Online Appendix to Measuring European Banks' Exposure To Climate Risk

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The appendix is organised in three sections. The first is devoted to representation of the tables and figures relative to the estimation results. The second reports the main risk decomposition figures and finally the third reports the analysis conducted on the climate risk factor.

1 Dynamic Betas estimation

In this section we report the main statistics of dynamic climate (Table 1) and market (Table 2) betas as well as the coefficients and t-stat of DCC model (Table 3) and the OLS (Table 4) model introduced for comparison purpose.

Table: Main statistics of dynamic climate betas' estimation.

#	Bank	Min	Max	Mean	St. Dev.	Skewness	Kurtosis	Count
1	CREDIT AGRICOLE SA	-0,42	0,60	0,04	0,12	0,04	3,58	5491
2	BNP PARIBAS	-0,54	0,67	0,01	0,11	0,41	4,87	5999
3	SOCIETE GENERALE SA	-0,46	0,92	0,04	0,14	0,86	5,46	5999
4	BANCO SANTANDER SA	-0,54	0,98	0,03	0,13	0,93	6,67	5999
5	BANCO BILBAO VIZCAYA ARGENTA	-0,47	0,99	0,02	0,12	0,89	7,90	5999
6	ING GROEP NV	-0,74	0,73	0,01	0,14	0,02	4,85	5999
7	UNICREDIT SPA	-0,37	0,49	0,03	0,13	0,33	3,09	5999
8	INTESA SANPAOLO	-0,48	0,62	0,00	0,13	0,26	4,24	5999
9	CAIXABANK SA	-0,47	1,15	0,10	0,15	0,74	6,29	3972
10	COMMERZBANK AG	-0,38	0,78	0,08	0,15	0,56	3,52	5999
11	DEUTSCHE BANK AG-REGISTERED	-0,46	0,83	0,05	0,14	0,58	4,68	5999
12	NORDEA BANK ABP	-0,46	0,59	0,03	0,09	0,03	4,95	5999
13	DNB BANK ASA	-0,20	0,44	0,08	0,10	0,26	2,88	5999
14	BANCO DE SABADELL SA	-0,61	1,68	0,04	0,20	1,64	9,63	5662
15	DANSKE BANK A/S	-0,29	0,64	0,02	0,11	0,64	4,81	5999
16	ERSTE GROUP BANK AG	-0,38	0,56	0,04	0,13	0,43	3,23	5999
17	KBC GROUP NV	-0,47	0,85	0,02	0,13	0,52	4,84	5999
18	SWEDBANK AB - A SHARES	-0,39	0,49	0,02	0,08	0,54	5,00	5999
19	RAIFFEISEN BANK INTERNATIONA	-0,51	0,66	0,10	0,12	0,28	5,42	4615
20	BANCO BPM SPA	-0,68	0,75	0,07	0,16	-0,15	4,06	4044
21	BANKINTER SA	-0,52	1,06	0,02	0,14	0,72	6,60	5999
22	OTP BANK PLC	-0,50	0,37	0,05	0,11	-0,28	4,02	5999
23	MEDIOBANCA SPA	-0,42	0,64	0,03	0,11	0,48	5,18	5999
24	BPER BANCA	-0,64	0,76	0,04	0,13	0,51	5,19	5999
25	JYSKE BANK-REG	-0,47	0,39	-0,01	0,09	-0,13	4,72	5999
26	PKO BANK POLSKI SA	-0,14	0,72	0,12	0,09	0,92	4,94	4733
27	BANK PEKAO SA	-0,30	0,53	0,09	0,12	0,25	3,69	5999
28	BANCA POPOLARE DI SONDRIO	-0,41	0,55	0,03	0,10	0,82	5,20	5999
29	BANK OF IRELAND GROUP PLC	-0,80	0,78	0,04	0,19	0,48	5,19	5999
30	BANCO COMERCIAL PORTUGUES-R	-1,08	0,86	0,04	0,16	-0,35	7,47	5999
31	BANCA MEDIOLANUM SPA	-0,41	0,58	0,00	0,10	0,53	6,06	5999
32	AAREAL BANK AG	-1,16	0,50	0,00	0,15	-1,62	11,19	5359
33	SPAREBANK 1 SR BANK ASA	-0,15	0,79	0,09	0,10	0,85	4,59	5999
34	SPAREBANK 1 SMN	-0,28	0,56	0,08	0,10	0,30	3,52	5999
35	SKANDINAVISKA ENSKILDA BAN-A	-0,39	0,54	0,03	0,09	0,28	4,69	5999

Table 1: Main statistics of banks' dynamic climate beta. Given the linearity assumption of banks' stock return with respect to CTFactor returns, dynamic climate betas are estimated moving from the dynamic variance/covariance matrix derived from GJRGARCH-DCC model (DCB model).

Table: Main statistics of dynamic market betas' estimation.

#	Bank	Min	Max	Mean	St. Dev.	Skewness	Kurtosis	Count
1	CREDIT AGRICOLE SA	0,16	3,76	1,44	0,51	0,91	4,49	5491
2	BNP PARIBAS	0,34	3,57	1,46	0,48	0,86	4,22	5999
3	SOCIETE GENERALE SA	0,07	4,88	1,61	0,57	1,09	5,68	5999
4	BANCO SANTANDER SA	0,38	3,45	1,42	0,42	0,78	4,02	5999
5	BANCO BILBAO VIZCAYA ARGENTA	0,31	3,15	1,39	0,42	0,59	3,63	5999
6	ING GROEP NV	0,16	5,45	1,54	0,59	0,87	4,79	5999
7	UNICREDIT SPA	0,33	7,13	1,45	0,75	1,91	10,46	5999
8	INTESA SANPAOLO	0,10	3,96	1,35	0,57	0,97	4,28	5999
9	CAIXABANK SA	0,21	2,95	1,16	0,41	0,55	3,27	3972
10	COMMERZBANK AG	0,21	4,55	1,53	0,57	0,59	3,55	5999
11	DEUTSCHE BANK AG-REGISTERED	0,36	3,85	1,60	0,52	0,73	3,56	5999
12	NORDEA BANK ABP	0,28	3,07	1,16	0,34	0,90	4,83	5999
13	DNB BANK ASA	0,09	3,02	1,04	0,40	0,59	3,86	5999
14	BANCO DE SABADELL SA	-0,06	4,79	1,04	0,57	1,15	5,64	5662
15	DANSKE BANK A/S	0,09	2,76	0,86	0,35	0,63	3,81	5999
16	ERSTE GROUP BANK AG	0,10	3,73	1,14	0,57	0,54	3,52	5999
17	KBC GROUP NV	0,16	5,38	1,28	0,64	1,58	7,08	5999
18	SWEDBANK AB - A SHARES	0,31	3,88	1,10	0,41	1,40	6,95	5999
19	RAIFFEISEN BANK INTERNATIONA	0,48	4,17	1,52	0,49	1,16	5,18	4615
20	BANCO BPM SPA	0,44	3,80	1,63	0,58	0,73	3,24	4044
21	BANKINTER SA	0,15	2,98	1,07	0,40	0,85	3,78	5999
22	OTP BANK PLC	0,15	3,42	1,06	0,49	0,87	3,95	5999
23	MEDIOBANCA SPA	0,25	3,95	1,15	0,50	1,40	6,48	5999
24	BPER BANCA	-0,32	4,82	0,86	0,81	1,08	3,92	5999
25	JYSKE BANK-REG	0,07	2,30	0,71	0,33	0,47	3,34	5999
26	PKO BANK POLSKI SA	0,38	2,74	1,15	0,35	0,78	3,95	4733
27	BANK PEKAO SA	0,20	2,78	1,04	0,41	0,66	3,86	5999
28	BANCA POPOLARE DI SONDRIO	-0,48	2,91	0,68	0,54	0,77	3,27	5999
29	BANK OF IRELAND GROUP PLC	0,12	4,89	1,34	0,78	1,12	4,36	5999
30	BANCO COMERCIAL PORTUGUES-R	0,09	4,00	0,99	0,59	1,27	5,00	5999
31	BANCA MEDIOLANUM SPA	0,42	3,15	1,35	0,40	0,76	4,14	5999
32	AAREAL BANK AG	0,03	4,40	1,25	0,58	0,77	4,45	5359
33	SPAREBANK 1 SR BANK ASA	-0,23	2,36	0,63	0,36	0,37	3,12	5999
34	SPAREBANK 1 SMN	0,03	1,88	0,64	0,30	0,36	2,74	5999
35	SKANDINAVISKA ENSKILDA BAN-A	0,26	3,14	1,26	0,39	1,17	5,72	5999

Table 2: Main statistics of banks' dynamic market beta. Given the linearity assumption of banks' stock return with respect to market returns, dynamic climate betas are estimated moving from the dynamic variance/covariance matrix derived from GJRGARCH-DCC model (DCB model).

Table: Coefficients and t-stat of DCC model.

#	Bank	Alfa	Tstat Alfa	Beta	Tstat Beta
1	CREDIT AGRICOLE SA	0,024	4,957	0,962	102,234
2	BNP PARIBAS	0,024	5,655	0,967	137,705
3	SOCIETE GENERALE SA	0,025	5,198	0,965	120,783
4	BANCO SANTANDER SA	0,022	5,424	0,970	167,599
5	BANCO BILBAO VIZCAYA ARGENTA	0,023	6,817	0,968	180,911
6	ING GROEP NV	0,020	5,561	0,973	180,370
7	UNICREDIT SPA	0,020	5,346	0,973	163,965
8	INTESA SANPAOLO	0,023	5,516	0,967	141,691
9	CAIXABANK SA	0,031	6,164	0,946	98,723
10	COMMERZBANK AG	0,016	5,155	0,978	209,843
11	DEUTSCHE BANK AG-REGISTERED	0,021	5,428	0,972	160,510
12	NORDEA BANK ABP	0,015	3,600	0,980	161,097
13	DNB BANK ASA	0,013	4,137	0,982	204,961
14	BANCO DE SABADELL SA	0,023	4,713	0,969	124,766
15	DANSKE BANK A/S	0,017	4,746	0,977	172,746
16	ERSTE GROUP BANK AG	0,018	3,387	0,977	131,247
17	KBC GROUP NV	0,025	5,707	0,963	127,060
18	SWEDBANK AB - A SHARES	0,014	3,888	0,981	181,047
19	RAIFFEISEN BANK INTERNATIONA	0,015	2,783	0,975	103,321
20	BANCO BPM SPA	0,017	5,369	0,973	157,181
21	BANKINTER SA	0,023	6,330	0,968	161,011
22	OTP BANK PLC	0,012	4,330	0,984	244,451
23	MEDIOBANCA SPA	0,020	4,609	0,971	130,606
24	BPER BANCA	0,011	5,474	0,986	364,483
25	JYSKE BANK-REG	0,013	4,244	0,983	223,329
26	PKO BANK POLSKI SA	0,011	3,558	0,982	155,772
27	BANK PEKAO SA	0,011	5,294	0,985	319,525
28	BANCA POPOLARE DI SONDRIO	0,012	3,890	0,984	227,257
29	BANK OF IRELAND GROUP PLC	0,016	5,166	0,979	206,723
30	BANCO COMERCIAL PORTUGUES-R	0,013	5,892	0,983	300,851
31	BANCA MEDIOLANUM SPA	0,015	4,293	0,978	170,794
32	AAREAL BANK AG	0,015	1,872	0,980	82,300
33	SPAREBANK 1 SR BANK ASA	0,009	3,330	0,989	268,220
34	SPAREBANK 1 SMN	0,014	3,941	0,982	187,040
35	SKANDINAVISKA ENSKILDA BAN-A	0,016	3,220	0,976	115,056

Table 3: The DCC model specifies the evolution of the pseudo-covariance matrix as illustrated in equation 4). Table 3 reports α and β parameters and their significativity in terms of t-stat.

Table: Coefficients and t-stat of OLS regression model.

#	Bank	Cons	Tstat Cons	Mkt	Tstat Mkt	CFactor	Tstat Cfactor
1	CREDIT AGRICOLE SA	0,000	-0,290	1,457	41,478	0,045	2,125
2	BNP PARIBAS	0,000	0,000	1,439	44,461	0,036	1,810
3	SOCIETE GENERALE SA	0,000	0,000	1,589	38,643	0,060	2,383
4	BANCO SANTANDER SA	0,000	0,000	1,408	53,501	0,058	3,922
5	BANCO BILBAO VIZCAYA ARGENTA	0,000	0,000	1,362	54,789	0,039	2,835
6	ING GROEP NV	0,000	0,000	1,758	46,187	0,082	3,411
7	UNICREDIT SPA	0,000	0,000	1,419	40,739	0,070	3,019
8	INTESA SANPAOLO	0,000	0,000	1,364	41,229	0,042	2,160
9	CAIXABANK SA	0,000	0,048	1,009	29,688	0,067	3,189
10	COMMERZBANK AG	0,000	0,000	1,520	39,613	0,120	4,191
11	DEUTSCHE BANK AG-REGISTERED	0,000	0,000	1,567	54,322	0,083	3,997
12	NORDEA BANK ABP	0,000	0,000	1,216	43,344	0,060	3,081
13	DNB BANK ASA	0,000	0,000	1,161	35,097	0,148	6,137
14	BANCO DE SABADELL SA	0,000	-0,045	0,909	24,709	0,089	4,575
15	DANSKE BANK A/S	0,000	0,000	0,917	34,247	0,051	2,787
16	ERSTE GROUP BANK AG	0,000	0,000	1,180	32,110	0,089	3,474
17	KBC GROUP NV	0,000	0,000	1,399	33,321	0,087	2,692
18	SWEDBANK AB - A SHARES	0,000	0,000	1,219	36,532	0,097	4,171
19	RAIFFEISEN BANK INTERNATIONA	0,000	-0,339	1,523	31,253	0,082	2,558
20	BANCO BPM SPA	0,000	0,022	1,418	27,862	0,036	1,174
21	BANKINTER SA	0,000	0,000	1,000	34,296	0,033	1,857
22	OTP BANK PLC	0,000	0,000	1,134	27,311	0,128	4,666
23	MEDIOBANCA SPA	0,000	0,000	1,025	27,879	0,027	1,556
24	BPER BANCA	0,000	0,000	0,842	20,636	0,069	3,429
25	JYSKE BANK-REG	0,000	0,000	0,719	29,123	0,049	2,714
26	PKO BANK POLSKI SA	0,000	-0,339	1,128	31,233	0,098	4,816
27	BANK PEKAO SA	0,000	0,000	0,988	25,617	0,117	5,037
28	BANCA POPOLARE DI SONDRIO	0,000	0,000	0,636	18,826	0,046	2,808
29	BANK OF IRELAND GROUP PLC	0,000	0,000	1,353	19,357	0,130	2,983
30	BANCO COMERCIAL PORTUGUES-R	0,000	0,000	0,900	26,211	0,055	2,858
31	BANCA MEDIOLANUM SPA	0,000	0,000	1,238	40,330	-0,020	-1,040
32	AAREAL BANK AG	0,000	-0,272	1,346	21,108	0,103	2,454
33	SPAREBANK 1 SR BANK ASA	0,000	0,000	0,690	16,624	0,147	7,059
34	SPAREBANK 1 SMN	0,000	0,000	0,663	20,360	0,115	5,350
35	SKANDINAVISKA ENSKILDA BAN-A	0,000	0,000	1,395	40,966	0,084	3,612

Table 4: The significativity in terms of t-stat is almost always confirmed both for market and climate factor, where "Cons" is the constant, "Mkt" is the Market return and "CTFactor" is the CTFactor return.

The estimates of dynamic climate transition betas are reported hereafter for each bank, grouped by country from Figure 1 to Figure 5 for Italy, Spain, France, Norway and Germany. In Figure 6 we report the dynamic betas of the remaining banks. All the Betas' time series have been smoothed with a six-months moving average.

Figure : Climate Transition Beta of Italian banks.

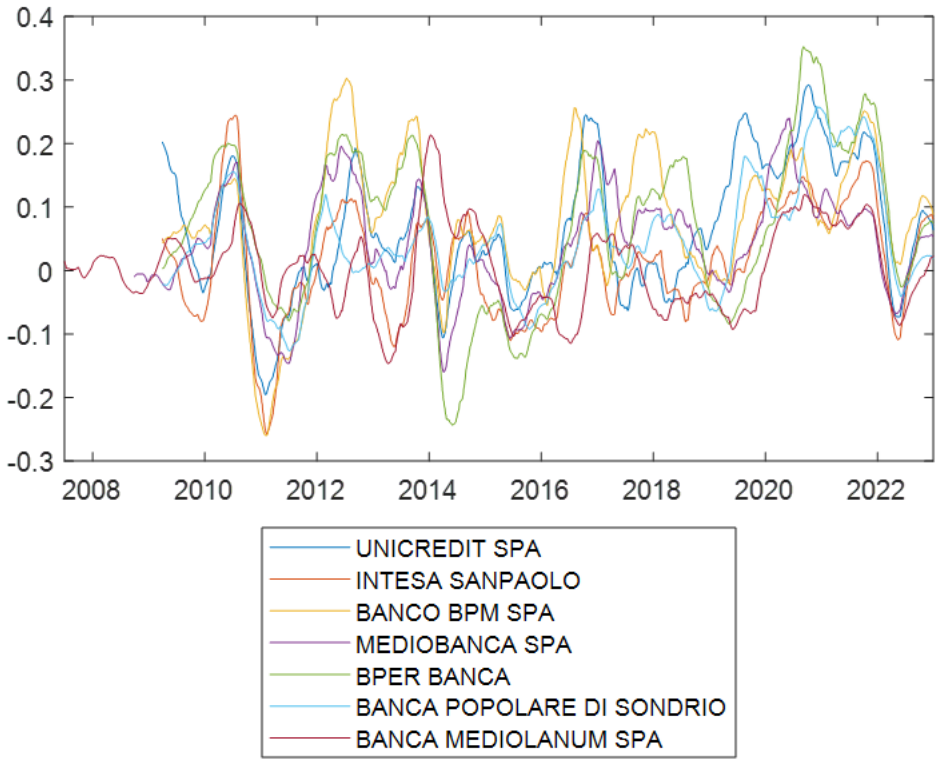

Figure 1: Dynamic climate betas are reported for 7 major Italian banks. Betas have been smoothed with a moving average of 126 days.

Figure : Climate Transition Beta of Spanish Banks.

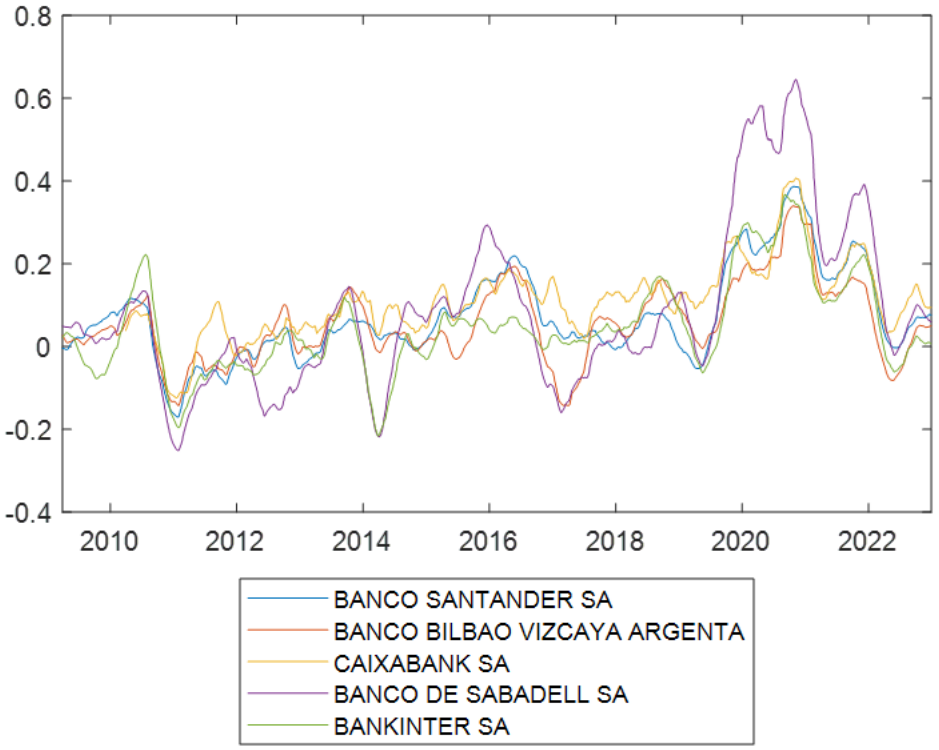

Figure 2: Dynamic climate betas are reported for 5 major Spanish banks. Betas have been smoothed with a moving average of 126 days.

Figure : Climate Transition Beta of French Banks.

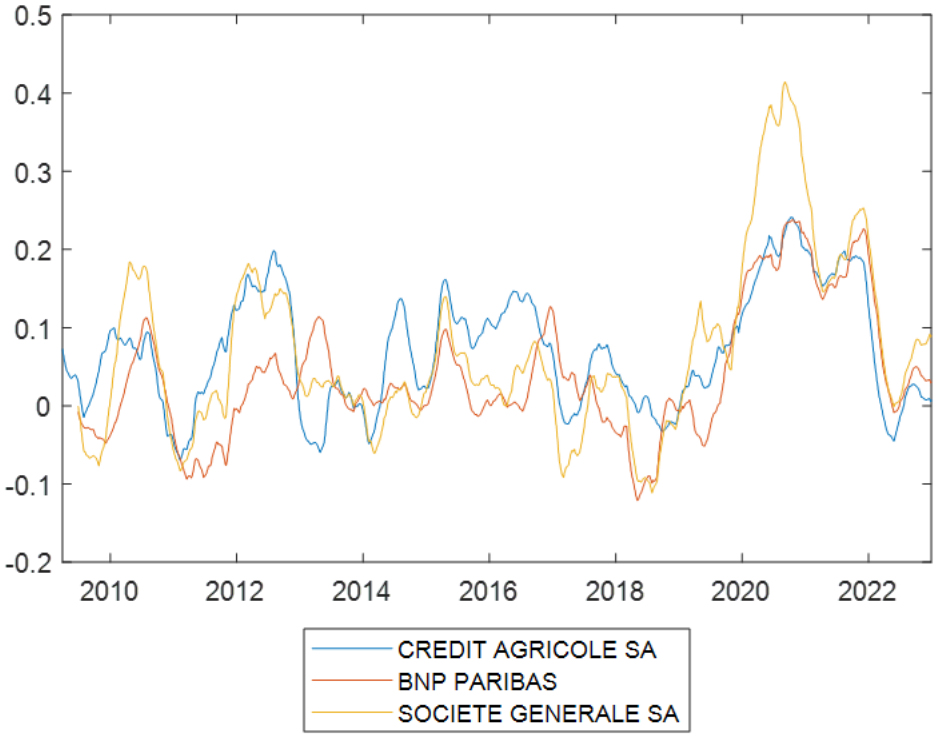

Figure 3: Dynamic climate betas are reported for 3 major French banks. Betas have been smoothed with a moving average of 126 days.

Figure : Climate Transition Beta of Norwegian Banks.

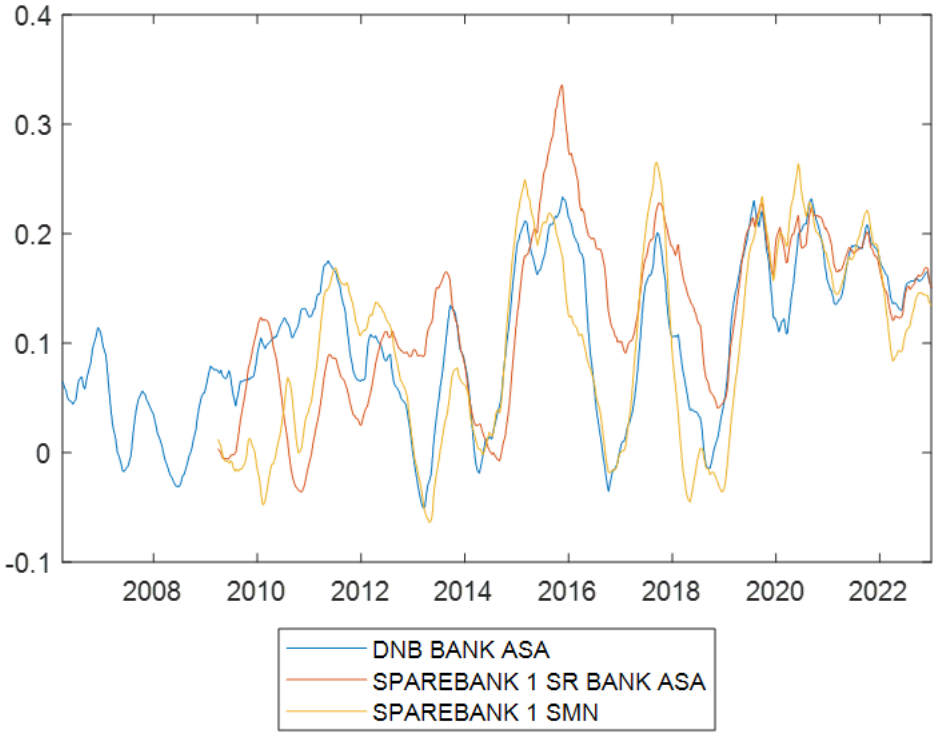

Figure 4: Dynamic climate betas are reported for 3 major Norwegian banks. Betas have been smoothed with a moving average of 126 days.

Figure: Climate Transition Beta of German Banks.

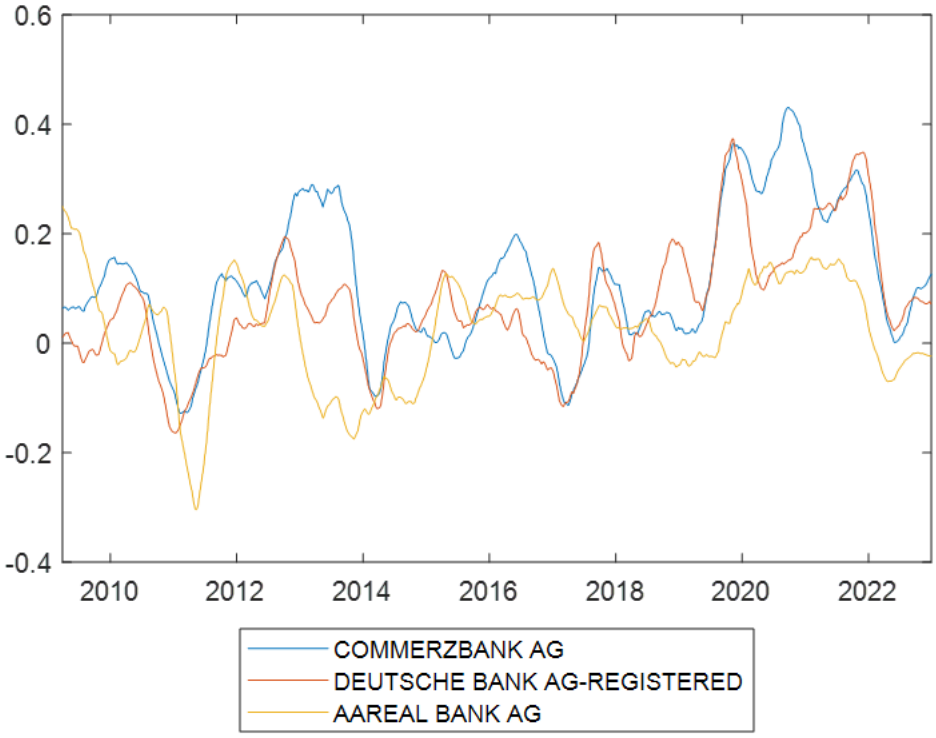

Figure 5: Dynamic climate betas are reported for 3 major German banks. Betas have been smoothed with a moving average of 126 days.

Figure : Climate Transition Beta of all other Banks.

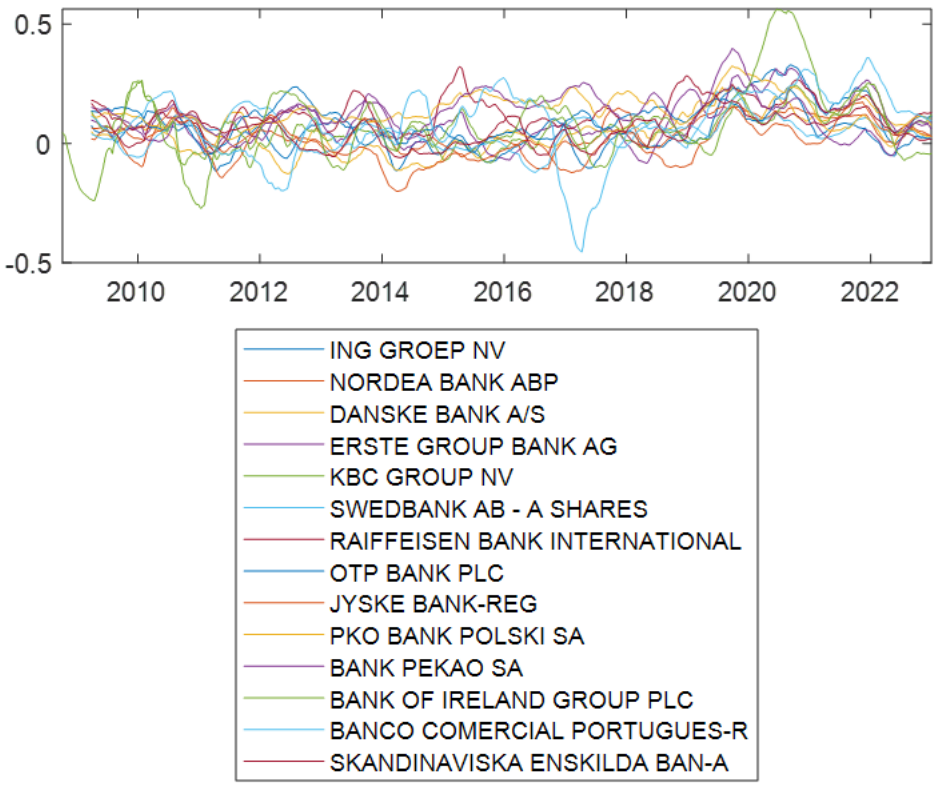

Figure 6: Dynamic climate betas are reported for 14 major European banks, exluding Italian, Spanish, French, Norwegian and German banks. Betas have been smoothed with a moving average of 126 days.

2 CRISK Decomposition

CRISKs for the selected Italian, German, French, Spanish and Norwegian institution are depicted in Figures from 7 to 11. CRISKs of all the other banks are not represented hereafter, but they are available upon request. Generally speaking, CRISK of many European banks have increased in recent years. Interestingly, French and German banks result to be the most exposed to climate risk, whereas Norwegian banks appear to be the most resilient to it.

Figure : CRISK of Italian banks.

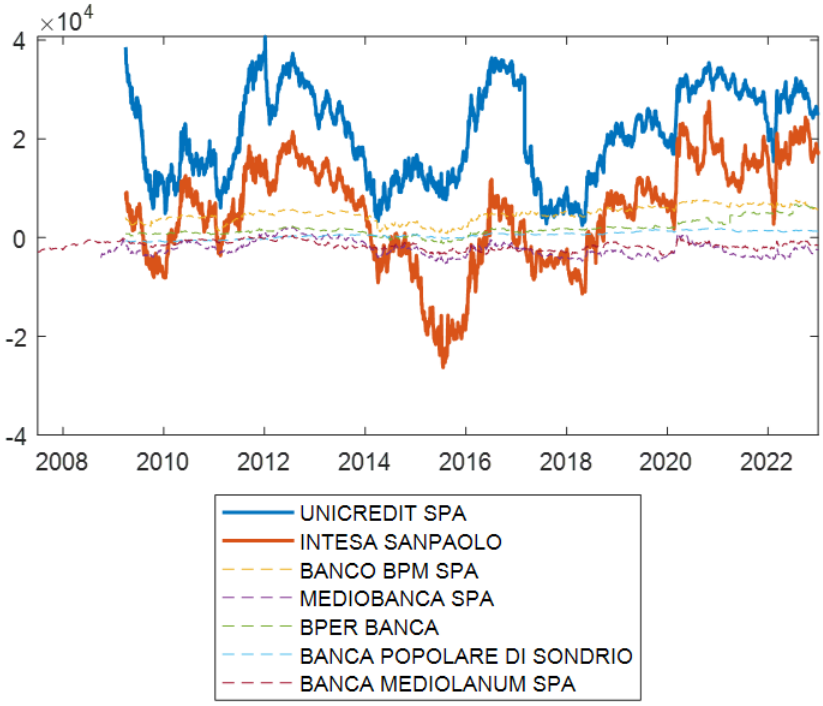

Figure 7: CRISK is reported for 7 major Italian banks. CRISK is computed as $CRISK_{i,t} = k \cdot DEBT_{i,t} - (1-k) \cdot EQUITY_{i,t} \cdot (1 - LRMES_{i,t})$. Climate betas have been smoothed with a moving average of 126 days.

Figure : CRISK of Spanish banks.

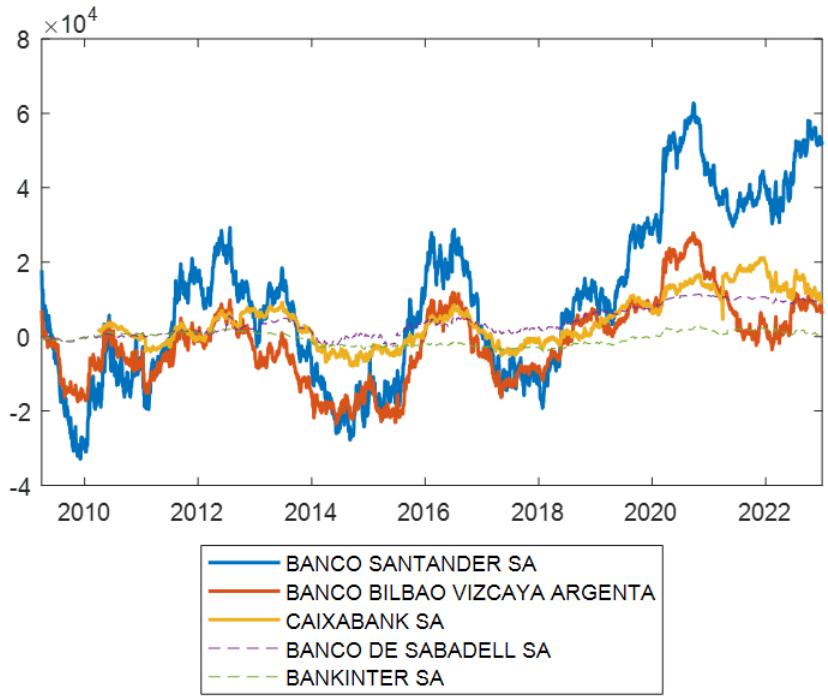

Figure 8: CRISK is reported for 5 major Spanish banks. CRISK is computed as $CRISK_{i,t} = k \cdot DEBT_{i,t} - (1-k) \cdot EQUITY_{i,t} \cdot (1 - LRMES_{i,t})$. Climate betas have been smoothed with a moving average of 126 days.

Figure : CRISK of French Banks.

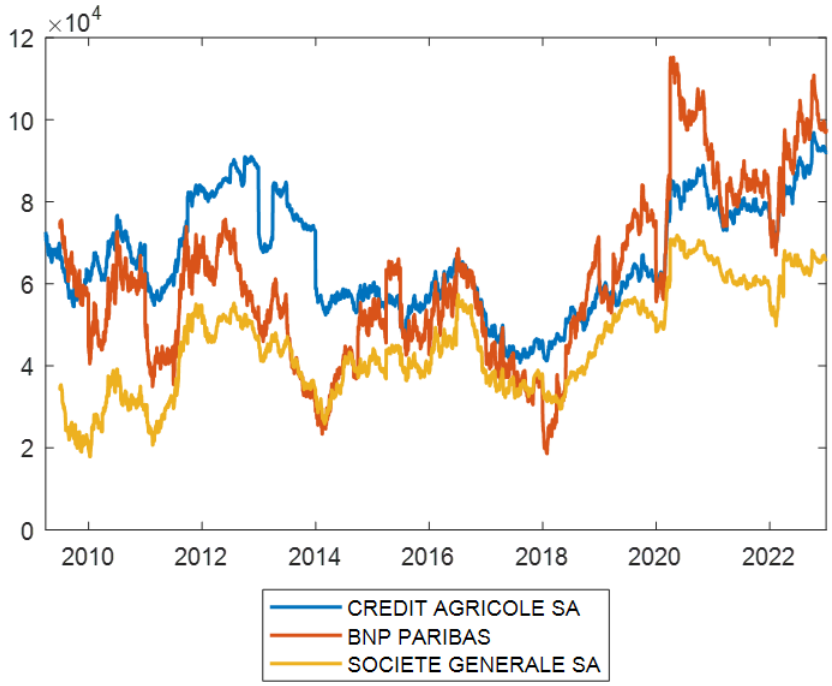

Figure 9: CRISK is reported for 3 major French banks. CRISK is computed as $CRISK_{i,t} = k \cdot DEBT_{i,t} - (1-k) \cdot EQUITY_{i,t} \cdot (1 - LRMES_{i,t})$. Climate betas have been smoothed with a moving average of 126 days.

Figure : CRISK of Norwegian Banks.

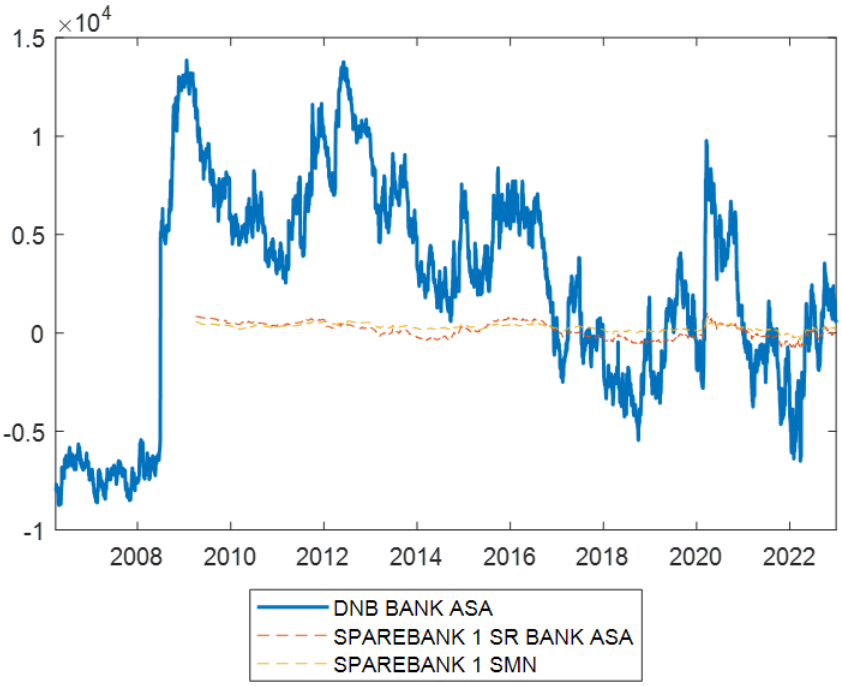

Figure 10: CRISK is reported for 3 major Norwegian banks. CRISK is computed as $CRISK_{i,t} = k \cdot DEBT_{i,t} - (1-k) \cdot EQUITY_{i,t} \cdot (1 - LRMES_{i,t})$. Climate betas have been smoothed with a moving average of 126 days.

Figure : CRISK of German Banks.

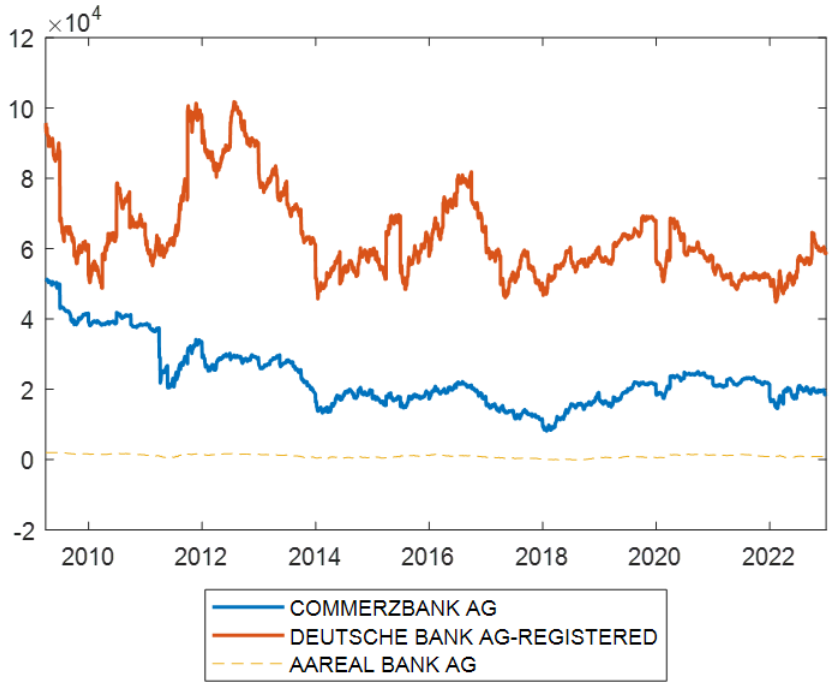

Figure 11: CRISK is reported for 3 major German banks. CRISK is computed as $CRISK_{i,t} = k \cdot DEBT_{i,t} - (1-k) \cdot EQUITY_{i,t} \cdot (1 - LRMES_{i,t})$. Climate betas have been smoothed with a moving average of 126 days.

To better understand the dynamics of CRISK in this period span, we decompose CRISK of each bank into the components due to debt, equity, and climate risk and then we aggregate them at country level, according to the methodology explained in section 2 of the paper. Tables from 5 to 9 show the yearly decomposition of CRISK (in EUR bn) for the most representative European countries in the period between 2019 – 2022.

Table: Decomposition of Italian CRISK.

Italy - CRISK decom.				
Date	**cDebt**	**cEquity**	**cRisk**	**ΔCRISK**
31/12/2019	1,5	-17,2	6,5	-9,2
31/12/2020	7,4	16,5	0,7	24,7
31/12/2021	1,8	-22,2	-1,4	-21,8
30/12/2022	1,6	8,8	-2,6	7,8
Total	**12,3**	**-14,1**	**3,3**	**1,4**

Table 5: cDebt: contribution of total liabilities to CRISK (EUR bn); cEquity: contribution of market capitalization to CRISK (EUR bn); cRisk: contribution of climate risk to CRISK (EUR bn); cCRISK is equal to the sum of cDebt, cEquity and cRisk. It approximates the capital shortfall (if positive) or capital surplus (if negative) in case of a climate stress scenario. All values are reported in EUR bn.

Table: Decomposition of French CRISK.

France - CRISK decom.				
Date	**cDebt**	**cEquity**	**cRisk**	**ΔCRISK**
31/12/2019	11,1	-26,6	11,9	-3,6
31/12/2020	21,8	25,0	4,8	51,7
31/12/2021	6,5	-34,2	-3,7	-31,3
30/12/2022	33,0	22,1	-10,2	45,0
Total	**72,5**	**-13,6**	**2,8**	**61,7**

Table 6: cDebt: contribution of total liabilities to CRISK (EUR bn); cEquity: contribution of market capitalization to CRISK (EUR bn); cRisk: contribution of climate risk to CRISK (EUR bn); cCRISK is equal to the sum of cDebt, cEquity and cRisk. It approximates the capital shortfall (if positive) or capital surplus (if negative) in case of a climate stress scenario. All values are reported in EUR bn.

Table: Decomposition of Spanish CRISK.

Spain - CRISK decom.				
Date	**cDebt**	**cEquity**	**cRisk**	**ΔCRISK**
31/12/2019	0,6	2,0	14,6	17,1
31/12/2020	6,3	25,5	3,8	35,6
31/12/2021	0,9	-19,5	-8,9	-27,5
30/12/2022	8,2	-7,5	-8,4	-7,7
Total	**15,9**	**0,5**	**1,1**	**17,5**

Table 7: cDebt: contribution of total liabilities to CRISK (EUR bn); cEquity: contribution of market capitalization to CRISK (EUR bn); cRisk: contribution of climate risk to CRISK (EUR bn); cCRISK is equal to the sum of cDebt, cEquity and cRisk. It approximates the capital shortfall (if positive) or capital surplus (if negative) in case of a climate stress scenario. All values are reported in EUR bn.

Table : Decomposition of German CRISK.

Germany - CRISK decom.				
Date	**cDebt**	**cEquity**	**cRisk**	**ΔCRISK**
31/12/2019	-3,7	0,2	2,3	-1,2
31/12/2020	3,3	-2,7	-1,0	-0,3
31/12/2021	-3,3	-5,2	0,7	-7,8
30/12/2022	9,6	-1,8	-3,7	4,0
Total	**6,0**	**-9,5**	**-1,6**	**-5,2**

Table 8: cDebt: contribution of total liabilities to CRISK (EUR bn); cEquity: contribution of market capitalization to CRISK (EUR bn); cRisk: contribution of climate risk to CRISK (EUR bn); cCRISK is equal to the sum of cDebt, cEquity and cRisk. It approximates the capital shortfall (if positive) or capital surplus (if negative) in case of a climate stress scenario. All values are reported in EUR bn.

Table : Decomposition of Norwegian CRISK.

Norway - CRISK decom.				
Date	**cDebt**	**cEquity**	**cRisk**	**ΔCRISK**
31/12/2019	0,7	-4,0	1,6	-1,7
31/12/2020	-0,6	1,7	0,5	1,6
31/12/2021	-0,4	-7,2	0,3	-7,3
30/12/2022	1,4	3,1	-0,5	4,0
Total	**1,1**	**-6,4**	**2,0**	**-3,4**

Table 9: cDebt: contribution of total liabilities to CRISK (EUR bn); cEquity: contribution of market capitalization to CRISK (EUR bn); cRisk: contribution of climate risk to CRISK (EUR bn); cCRISK is equal to the sum of cDebt, cEquity and cRisk. It approximates the capital shortfall (if positive) or capital surplus (if negative) in case of a climate stress scenario. All values are reported in EUR bn.

3 Climate Risk Factor

The Climate risk factor is computed as a stranded asset portfolio consists of a long position in the stranded asset index comprised of 30% in Energy Select Sector SPDR ETF (**XLE**) and 70% in VanEck Vectors Coal ETF (**KOL**), and a short position in the markey index.

Figure : Scaled Transition Risk Index and Scaled Market Index.

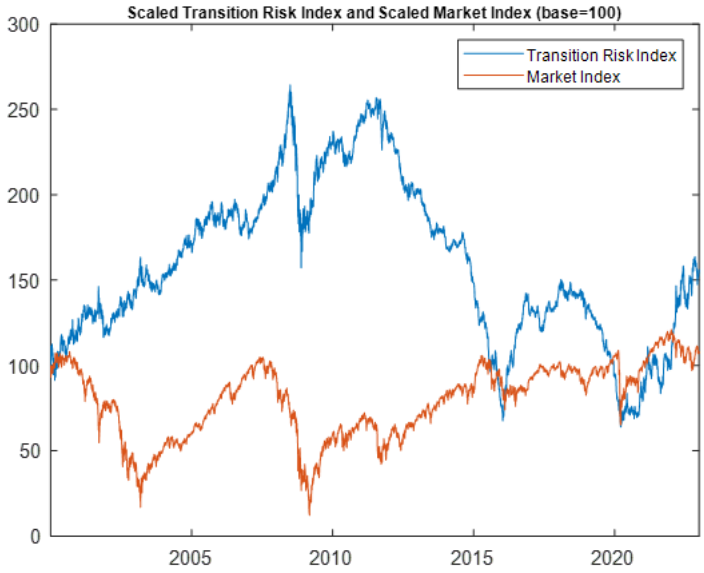

Figure 12: Transition risk index and market index are scaled on a 100-basis at the beginning of January 2000. Transition risk index is computed as $CTFactor = 0.3 \cdot XLE + 0.7 \cdot KOL - 1.0 \cdot MSCI$, until KOL liquidation. Before KOL inception and after KOL liquidation, CTFactor is computed as $CTFactor = 1.0 \cdot XLE - 1.0 \cdot MSCI$. European market is approximated by MSCI Europe.

Transition betas and loan exposure towards energy sector show a positive correlation for three out of four quarters taken into account. More specifically (see Figure 13), over the four quarters, we find a pattern of correlation loosening until a change in sign (from positive to negative) in June 2022.

Figure : Correlation between climate transition risk beta and NFC loans towards energy sector.

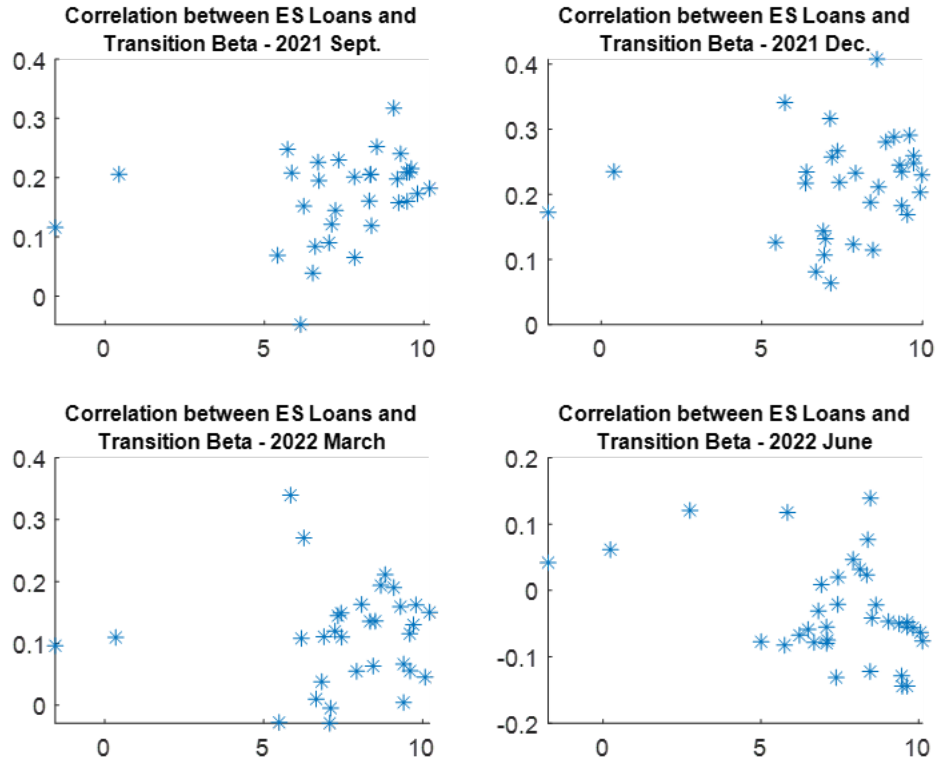

Figure 13: Correlation between climate transition risk beta and NFC loans towards energy sector is reported for 35 European banks. Analysis has been conducted at the end of 4 quarters (September 2021, December 2021, March 2022 and June 2022), based on data availability. Log of Energy loans is reported on x-axis. Dynamic climate beta is reported on y-axis.

In our analysis we estimate the risk premia for the risk factors: from the DCC model we obtain an estimate of the covariance matrix from which we derive time series of conditional loadings for market and climate risk factors.

Then, by sectioning time series of banks' stocks, market and CTFactor returns, for each day we perform a 126-days-rolling cross sectional linear regression of average European banks' stock returns against average market and CTFactor returns. Each cross sectional regression, performed at time t, is represented by the following equation:

$$\bar{Z}_t = \alpha_t + \lambda_t^{Climate} \cdot \bar{B}_t^{Climate} + \lambda_t^{Market} \cdot \bar{B}_t^{Market} + \xi_t \tag{1}$$

where:

1. $\bar{Z}_t$ is the (35×1) vector of average returns in [t-126,t];
2. $\bar{B}_t^{Climate}$ is the (35×1) vector of average dynamic climate betas in [t-126,t];

3. $\bar{B}_t^{Market}$ is the (35×1) vector of average dynamic market betas in [t-126,t];

4. ξ_t is the (35×1) vector of error terms;

5. α_t, $\lambda_t^{Climate}$, λ_t^{Market} are the scalar parameters at time t.

Although significativity of regressors is not confirmed over the whole decade, on average we report a t-stat equal to 1.99 ($p-value < 0.1$) for market risk premium and to 1.84 for transition risk premium ($p - value < 0.1$).

Interestingly, while the daily market premium appears to be close to zero and less volatile than $\lambda^{Climate}$, we document an average $\lambda^{Climate}$ range between -1.7% and +1.1% with higher volatility which has notably increased during period 2020-2022, presumably as a consequence of the European energy crisis and economic turmoil.

Figure 14 depicts the dynamic of $\lambda^{Climate}$ and λ^{Market} between June 2013 and December 2022. T-stats are reported in Figure 15.

Figure : Dynamic market and transition risk premium.

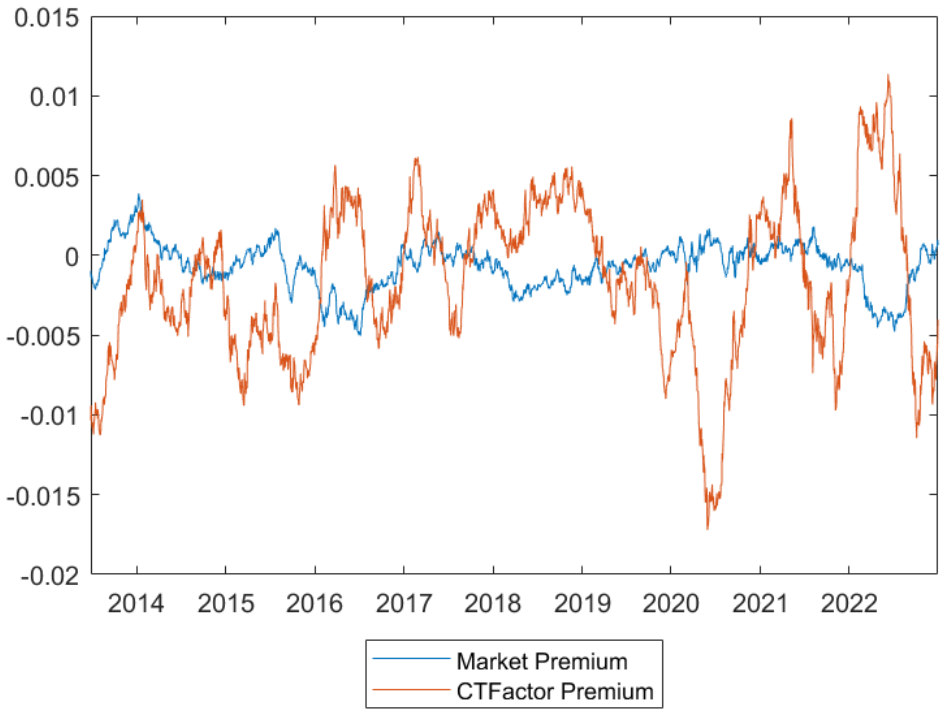

Figure 14: 126-days-rolling cross sectional linear regression of average European banks' stock returns against average market and CTFactor returns. Each regression is computed as $\bar{Z}_t = \alpha_t + \lambda_t^{Climate} \cdot \bar{B}_t^{Climate} + \lambda_t^{Market} \cdot \bar{B}_t^{Market} + \xi_t$, where $\lambda_t^{Climate}$ is CTFactor Premium and λ_t^{Market} is Market Premium at time t.

Figure : T-stats of dynamic market and transition risk premium.

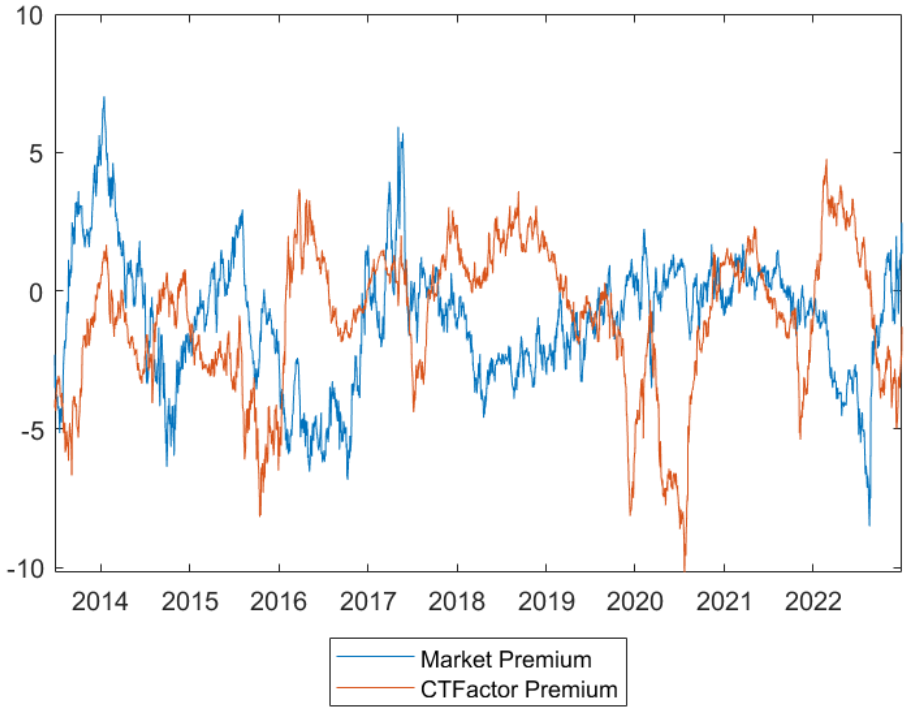

Figure 15: 126-days-rolling cross sectional linear regression of average European banks' stock returns against average market and CTFactor returns. Each regression is computed as $E_{t,t-126}(r) = \alpha + \lambda^{Climate} \cdot E_{t,t-126}(\beta^{Climate}) + \lambda^{Market} \cdot E_{t,t-126}(\beta^{Market}) + \xi$, where $\lambda^{Climate}$ is CTFactor Premium and λ^{Market} is Market Premium.