender**
CaixaBank S.A.	**SPA**	**685,737**	**Diversified lender**
Unicaja Banco SA	**SPA**	**109,144**	**Retail lender and consumer credit lender**

Data source Bloomberg
Notes: Data in million, Business Model according to Supervisory Banking Statistics according to 3rd Q statements (ECB, 2021). In bold banks in the main sample.

The main sample resulting from the above restrictions and highlighted in bold in Table 1 consists of 33 banks: as Figure 2 shows most of them are in Italy and Spain, the great majority is Diversified lender in terms of Business model and are quite uniformly distributed in the three dimensional classes (€30-100 bn, €100-500 bn, >€500 bn).

Figure 2 – Distribution by country, business model and total asset



5. Results

Daily data and a 6-month estimation window (non-overlapping with the event windows) are used to estimate normal return according to the model explained in Section 3, whose residual provides the abnormal returns $AR_{i,t}$. The cumulative average abnormal returns (*CAAR*) over the period +/- k from the event date (t_0) are:

$$CAAR_{t_0+/-k} = \sum_{t=t_{0-k}}^{t_0+k} AAR_t \quad (3)$$

where

$$AAR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{i,t} \quad (4)$$

AAR_t is the average abnormal return over the sample of N = 33 banks, k=1,3,5,10.

The event windows of +/-1,3,5 days are chosen in line with Loipersberger (2018), and the widest range of +/-10 days is taken so as to test the robustness of the results. Moreover, as it is sometimes applied in the literature (e.g. Petrella and Resti 2013), in order to obtain a more complete representation of the market reactions we also examine the post-event only window, that is we consider as the event window +1,+3,+5 and +10 days.

The null hypothesis is tested against the alternative of cumulative average abnormal return statistically different form zero, i.e.:

$$\begin{cases} H_0: E(CAAR_{i,t}) = 0 \\ H_1: E(CAAR_{i,t}) \neq 0 \end{cases} \tag{5}$$

To assess the statistical significance of the CAARs, we consider two tests. We start with the test proposed by Boehmer et al. (1991), which is robust to so-called event-induced variance (i.e. when the event itself changes the variance of the distribution of stock returns) and therefore it is supposed to be more conservative when there is a variance increase due to the event. We have to consider that when there is event- date clustering, like in our case, cross-correlation among abnormal returns may lead to over-rejection of the null hypothesis. To control for this, we follow Kolari and Pynnönen (2010) and we adjusted the test statistics for cross-sectional correlation. The adjustment is specifically proposed by Kolari and Pynnonen (2010) to overcome the event date clustering issue. As an alternative, we implement a nonparametric rank test proposed by Kolari and Pynnonen (2011), which beside the absence of distributional assumptions, proved to be robust to cross-sectional and serial correlation in abnormal returns in simulation studies. This test is also adopted in Loipersberger (2018).[13]

Results for the three event dates are reported in Table 2 and Table 3 and are discussed in the following subsections.

[13] We also consider the portfolio approach proposed by Jaffe (1974), which is traditionally adopted to deal with correlations of abnormal returns, but shows lower power compared to the other tests (see Kolari and Pynnonen 2010). Results are not reported but are available upon request. They are in line with the results of the other tests, even if the significance is reduced.

Table 2 Statistical significance of CAARs at the three event dates

Window	**+/-10 days**	**+/-5 days**	**+/-3 days**	**+/-1 days**	**+/-0 days**
18-03-2021					
CAAR	-0.949%	1.175%	0.846%	-0.924%	-0.811%
BMP Adj	0.333	1.394	1.406	0.720	-0.165
KP rank	0.362	1.393	1.584	1.037	-0.110
22-09-2021					
CAAR	4.623%	3.426%	2.200%	0.066%	0.381%
BMP Adj	1.985*	1.961*	1.777*	-0.044	1.487
KP rank	1.975**	1.920*	1.727*	0.131	1.811*
01-11-2021					
CAAR	-0.905%	-0.217%	-0.370%	-0.252%	-0.375%
BMP Adj	0.255	0.308	0.131	0.315	-0.669
KP rank	-0.065	-0.003	0.110	0.396	-0.702

Notes: BMP Adj is the test by Boehmer et al (1991) modified to account for event date clustering, as proposed in Kolari and Pynnonen (2010). KP rank is the generalized rank t test proposed by Kolari and Pynnonen (2011). The asterisks relate to the level of significance: *** <1%, ** <5%, * <10%.

Table 3 - Statistical significance of CAARs at the three event dates: post event days only

Window	**+10 days**	**+5 days**	**+3 days**	**+1 days**	**+0 days**
18-03-2021					
CAAR	-1.853%	-1.012%	-0.854%	-1.286%	-0.811%
BMP Adj	0.096	0.749	0.538	-0.054	-0.165
KP rank	0.268	1.044	0.901	0.399	-0.110
22-09-2021					
CAAR	3,862%	2,212%	1,349%	0,234%	0,381%
BMP Adj	2,861***	2,467***	1,974*	0,857	1,487
KP rank	2,740***	2,448***	1,914*	0,816	1,811*
01-11-2021					
CAAR	-0.814%	0.088%	-0.034%	-0.030%	-0.375%
BMP Adj	0.284	0.618	0.374	0.653	-0.669
KP rank	0.005	0.275	0.312	0.710	-0.702

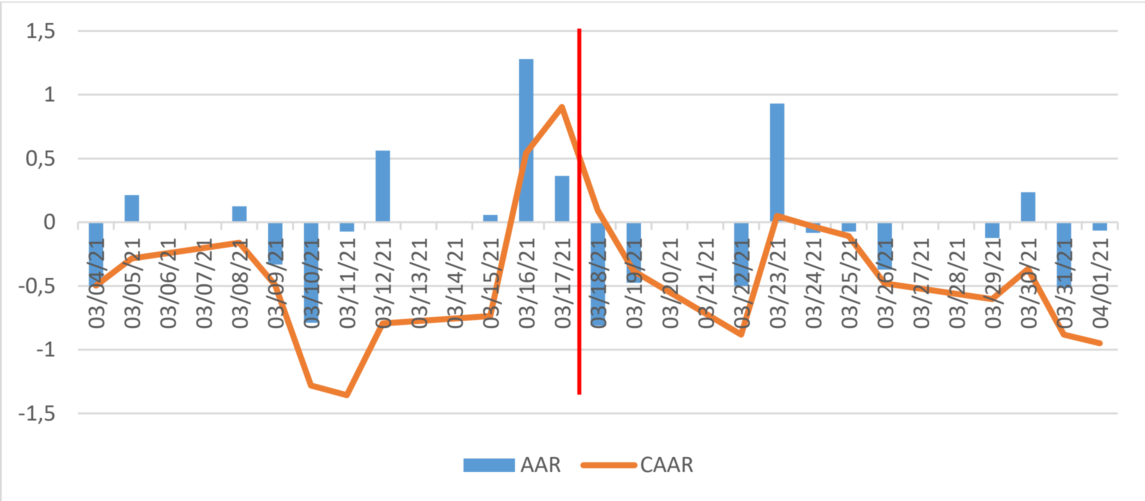
Notes: BMP Adj is the test by Boehmer et al (1991) modified to account for event date clustering, as proposed in Kolari and Pynnonen (2010). KP rank is the generalized rank t test proposed by Kolari and Pynnonen (2011). The asterisks relate to the level of significance: *** <1%, ** <5%, * <10%.

5.1 Event date 18.03.21

On the day in which the methodology and some preliminary mainly qualitative results were announced, the market appears to have no reaction since CAARs range around zero in all windows and, according to all tests, there is no statistical significance. This can be explained by the fact that the implications of the news over this exercise for banks are unpredictable because they are too difficult to quantify for market participants based on the information available at this stage.

In Figure 3 we plot AARs and AARs cumulated from the beginning of the event window: a negative initial market reaction does not reflect a significant impact.

Figure 3 – AARs and CAARs (18.03.21)

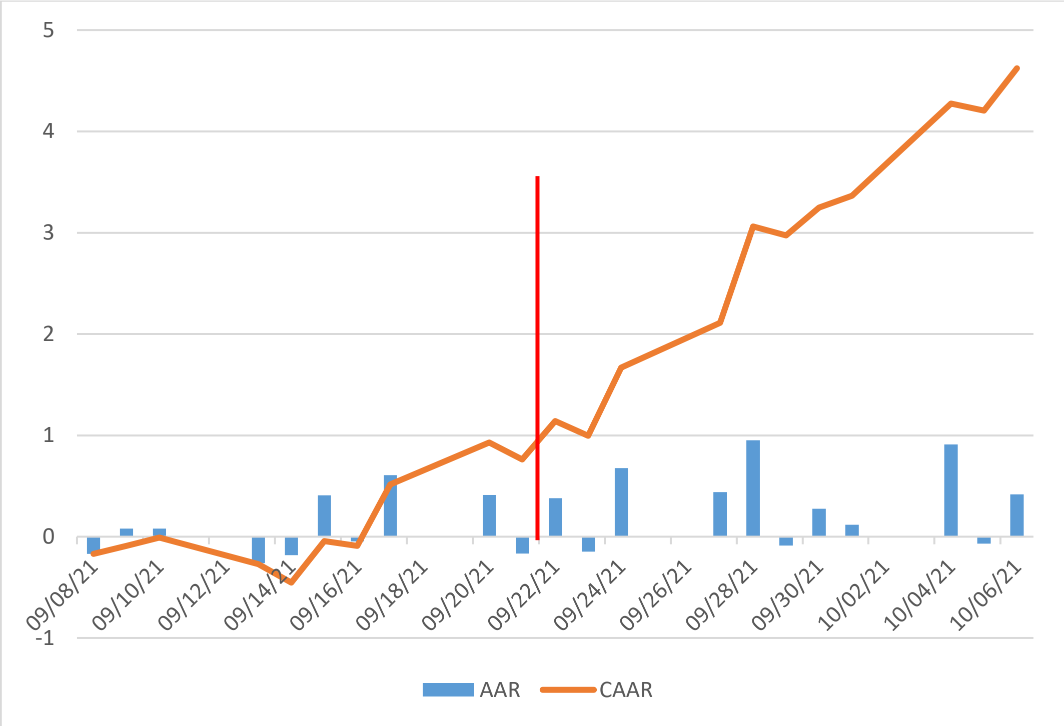


5.2 Event date 22.09.21

When ECB published final results of its economy-wide climate stress test, investors had an optimistic reaction with the CAARs that are positive and significant according to both tests starting from the +/-3 day window. The need of a few days for a strongly significant reaction points to market participants needing some days to really understand the result of this exercise whose complexity is apparent from the ECB paper describing the exercise and the results (Alogoskoufis et al, 2021). Specifically, the CAARs on the event date is +0.38%, and increases as the event window becomes wider: +2.2% at +/-3 days, + 3.43% at +/-5 days, +4.62% at +/-10 days. The reaction is even more clear cut by considering the post-event window only: both tests display in fact a fully significant impact over the +5 days and +10 days windows.

Figure 4 displays daily AARs and CAARs, highlighting a first positive market reaction in the very same day of publication. Reactions remain positive in the following days and CAARs have a clear upward trend.

Figure 4 - AARs and CAARs (22.09.21)



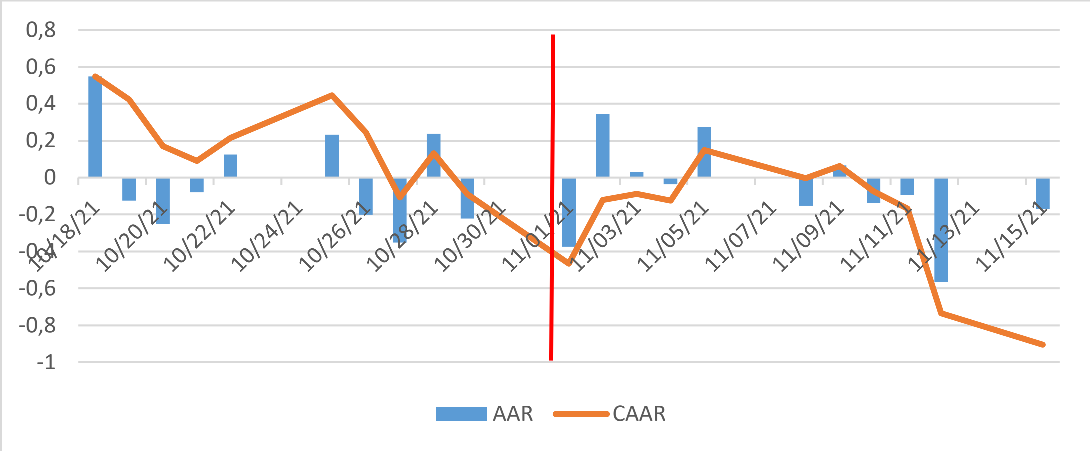
To interpret these results, recall that the outcomes the ECB climate stress test published on 22.09.21 were overall not really positive, pointing to transition costs in the short term, compensated only in the long term, and a higher exposure of significant banks to climate risk. Hence the positive market reaction has to be interpreted as a positive surprise for investors, who had likely expected a higher exposure to climate risk and more negative impacts. In fact, following the communication by the Vicepresident of the ECB, Luis de Guindos on 18.03.21, on one hand the markets became aware of the climate stress test, on the other they obtained only qualitative information about the banking system exposure to it.

5.3 Event date 01.11.21

The COP26 event produced a negative CAARs over all event windows, which are however not statistically significant.

From Figure 5 it is apparent that CAARs start becoming negative before the beginning of COP26, likely because of anticipations about China and India critical on too ambitious goals. The behavior of abnormal returns however does not suggest any significant impact of this event.

Figure 5 - AARs and CAARs (01.11.21)



The progresses reached by COP26 were quite mild and not adequate to reach the Paris Agreement goals with the "hot house world" scenario possibly more likely with respect to an "orderly transition" scenario, but the market could not draw straightforward implications for banks.

6. Robustness

Focusing on the release of the final results (22/9/2021)[14], which emerge as the only statistically significant event from the previous analysis, robustness tests are performed in two main directions. First, some of the assumptions to make the sample more homogeneous are relaxed so that the sample is extended both in relation to the bank dimension (Section 6.1) and to the bank business model (Section 6.2). Second, we test robustness of results against a different length of the estimation window (Section 6.3).

6.1 Sample including smaller banks

We set up a sample starting from the one represented in Table 1 dropping the restriction of assets above €30 billion. The restriction is set in order to have only those banks under the direct SSM supervision, but dimensionality is not the only criterion that implies falling under the SSM supervision. In fact, two Cypriot banks, Bank of Cyprus Holdings PLC and Hellenic Bank, are under SSM supervision since their assets are larger than 20% of the country GDP.

Results are summarized in Table 4. Overall results show that the effects on CAARs are the same in terms of sign and significance. It can be observed that the magnitude of CAARs is lower, possibly because of the less direct ECB supervision on the smaller banks.

[14] The robustness analyses on the other two event dates confirm non significant effects. The results are available upon request.

Table 4 – Statistical significance of CAARs: sample extended by size

Window	**+/-10**	**+/-5**	**+/-3**	**+/-1**	**+/-0**
CAAR	2.643%	2.475%	1.917%	-0.057%	0.363%
BMP Adj	1.836*	2.048**	1.941*	-0.183	1.387
KP rank	1.737*	1.862*	1.884*	0.232	1.567
Window	**+10**	**+5**	**+3**	**+1**	**+0**
CAAR	2.361%	1.837%	0.893%	0.096%	0.363%
BMP Adj	2.487***	2.492***	1.827*	0.803	1.387
KP rank	2.371**	2.327***	1.751*	0.959	1.567

Notes: BMP Adj is the test by Boehmer et al (1991) modified to account for event date clustering, as proposed in Kolari and Pynnonen (2010). KP rank is the generalized rank t test proposed by Kolari and Pynnonen (2011). The asterisks relate to the level of significance: *** <1%, ** <5%, * <10%.

6.2 Sample including other business models

Including banks with a different business model does not alter the previous results, as it is evident in Table 5: a positive significant reaction is confirmed starting from the +/-3 days event windows.

Table 5 – Statistical significance of CAARs: sample extended by business model

Window	**+/-10**	**+/-5**	**+/-3**	**+/-1**	**+/-0**
CAAR	4.495%	3.324%	2.116%	0.151%	0.340%
BMP Adj	2.037**	2.036**	1.813*	0.175	1.335
KP rank	2.000**	2.005*	1.772*	0.341	1.657
Window	**+10**	**+5**	**+3**	**+1**	**+0**
CAAR	3.306%	2.103%	1.305%	0.2714%	0.340%
BMP Adj	2.842***	2.450***	2.034**	1.004	1.335
KP rank	2.679***	2.406***	1.998**	0.955	1.657

Notes: BMP Adj is the test by Boehmer et al (1991) modified to account for event date clustering, as proposed in Kolari and Pynnonen (2010). KP rank is the generalized rank t test proposed by Kolari and Pynnonen (2011). The asterisks relate to the level of significance: *** <1%, ** <5%, * <10%.

6.3 Longer estimation window

In the main analysis we take a 6-month length estimation window, since it allows to have sufficiently stable estimates and is in line with the comparable work by Loipersberger (2018). Moreover, we expect a longer period to be affected by the Covid pandemic negative effects on financial markets. The estimation window taken in the present robustness test is a 3-year one.

Results are reported in Table 6. On the whole, they are qualitatively the same although the difference in the estimation window.

Table 6 – Statistical significance of CAARs: Three-year estimation window

Window	**+/-10**	**+/-5**	**+/-3**	**+/-1**	**+/-0**
CAAR	4.542%	3.299%	2,052%	-0.050%	0.337%
BMP Adj	2.036**	1.805*	1.550	-0.307	0.636
KP rank	2.016**	1.805*	1.586	-0.379	0.782
Window	**+10**	**+5**	**+3**	**+1**	**+0**
CAAR	3.780%	2.090%	1.199%	0.148%	0.337%
BMP Adj	2.560***	1.842*	1.198	0.225	0.636
KP rank	2.564***	1.934*	1.060	0.1219	0.782

Notes: BMP Adj is the test by Boehmer et al (1991) modified to account for event date clustering, as proposed in Kolari and Pynnonen (2010). KP rank is the generalized rank t test proposed by Kolari and Pynnonen (2011). The asterisks relate to the level of significance: *** <1%, ** <5%, * <10%.

Conclusions

Climate change is likely the most challenging issue to be faced in this century also by financial institutions and at no surprise the ECB has engaged in many supervisory actions. First, in order to foster a homogeneous climate risk management approach lacking so far among banks, the ECB has published its supervisory expectations on the management of climate risks (ECB, 2020). Moreover in 2021, its first economy-wide climate stress test was implemented in order to assess the resilience of non-financial companies and euro area banks to transition and physical risk under climate policy scenarios. Given the relevance this type of tests may have in the future also in terms of regulatory requirements for banks, an impact on banks market value was in principle to be expected.

In this paper we assess how the 2021 ECB Climate stress test affected the market view of the climate risk impact on the banking sector, and, as far as we know we are the first to address the issue. To this end an event study analysis was implemented to answer a set of related research questions: have market investors reacted to 2021 ECB climate stress test? If so, have bank quotes anticipated and/or reflected (expected) outcomes of this first test? Given that information was released in two steps, i.e. first announcement of methodology and preliminary (March 2021) then final results (September 2021), was the reaction alike? Was an important climate related initiative such as COP26 (November 2021) also bearing information to the market? To answer these questions, we set up an event study analysis, whereby at the relevant dates we have used market data in order to test for the existence of abnormal returns.

A few main results emerge from our research. First, the announcement of the methodology of the ECB climate stress test and some preliminary mainly qualitative evidence had no impact on the stock prices of the banks included in the exercise. Second, on the date of publication of the final results, the evidence shows a significant positive reaction from market participants with positive cumulative average returns ranging from +2.2% (+/-3 days window) to +4.62% (+/-10 days window). This positive reaction can be interpreted as a positive surprise with respect to the announcement, as the market expected the banks' exposure to climate risks to be greater than the one emerging from final results. Third, on the starting date of COP26, there is no significant effect on banks' quotes, which can be explained by the event being much related to climate policy but only indirectly related to climate stress test. Finally, robustness tests including smaller banks and banks with a business model not focused on credit intermediation provide results aligned with the main sample ones.

Our results may have policy implications for future climate stress tests and institutional initiatives needed to manage climate risk, and for the academic research agenda. First, the way information is released is relevant especially if it is provided to the public in one or more steps and, in the latter case, the consistency between the various pieces of information may determine different market reactions. Finally, models for measuring financial fragility of banks (e.g Aspachs et al., (2007), Lee et al., 2013), may be usefully extended to account for climate risk.

References

Alogoskoufis S., Dunz N., Emambakhsh T., Hennig T., Kaijser M., Kouratzoglou C., Muñoz M.A., Parisi L., Salleo C., (2021), "ECB economy-wide climate stress test: methodology and results", Occasional Paper Series, N. 281, September.

Aspachs, O., Goodhart, C.A.E., Tsomocos, D.P., Zicchino, L., (2007), Towards a measure of financial fragility. *Annals of Finance*, 3, 37–74.

BCBS (Basel Committee on Banking Supervision), (2021a), "Climate related financial risks – measurement methodologies", Report, April

BCBS (Basel Committee on Banking Supervision), (2021b), "Climate related risk drivers and their transmission channels", Report, April

Bolton P., Despres M., Pereira Da Silva S.A., Samama F., Svartzman R., (2020), "The green swan; Central banking and financial stability in the age of climate change", Bank for International Settlement, January

Boehmer E., Musumeci J., Poulsen A.B., (1991), "Event-study methodology under conditions of event-induced variance", *Journal of Financial Economics*, 30, p. 253-272

Clerc L., Bontemps-Chanel A., Diot S., Overton G., Soares De Albergaria S., Vernet L., Louardi M., (2021), "A First assessment of financial risks stemming from climate change: The main results of the 2020 climate pilot exercise", Autorité de contrôle prudentiel et de résolution (ACPR), Banque De France (BdF), April

Corrado C., (1989), "A nonparametric test for abnormal security price performance in event studies", *Journal of Financial Economics*, Vol. 23, 385-395.

De Guindos L., (2021), "Shining a light on climate risk: the ECB's economy-wide climate stress test", Blog post, The ECB Blog, 18 March.

ECB (European Central Bank), (2020), "Guide on climate-related and environmental risks: Supervisory expectations relating to risk management and disclosure", November

ECB (European Central Bank), (2021), "Methodological note for the publication of aggregated Supervisory Banking Statistics", Third Quarter

European Commission, (2021a), "'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality", Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Communication 550, 14 July, Brussels

European Commission, (2021b), "Establishing a Social Climate Fund", Proposal for a regulation of the European Parliament and of the Council, Communication 568, 14 July, Brussels

FSB (Financial Stability Board), (2020), "The Implications of Climate Change for Financial Stability", 23 November

Jaffe J. F., (1974), "The Effects of Regulation Changes on Insider Trading", *Bell Journal of Economics and Management Science*, 5,93-121.

Kolari J.W., Pynnonen S., (2010), "Event Study Testing with Cross-sectional Correlation of Abnormal Returns", *Review of Financial Studies*, 23(11), 3996-4025.

Kolari J.W., Pynnonen S., (2011), "Nonparametric rank tests for event studies", *Journal of Empirical Finance*, 18, 953-971.

Kruger P., (2015), "Corporate goodness and shareholder wealth." *Journal of Financial Economics*, 115(2), 304-329.

Lee J-H., Ryu J., Tsomocos D., (2013), "Measures of Systemic Risk and Financial Fragility in Korea", *Annals of Finance*, 9, 757-787.

Loipersberger F., (2018), "The effect of supranational banking supervision on the financial sector: Event study evidence from Europe", *Journal of Banking and Finance*, 91, 34-48.

Network for Greening the Financial System (2020), *NGFS Climate scenarios for central banks and supervisors*, Paris, June.

Pederzoli C., Torricelli C., (2017), "Systemic risk measures and macroprudential stress tests - An assessment over the 2014 EBA exercise", *Annals of Finance*, 13, 237-251.

Petrella G., Resti A., (2013). "Supervisors as information producers: Do stress tests reduce bank opaqueness?" *Journal of Banking & Finance* 37(12), 5406-5420.

United Nations (UN) (2015), *Transforming our world: the 2030 Agenda for Sustainable Development.* Available at https://sdgs.un.org/2030agenda