Early warning indicators of banking crises: expanding the family - ONLINE APPENDIX[1]

Variables: sources and definitions

Credit-to-GDP gaps

For credit to both the non-financial private sector and the household sector, the credit-to-GDP gaps are defined as the *difference* between the credit-to-GDP ratio and its long-run trend, based on a one-sided HP filter with the smoothing parameter equal to 400,000. The aggregate credit-to-GDP ratio as published in the BIS database of total credit to the private non-financial sector, capturing total borrowing from all domestic and foreign sources, is used as input data. The subcategory corresponding to the household sector is used for our measure of the household credit-to-GDP gap.

Debt service ratios

The debt service ratio (DSR) is defined as the ratio of interest payments plus amortisations to income. As such, the DSR provides a flow-to-flow comparison – the flow of debt service payments divided by the flow of income.

The BIS constructs and publishes quarterly data on DSRs for the private non-financial sector (what we refer to as "total DSR" in the special feature), as well as sectoral DSRs for households and private non-financial corporations. We use the series for the total DSR, as well as the subcategory for the household sector. The published data start in 1999. We use non-published data to extend the series as far back as possible (for details on the sample used in the analysis, see Table A1).

As there are country-specific differences in the level of DSRs, it is important to remove the long-run trend. We do so by computing the difference of the respective DSR from its country-specific 20-year rolling average. For the first 20 years of data the average is constant.

Property price gaps

Property price gaps build on residential property price data collected at the BIS. The residential property price gap is the *deviation* of inflation-adjusted residential property prices from their long-run trend, based on a one-sided Hodrick-Prescott filter with the smoothing parameter equal to 400,000.

Cross-border claims

Cross-border claims are taken from the BIS locational banking statistics. For each counterparty country, we use the stock of cross-border claims in all currencies against both banks and non-banks. We adjust the series for breaks due to methodological or

[1] This appendix accompanies the feature "Early warning indicators of banking crises: expanding the family" by Iñaki Aldasoro, Claudio Borio and Mathias Drehmann.

sample changes. Given major breaks prior to 1984, we only use data from the first quarter of 1984 onwards. We then divide this by nominal GDP and compute the 12-quarter growth rates.

Foreign currency debt

Foreign currency debt combines information from the BIS locational banking statistics and the debt securities statistics, applying the methodology used to construct the BIS global liquidity indicators' total credit to non-residents. We add cross-border foreign currency claims on non-banks, international debt securities issued in foreign currency by non-banks, and local claims in foreign currency on non-banks. Foreign currency includes loans and debt securities denominated in US dollars, euros, Japanese yen, Swiss francs and sterling. The published data disaggregated at the currency level used to construct the series starts in 1999. We extend it backwards until the fourth quarter of 1995 using non-published data. As for the cross-border claims, we adjust for breaks in series. Before 1995, we approximate the change in foreign currency debt by the change in cross-border claims on non-banks in all currencies. The results are robust to alternatively using the changes in total cross-border claims or cross-border claims on banks. We opt for cross-border claims on non-banks since these are the largest component of foreign currency credit for the majority of countries, and therefore show a similar time series behaviour. We then divide this by nominal GDP and compute the 12-quarter growth rates.

The sample

Table A1

	Credit-to-GDP gap		Total DSR		Property price gap		Household credit-to-GDP gap		Household DSR		Cross-border claims to GDP		Foreign currency debt to GDP		Crises
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	
AR	Q4 1994	Q2 2017					Q1 1999	Q2 2017			Q1 1990	Q2 2017	Q1 1990	Q2 2017	Q3 1980, Q3 1989, Q3 1995, Q3 2001
AT	Q1 1980	Q2 2017	Q1 2003	Q4 2016			Q4 2000	Q2 2017	Q4 1995	Q4 2016	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 2007
AU	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
BE	Q4 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1985	Q2 2017	Q4 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
BR	Q1 2006	Q2 2017	Q1 1997	Q2 2017	Q1 2006	Q2 2017	Q1 2001	Q2 2017			Q2 1995	Q2 2017	Q2 1995	Q2 2017	Q3 1990, Q3 1994
CA	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
CH	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 2004	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1991
CL	Q1 1993	Q2 2017			Q1 2007	Q2 2017	Q4 2007	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1981
CN	Q4 1995	Q2 2017	Q4 1987	Q2 2017	Q2 2010	Q2 2017	Q1 2011	Q2 2017			Q1 1984	Q2 2017			Q3 1998
CO	Q4 2006	Q2 2017			Q1 1993	Q2 2017	Q4 2001	Q2 2017			Q1 1994	Q2 2017	Q1 1994	Q2 2017	Q3 1982, Q3 1998
CZ	Q1 2003	Q2 2017	Q4 1995	Q2 2017	Q1 2013	Q2 2017	Q4 2000	Q2 2017	Q4 1995	Q2 2017	Q4 1993	Q2 2017	Q4 1993	Q2 2017	
DE	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q4 1991	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q1 2001
DK	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1999	Q2 2017	Q4 1994	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q1 1987, Q1 2008
ES	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1985	Q2 2017	Q1 1999	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q1 2009
FI	Q4 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1991

Sources: IMF, *International Financial Statistics*; national data; BIS credit to the non-financial sector, debt securities, locational banking and property price statistics; authors' calculations.

The sample (cont)

Table A1

	Credit-to-GDP gap		Total DSR		Property price gap		Household credit-to-GDP gap		Household DSR		Cross-border claims to GDP		Foreign currency debt to GDP		Crises
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	
FR	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q4 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q2 1991, Q2 2008
GB	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1991, Q3 2007
GR	Q4 1980	Q2 2017	Q1 1999	Q2 2017	Q4 1998	Q2 2017	Q4 1999	Q2 2017	Q4 1995	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q2 2010
HK	Q4 1988	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q4 1995	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	
HU	Q4 1999	Q2 2017	Q4 1995	Q2 2017	Q1 2012	Q2 2017	Q4 1994	Q2 2017	Q4 1995	Q4 2015	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
ID	Q1 1986	Q2 2017	Q4 1990	Q2 2017	Q1 2007	Q2 2017	Q4 2006	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 1997
IE	Q2 1981	Q2 2017	Q1 2002	Q2 2017	Q1 1980	Q2 2017	Q1 2007	Q2 2017	Q1 2002	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 2008
IL	Q4 2000	Q2 2017			Q1 1999	Q2 2017	Q3 1997	Q2 2017			Q1 1990	Q2 2017	Q1 1990	Q2 2017	
IN	Q1 1980	Q2 2017	Q1 1999	Q2 2017			Q2 2012	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1993
IT	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 2011
JP	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q4 1994	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 1992
KR	Q1 1980	Q2 2017	Q1 1996	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1996	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 1997
MX	Q4 1990	Q2 2017	Q4 1980	Q2 2017	Q1 2010	Q2 2017	Q4 1999	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 1981, Q4 1994
MY	Q1 1980	Q2 2017	Q4 1991	Q2 2017	Q1 1993	Q4 2016	Q1 2011	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 1997
NL	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1995	Q2 2017	Q4 1990	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q1 2008
NO	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q4 1995	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1988

Sources: IMF, *International Financial Statistics*; national data; BIS credit to the non-financial sector, debt securities, locational banking and property price statistics; authors' calculations.

The sample (cont)

Table A1

	Credit-to-GDP gap		Total DSR		Property price gap		Household credit-to-GDP gap		Household DSR		Cross-border claims to GDP		Foreign currency debt to GDP		Crises
	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	Start	End	
NZ	Q1 1980	Q2 2017	Q2 1998	Q4 2014	Q1 1984	Q2 2017	Q4 1995	Q2 2017	Q4 1990	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
PL	Q1 2002	Q2 2017	Q4 1995	Q2 2017	Q1 2015	Q2 2017	Q4 2000	Q2 2017	Q4 1995	Q1 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	
PT	Q1 1980	Q2 2017	Q1 1983	Q2 2017	Q1 1993	Q2 2017	Q4 1984	Q2 2017	Q1 1983	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q4 2008
RU	Q2 2005	Q2 2017	Q2 1995	Q1 2017	Q1 2006	Q2 2017	Q1 2003	Q2 2017	Q1 1998	Q1 2017	Q4 1993	Q2 2017	Q4 1993	Q2 2017	Q3 1998, Q4 2008
SA	Q1 2003	Q2 2017					Q1 2003	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	
SE	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1985	Q2 2017	Q4 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q1 1991
SG	Q4 1980	Q2 2017			Q1 2003	Q2 2017	Q1 1996	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	
TH	Q4 1980	Q2 2017	Q4 1993	Q2 2017	Q1 1996	Q2 2017	Q4 1996	Q2 2017	Q4 1993	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1983, Q3 1997
TR	Q1 1996	Q2 2017	Q1 2002	Q2 2017	Q1 2015	Q2 2017	Q1 1991	Q2 2017			Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q3 1982, Q3 2000
US	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q4 1984	Q2 2017	Q1 1980	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	Q2 1990, Q4 2007
ZA	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 1980	Q2 2017	Q1 2013	Q2 2017	Q1 2008	Q2 2017	Q1 1984	Q2 2017	Q1 1984	Q2 2017	

Sources: IMF, *International Financial Statistics*; national data; BIS credit to the non-financial sector, debt securities, locational banking and property price statistics; authors' calculations.

Credit-to-GDP gap performance for different threshold values

Table A2

Threshold[1]	All available data[2]			Homogenous sample[3]		
	Predicted[4]	NTS[5]	# crises[6]	Predicted[4]	NTS[5]	# crises[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
3	93	47	30	95	50	19
4	93	42	30	**95**	**46**	**19**
5	**90**	**39**	**30**	89	44	19
6	87	36	30	84	43	19
7	83	33	30	84	39	19
8	83	28	30	84	35	19
9	**80**	**26**	**30**	**79**	**33**	**19**
10	63	28	30	63	35	19
11	60	25	30	63	31	19
12	57	23	30	58	31	19
13	53	22	30	53	31	19
14	50	20	30	53	27	19
15	50	17	30	53	22	19
16	50	14	30	53	17	19

[1] Optimal EWI threshold that minimises the noise-to-signal ratio while capturing at least 66% of historical crises; in percentage points. [2] Results are based on the broadest data coverage. [3] Results are based on a common sample, when all four indicators used in Table 2 of the main text are available. [4] Percentage of correctly predicted crises. A crisis is judged to be correctly predicted if the indicator variable breached the critical threshold (column 1) anytime within a three-year horizon before a crisis. [5] NTS: noise-to-signal ratio; fraction of type II errors (the threshold is breached but no crisis occurs within the next three years) divided by the fraction of correctly predicted crises (column 2 or 5). [6] Number of crises included in the analysis.

Sources: National data; BIS credit to the non-financial sector statistics; BIS calculations.

Total DSR performance for different threshold values

Table A3

Threshold[1]	All available data[2]			Homogenous sample[3]		
	Predicted[4]	NTS[5]	# crises[6]	Predicted[4]	NTS[5]	# crises[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	93	39	28	95	42	19
0.1	**93**	**38**	**28**	95	41	19
0.2	89	38	28	**95**	**39**	**19**
0.3	86	38	28	89	40	19
0.4	86	36	28	89	38	19
0.5	82	36	28	84	38	19
0.6	82	34	28	84	36	19
0.7	79	34	28	79	36	19
0.8	79	33	28	79	34	19
0.9	79	31	28	79	33	19
1	79	30	28	79	32	19
1.1	79	28	28	79	30	19
1.2	75	28	28	79	29	19
1.3	71	28	28	74	30	19
1.4	71	27	28	74	29	19
1.5	71	25	28	74	27	19
1.6	71	24	28	74	26	19
1.7	68	24	28	68	26	19
1.8	**68**	**22**	**28**	**68**	**24**	**19**
1.9	64	22	28	63	24	19
2	64	21	28	63	23	19

[1] Optimal EWI threshold that minimises the noise-to-signal ratio while capturing at least 66% of historical crises; in percentage points. [2] Results are based on the broadest data coverage. [3] Results are based on a common sample, when all four indicators used in Table 2 of the main text are available. [4] Percentage of correctly predicted crises. A crisis is judged to be correctly predicted if the indicator variable breached the critical threshold (column 1) anytime within a three-year horizon before a crisis. [5] NTS: noise-to-signal ratio; fraction of type II errors (the threshold is breached but no crisis occurs within the next three years) divided by the fraction of correctly predicted crises (column 2 or 5). [6] Number of crises included in the analysis.

Sources: National data; BIS credit to the non-financial sector statistics; BIS calculations.

Household DSR performance for different threshold values

Table A4

Threshold[1]	All available data[2]			Homogenous sample[3]		
	Predicted[4]	NTS[5]	# crises[6]	Predicted[4]	NTS[5]	# crises[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	100	49	19	100	54	19
0.1	100	46	19	100	51	19
0.2	100	42	19	100	48	19
0.3	100	39	19	100	44	19
0.4	100	36	19	100	41	19
0.5	100	33	19	100	38	19
0.6	**95**	**32**	**19**	**95**	**37**	**19**
0.7	89	31	19	89	36	19
0.8	84	30	19	84	35	19
0.9	74	31	19	74	36	19
1	74	27	19	74	33	19
1.1	68	26	19	68	31	19
1.2	68	23	19	68	28	19
1.3	68	21	19	68	26	19
1.4	**68**	**19**	**19**	**68**	**23**	**19**
1.5	63	18	19	63	22	19
1.6	63	16	19	63	19	19
1.7	63	14	19	63	18	19
1.8	58	15	19	58	18	19
1.9	58	13	19	58	16	19
2	58	12	19	58	15	19

[1] Optimal EWI threshold that minimises the noise-to-signal ratio while capturing at least 66% of historical crises; in percentage points. [2] Results are based on the broadest data coverage. [3] Results are based on a common sample, when all four indicators used in Table 2 of the main text are available. [4] Percentage of correctly predicted crises. A crisis is judged to be correctly predicted if the indicator variable breached the critical threshold (column 1) anytime within a three-year horizon before a crisis. [5] NTS: noise-to-signal ratio; fraction of type II errors (the threshold is breached but no crisis occurs within the next three years) divided by the fraction of correctly predicted crises (column 2 or 5). [6] Number of crises included in the analysis.

Sources: National data; BIS credit to the non-financial sector statistics; BIS calculations.

Property price gap performance for different threshold values

Table A5

Threshold[1]	All available data[2]			Homogenous sample[3]		
	Predicted[4]	NTS[5]	# crises[6]	Predicted[4]	NTS[5]	# crises[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	87	67	23	88	75	16
1	87	64	23	88	72	16
2	83	65	23	82	74	16
3	83	61	23	82	69	16
4	79	60	23	75	70	16
5	79	55	23	75	65	16
6	79	51	23	75	59	16
7	70	53	23	69	59	16
8	66	51	23	63	59	16
9	66	47	23	63	54	16
10	66	44	23	63	49	16
11	**66**	**40**	**23**	**63**	**45**	**16**
12	61	40	23	63	41	16
13	57	40	23	57	41	16
14	57	36	23	57	37	16
15	53	35	23	57	32	16

[1] Optimal EWI threshold that minimises the noise-to-signal ratio while capturing at least 66% of crises; in percentage points. [2] Results are based on the broadest data coverage. [3] Results are based on a common sample, when all four indicators used in Table 2 of the main text are available. [4] Percentage of correctly predicted crises. A crisis is judged to be correctly predicted if the indicator variable breaches the critical threshold (column 1) anytime within a three-year horizon before a crisis. [5] NTS: noise-to-signal ratio; fraction of type II errors (the threshold is breached but no crisis occurs within the next three years) divided by the fraction of correctly predicted crises (column 2 or 5). [6] Number of crises included in the analysis.

Sources: BIS property price statistics; BIS calculations.

Cross-border claims to GDP performance for different threshold values

Table A6

Threshold[1]	All available data[2]			Homogenous sample[3]		
	Predicted[4]	NTS[5]	# crises[6]	Predicted[4]	NTS[5]	# crises[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
15	93	39	29	95	44	19
16	93	38	29	95	43	19
17	93	37	29	95	42	19
18	93	36	29	**95**	**40**	**19**
19	**90**	**36**	**29**	89	41	19
20	86	36	29	84	42	19
21	86	35	29	84	41	19
22	86	34	29	84	39	19
23	86	33	29	84	37	19
24	86	32	29	84	36	19
25	86	31	29	84	35	19
26	83	31	29	79	36	19
27	79	31	29	74	37	19
28	79	30	29	74	36	19
29	79	29	29	74	34	19
30	79	28	29	74	33	19
31	76	29	29	68	34	19
32	76	28	29	68	33	19
33	72	28	29	68	32	19
34	**72**	**27**	**29**	**68**	**31**	**19**
35	69	28	29	63	32	19

[1] Optimal EWI threshold that minimises the noise-to-signal ratio while capturing at least 66% of crises; in percentage points. [2] Results are based on the broadest data coverage. [3] Results are based on a common sample, when all four indicators used in Table 2 of the main text are available. [4] Percentage of correctly predicted crises. A crisis is judged to be correctly predicted if the indicator variable breaches the critical threshold (column 1) anytime within a three-year horizon before a crisis. [5] NTS: noise-to-signal ratio; fraction of type II errors (the threshold is breached but no crisis occurs within the next three years) divided by the fraction of correctly predicted crises (column 2 or 5). [6] Number of crises included in the analysis.

Sources: BIS locational banking statistics; BIS calculations.