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Part I: Financial crises

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The long history of financial boom-bust cycles in Iceland Part I: Financial crises*

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Abstract

Iceland suffered a severe financial crisis in 2008 which can only be described as the perfect storm, with the currency falling by more than 50% and over 90% of the domestic financial system collapsing. What followed was a deep recession. This was not the first financial crisis experienced in Iceland, however. In fact, over a period spanning almost one and a half century (1875-2013), we identify over twenty instances of financial crises of different types. Recognising that crises tend to come in clusters, we identify six serious multiple financial crisis episodes occurring every fifteen years on average. These episodes seem to share many commonalities and the tragic but universal truth that "we've been there before" when it comes to financial crises really becomes all too clear. We find that these episodes usually involve a large collapse in domestic demand that in most cases serves as a trigger for the ensuing crisis. What typically follows is a currency crisis, sometimes coinciding with a sudden stop of capital inflows and an inflation crisis, and most often a banking crisis. In line with international evidence, we find that contractions coinciding with these large financial crises tend to be both deeper and longer than regular business cycle downturns. Although the crisis episodes share many common elements, each one of them is also different to some extent. We are therefore not able to find financial variables that consistently provide an early-warning signal of an upcoming financial crisis across all the six episodes. However, we find that some key macroeconomic variables give a somewhat more robust signal. Our results also suggest that five of the six multiple crisis episodes coincide with a global financial crisis of some type, and that the most serious global episodes coincide with a two- to threefold increase in the probability of a financial crisis in Iceland. A companion paper (Part II) extends our analysis of the Icelandic financial boom-bust cycle to identifying financial cycles in our long data set, i.e. cycles that are of lower frequency and last longer than common business cycles and are characterised by co-movement of many key financial variables and often have peaks closely associated with financial crises.

Keywords: Financial crises, economic fluctuations, Iceland
JEL Classification: E32, E44, G01, G20, H12, N1

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"There is nothing new except what has been forgotten"
Marie-Jeanne Rose Bertin (Queen Marie Antoinette's dressmaker and confidante)

1 Introduction

Iceland suffered a severe financial crisis in 2008 which can only be described as the perfect storm, with the currency falling by more than 50% and over 90% of the domestic financial system collapsing. What followed was a deep recession, with output declining by almost 12% from its pre-crisis peak in late 2007 to its post-crisis trough in early 2010. The collapse in domestic demand was even more punishing: consumption fell by 21% from peak to trough and total domestic absorption by 30%, while unemployment rose by 7 percentage points.

This was not the first financial crisis experienced in Iceland, however. In fact, over a period spanning almost one and a half century, we identify over twenty instances of financial crises of different types. Recognising that crises tend to come in clusters, we identify six serious multiple financial crisis episodes occurring every fifteen years on average. The first two episodes occur during the early 1900s: the first coincided with the First World War (WWI) and lasted into the early 1920s, when a sharp collapse in economic activity led to an inflation crisis that was followed by a sudden stop of capital inflows and a currency crisis and eventually by a systemic banking crisis; while the second crisis coincided with the outbreak of the Great Depression in the early 1930s when another systemic banking crisis followed a recession and morphed into a currency crisis in 1932. There are two further episodes occurring at the end of the 1940s and in the late 1960s that are related to a serious deterioration of external conditions, in both cases leading to currency and inflation crises: the first followed a sharp deterioration of terms of trade and a contraction in economic activity; the second of these episodes following a collapse in fish catch. The fifth episode occurs during the early 1990s when falling economic activity, following the rein in of the chronic inflation of the 1970s and the 1980s, led to a twin currency and (non-systemic) banking crisis in 1993. The final episode is the most recent one when a build-up of enormous imbalances in the run-up to the crisis were followed by a sudden stop and a twin currency and banking crisis in 2008, further compounded by the global financial crisis occurring at the same time.

These financial crisis episodes seem to share many commonalities. They usually involve a large collapse in demand that in most cases serves as a trigger for the ensuing crisis. What typically follows is a currency crisis, sometimes coinciding with a sudden stop of capital inflows and an inflation crisis, and most often a banking crisis – usually towards the end of the episode. Three of those episodes involve a systemic banking crisis and they tend to leave the largest footprints on the real economy although all six episodes lead to large contractions in demand and output. In line with international evidence, we find that contractions coinciding with these large financial crises tend to be about twice as deep as regular business cycle downturns and last almost twice as long. We also find that two of

the more serious episodes coincide with a sudden stop crisis. Although the crisis episodes share many common elements, each one of them is also different to some extent. While we find evidence of financial imbalances playing an important role in the run up to the first three financial crises – as reflected in markedly above-trend growth in money, credit and bank leverage (and to a lesser extent, house prices), the financial crises in the late 1960s and early 1990s had pure real economy sources. The latest episode saw major financial and macroeconomic imbalances combine to make it the most serious crisis of them all. We therefore find no single financial variable consistently providing an early-warning signal of an upcoming financial crisis across all the six episodes. However, we find that some macroeconomic variables, such as output, domestic demand, the trade deficit and, to a lesser extent, the real exchange rate, give a somewhat more robust warning signal.

Our results also suggest an important role of contagion from global financial crises in most of these episodes, with five of the six episodes coinciding with a global financial crisis of some type; only the financial crisis in the late 1960s seems almost exclusively local. Our results also suggest that of the different types of financial crises, banking crises have the strongest global component while currency and inflation crises mainly seem to be of local nature. We also find that the most serious global episodes coincide with a two- to threefold increase in the probability of a financial crisis in Iceland.

The paper is organised as follows. In Section 2 we use data on aggregate economic activity to identify regular business cycle downturns and the more serious demand disasters used for reference in our analysis of the financial boom-bust episodes over the period 1875-2013. We also introduce the macroeconomic and financial variables that we use in the paper and discuss their key business cycle properties and historical context. In Section 3, we move on to identify and date different types of financial crises, i.e. the closely related currency and inflation crises, and banking crises. Not surprisingly, we find that these different types of financial crises often tend to overlap and to capture this clustering nature of financial crises, Section 4 applies a non-parametric common cycle algorithm to identify the more serious, multiple financial crises in a single indicator. This approach allows us to identify six major financial crisis episodes that we discuss in more detail in the remainder of Section 4. We discuss the main properties of these episodes and the development of our macroeconomic and financial variables in the run-up to these crises and in the period when the crises unfold. In Section 5, we analyse whether our financial and macroeconomic variables consistently provide early-warning signals in the run up to the multiple financial crises, whether these crises make recessions worse, and to what extent these episodes coincide with global financial crises. Section 6 concludes the paper. Robustness checks, documented in Appendices 1 and 2, suggest that our key results are robust to variations in crisis definitions. In a companion paper (Part II) we use the same dataset to identify and analyse financial cycles, i.e. cycles that are of lower frequency and last longer than common business cycles and are characterised by co-movement of many key financial variables and often have peaks closely associated with financial crises. The companion paper also contains discussions of policy implications of our findings.

2 The data

Our analysis of the financial boom-bust cycle in Iceland and its relationship with financial crises and the traditional business cycle encompasses data on overall economic activity, exchange rates, terms of trade and inflation, asset prices, money and credit, and data on the banking system assets, leverage, and liability composition. This section of the paper describes the data we use and gives a broad-brush description of its main properties and stylised historical context, as well as presenting our identified dates of economic downturns (both regular cyclical downturns and more punishing demand disaster episodes).

The fact that financial boom-bust cycles usually take a long time to complete – decades even – calls for a longer data span than is usually required for analysing most other macroeconomic phenomena. We have therefore constructed an annual frequency database covering a 139 year period from 1875 to 2013 (described in more detail in Appendix 3). As is often the case, the need for a long data span comes at the cost of only having annual data available and thus the loss of higher frequency information found in quarterly data. Although we acknowledge that some finer points of dating business cycles and financial booms and busts may be lost using annual data, our focus on financial crises necessitates it. At the same time we gain some unique insight into the domestic financial boom-bust cycle that would be lost by focusing on a shorter time period, and the tragic but universal truth that "we've been there before" when it comes to financial crises really becomes all too clear.

2.1 Economic activity and downturns

A central variable in any analysis of financial boom-bust cycles is some measure of aggregate economic activity, not only for measuring the real economy consequences of financial crises but also for analysing the interactions of economic activity and financial booms and busts, and phasing the crisis episodes in terms of the business cycle. We use GDP as our measure of overall activity and as a basis for estimating and dating cyclical downturns although we acknowledge that a more broad-based analysis of multiple indicators for identifying the business cycle might be more appropriate. For example, small open economies can use the current account to absorb shocks and smooth output although there is also ample evidence suggesting that this risk sharing property may be overstated as discussed below. Thus, we also look at overall domestic demand as it can shed important additional light on economic activity over the financial boom-bust cycle.

The data on GDP and domestic demand comes from official national accounts for the period from 1945. Prior to that we use data compiled by the economic historian Gudmundur Jónsson and published by the now defunct National Economic Institute in 1999 (see also Jónsson, 2004). This dataset does not directly include data on domestic demand but we construct the series by subtracting nominal net exports (available from the same source) from nominal GDP and use the implicit GDP price deflator to construct real domestic demand. Appendix 3 gives the details.

Table 1 Summary statistics

	Total sample (1875-2013)		First half (1875-1944)		Second half (1945-2013)	
	Mean	St.dev.	Mean	St.dev.	Mean	St.dev.
Real house prices	0.010	0.064	0.015	0.062	0.008	0.066
Real credit	0.064	0.129	0.072	0.149	0.057	0.110
Credit-to-GDP ratio	1.082	0.734	0.644	0.377	1.457	0.759
Real M3	0.061	0.113	0.090	0.110	0.036	0.110
M3-to-GDP ratio	0.381	0.203	0.303	0.189	0.448	0.192
Credit-to-M3 ratio	2.814	1.182	2.179	0.794	3.356	1.194
Bank assets-to-GDP ratio	0.676	1.132	0.349	0.257	1.008	1.520
Bank leverage ratio	11.085	3.945	10.042	4.113	12.143	3.486
Foreign non-core liabilities	0.096	0.108	0.059	0.053	0.128	0.132
Total non-core liabilities	0.169	0.135	0.161	0.121	0.176	0.146
Real GDP	0.034	0.051	0.030	0.058	0.037	0.042
Real domestic demand	0.033	0.084	0.031	0.087	0.035	0.082
Trade deficit-to-GDP ratio	-0.009	0.063	-0.036	0.062	0.018	0.052
USD exchange rate	-0.059	0.163	-0.008	0.101	-0.109	0.196
Real exchange rate	0.000	0.106	0.014	0.083	-0.014	0.123
Terms of trade	0.006	0.123	0.010	0.160	0.002	0.068
Inflation	0.081	0.133	0.028	0.107	0.136	0.136

The table reports summary statistics for the total sample from 1875-2013 (139 years) and for two subsamples: the period 1875-1944 (70 years) and the period 1945-2013 (69 years). USD exchange rate refers to number of US dollars per 1 unit of Icelandic króna. Bank leverage ratio refers to the ratio of total banking system assets to equity. The non-core financing ratios refer to the ratio of non-core banking liabilities (either foreign or total) to total banking liabilities. Real house prices, real credit, real M3, real GDP, real domestic demand, USD exchange rate, real exchange rate, and terms of trade are reported as log differences of each variable. Inflation is measured as the log difference of consumer prices.

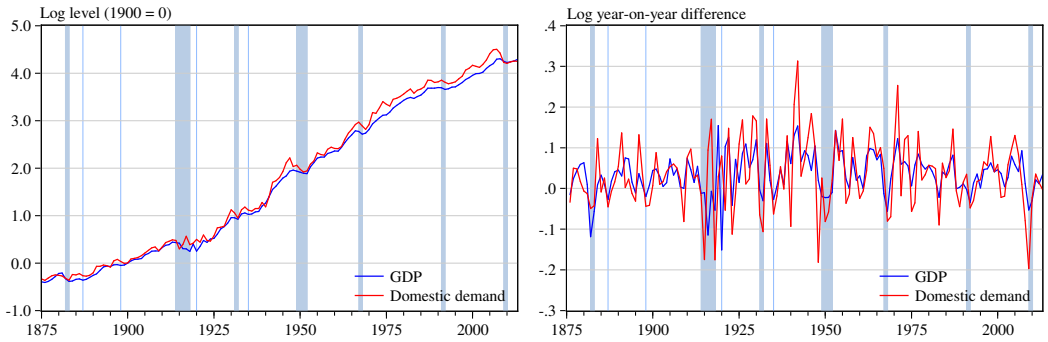
Source: Authors' calculations (data sources described in Appendix 3).

Table 1 summarises key properties of output and demand, together with other variables in our dataset, for the whole sample and for two subsamples which divide the data into two roughly equally long periods and coincide with the period up to the end of World War II (WWII) and the post-WWII period, respectively. The first subsample therefore covers the modernisation of the Icelandic economy, beginning around 1890, when increased foreign demand, technological innovation, and financial deepening paved the way for export-oriented industrialisation and ends with a "great leap forward" in terms of the modernisation of the economy during WWII (Jónsson, 2004), while the second subsample covers the period from which Iceland had caught up with other advanced economies in terms of income levels. As Table 1 shows, average annual growth of real GDP and demand over the whole sample has measured just under 3½%, somewhat higher and less volatile in the post-WWII period – although the economy remains very volatile compared to other industrial countries as documented in Einarsson et al. (2013).

Figure 1 shows real GDP and domestic demand in levels and growth rates for the period 1875-2013 together with dates of business cycle downturns as identified by the Harding & Pagan (2002) turning point algorithm.[1] This seeks to identify cyclical peaks and troughs

[1]This turning point approach to dating business cycles goes back to the pioneering work of Burns

Figure 1 GDP and domestic demand
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

in the GDP series using a simple algorithm that identifies local maxima and minima over a specific window by imposing restrictions on the minimum length of the cycle (the distance between two consecutive peaks and troughs) and the minimum length of each phase (the length from peak to trough or trough to peak). The screening process also requires peaks and troughs to alternate. If two peaks (troughs) occur in a row the higher (lower) one is chosen.

The duration of business cycles is typically assumed to last between 5 quarters and 8 years. With this in mind, and given the restrictions imposed by using annual data, we assume that the minimum phase of expansions and contractions is 1 year and the minimum length of a complete cycle is 2 years. Given these restrictions, we define the peak (trough) of the business cycle in a given year as the highest (lowest) value of GDP within a 2-year symmetric window (i.e. within a 5 year window centred at the given year). The use of a 2-year symmetric window is not ideal though as it will probably lead to an identification of too few business cycle turning points. However, the alternative of using a 1-year symmetric window is even less appealing, especially given the relatively high volatility in Icelandic macroeconomic data, as it would simply replicate all years of contractions in GDP (however small) and thus arguably identify too many cycles (see the second panel of Figure 1). To compensate for this drawback (which comes from using annual data), we also allow for the algorithm to be overruled if the annual contraction in GDP exceeds one standard deviation of total sample GDP growth. Although it is still likely that we are missing some of the smaller business cycle downturns, our filtering choices allow us to concentrate on the most important ones which are the ones of most interest to us in the context of our analysis of financial booms and busts.

This approach identifies eleven downturns in GDP over the 139 year period (17% of the total sample). This gives a cyclical downturn every 10 years which lasts for 2.1 years with output contracting by 7.6% on average. The identified dates are reported in Table 2.

& Mitchell (1946) and is widely used for dating business cycles, see Claessens et al. (2011, 2012) for a discussion and Einarsson et al. (2013) for an application using Icelandic quarterly data since 1970.

Table 2 Economic downturns in Iceland

Business cycle downturns			Demand disasters		
Date	GDP contraction	Duration (in years)	Date	Per capita domestic demand contraction	Duration (in years)
1882-83	0.161	2			
1887	0.027	1			
1898	0.020	1			
1914-18	0.179	5	1914-15	0.192	2
			1918	0.166	1
1920	0.140	1	1923-24	0.137	2
1931-32	0.034	2	1931-32	0.179	2
1935	0.027	1			
1949-52	0.071	4	1948-51	0.309	4
1967-68	0.067	2	1968-69	0.155	2
			1975-76	0.106	2
1991-92	0.036	2	1988-93	0.136	6
2009-10	0.079	2	2007-10	0.276	4
Average	0.076	2.1	Average	0.184	2.8

The table gives the dates of economic downturns identified by the Harding & Pagan (2002) turning point algorithm and the dates of domestic demand disasters based on the criteria suggested by Barro & Ursúa (2008) for consumption disasters. The table reports the duration of the given episode in years and the contraction in GDP for business cycle downturns and per capita domestic demand for demand disaster dates between the start and end of the crisis.

Source: Authors' calculations (data sources described in Appendix 3).

Most of the downturns identified are well-known in the chronology of the Icelandic business cycle. The first one we identify occurs in 1882-1883 when output contracts by no less than 16%. This and the short contraction in 1887 are mainly due to large negative terms of trade shocks and unusually cold weather (see Jónsson, 1999, 2004). Another short and relatively shallow contraction follows in 1898, which is mainly related to a collapse of the important export market for wool in the UK.[2] The first and most severe downturn identified in the 20$^{\text{th}}$ century occurs during WWI with output contracting by almost 18%. This is followed by a short but sharp contraction in 1920 when output fell by 14% following a 40% deterioration of terms of trade during the global post-WWI recession and widespread foreign liquidity shortages in the domestic banking system. Two relatively short contractions occurred in the Great Depression in the early 1930s coinciding with a systemic banking crisis (see the discussion on banking crises in Section 3.2).

The cyclical downturns are fewer and less severe in the post-WWII period, as reflected in the declining output volatility referred to earlier. The first downturn is a relatively sharp contraction following large negative terms of trade shocks in the late 1940s due to a weakening of export prices that were further exacerbated by a global trade contraction in connection with the Korean War and an overvalued real exchange rate. This is followed by another sharp contraction in the late 1960s with the collapse of fish stocks causing output to fall by close to 7%. No business cycle contraction is identified until the early 1990s when

[2]The downturns in the late 1800s coincide, and are followed, by unusually large emigration flows to North America (mainly Canada), which lasted into the first decades of the 20$^{\text{th}}$ century.

output fell by 3½% following a tightening of monetary conditions in the latter half of the previous decade (see Pétursson, 2002), further exacerbated by a negative terms of trade shock and a contraction in fish catches in the early 1990s. Finally, a sharp contraction is identified in 2009-10 following the most recent financial crisis when output fell by 8%.

Although some of these downturns can be attributed to different types of financial distress, it is clear that downturns related to negative supply shocks (whether they are terms of trade or fish catch shocks) dominate the Icelandic business cycle.[3] These shocks can obviously also trigger some type of financial distress or interact with the underlying financial cycle to amplify financial shocks occurring at a similar time. We will indeed see examples of both when we revisit some of these episodes in our discussion of financial crises below.

Using the turning point algorithm on domestic demand gives broadly the same dates, although the exact start or finish of some differs slightly from those identified using GDP. However, not surprisingly given that domestic demand is more volatile than output, the algorithm also identifies additional downturns using the demand series. By focusing on the more severe episodes, i.e. what we can call "demand disasters" following the definition of Barro & Ursúa (2008) of "consumption disasters" as periods where per capita demand contracts by more than 10% from peak to trough, gives us nine disaster episodes occurring every 12 years on average with duration of almost 3 years.[4] In most cases, these episodes coincide with the downturns identified by the turning point algorithm for GDP (see Table 2) although the downturns in the late 1800s drop out as the large contractions in domestic demand are offset by a large decline in total population, so that the per capita measures falls below the 10% threshold. The sharp contraction in domestic demand in 1909, following a large terms of trade deterioration and loss of foreign bank funding in the aftermath of the global bank panic of 1907 (see below), and the downturn in the mid-1930s, related to the loss of important export markets in Southern Europe, also drop out as the cumulative contractions fall just shy of 10%. By this measure, there was also a downturn in the mid-1970s related to the first oil shock where per capita demand fell by 10½% while GDP growth only slowed down to 0.7% in 1975 and picked up strongly the year after.

[3]This is indeed what Gudmundsson et al. (2000) find using a structural VAR (see also Daníelsson, 2008). Although our focus is mainly on the largest downturns, the business cycle chronology presented here corresponds quite well to conventional wisdom, such as Jónsson (2004), Magnússon & Einarsson (1985) and Pétursson (2000). Pétursson uses Hamilton's (1989) Markov-switching model to identify cyclical downturns in the post-WWII period, finding similar results over the period in question but additional downturns in the mid-1970s and early- to mid-1980s. Using this Markov-switching model over the extended period analysed here gives broadly similar results, although it misses the pre-WWII downturns in the late 1880s and 1890s, and the ones in 1920 and 1930s identified by the turning point approach, but as in Pétursson (2000) also adding the slow post-WWII growth periods in 1956-57 and 1961, and the short-lived contraction in 1983. Einarsson et al. (2013) focus on the post-1970 period where quarterly data is available and find broadly similar results, although the quarterly data allows them to identify a larger number of short downturns which are missed using annual data.

[4]We use per capita domestic demand as consumption data is not available before 1945. Using domestic demand (the bulk of which is private consumption) gives almost identical disaster dates (also identified by Barro & Ursúa, 2008) as using consumption does in the period where both series are available (the episodes are identical but start or end dates differ slightly in some cases).

2.2 Trade balance

As previously discussed, a small open economy should in principle be able to use its external accounts to absorb shocks and smooth activity by borrowing in bad times and saving when conditions improve. A current account deficit would therefore open up during bad times, which is reversed when the economy improves. At the same time, numerous studies suggest that the current account and capital flows tend to be pro-cyclical and fuel asset price and financial boom-bust cycles, in particular among emerging market economies (cf. Kaminsky & Reinhart, 1999, Aguiar & Gopinath, 2007, and Korinek, 2011).[5]

With no data on the current account available for the whole period, we use the trade balance as a proxy for this net capital flow cycle (see also Reinhart & Rogoff, 2009).[6] This is shown in Figure 2 together with the previously identified business cycle downturns (the trade balance data we use is obtained from Jónsson, 1999, as described above). One noteworthy feature of the data is the shift from persistent trade surpluses in the first half of our sample to persistent deficits after WWII. This is also borne out in Table 1 which shows how the average balance goes from a surplus of 3.6% of GDP in the first period to a deficit of 1.8% in the second. Another striking feature is the general tendency for large deficits to build up in the period leading into recessions only to be reversed around the time a cyclical downturn starts (of which the latest crisis period is a notable example). Exceptions to this, where the temporal order is reversed, i.e. from a surplus leading into the recession reversing into a deficit, emerge in the period prior to 1922, during Iceland's membership in a monetary union with Denmark. In that period there was a limited role for nominal exchange rate adjustment and hence deflationary pressures often emerged during downturns and in turn reinforced them (see the discussion in the next section). Most of the trade balance reversals in our sample are therefore consistent with a build-up of deficits leading into the recessions with the accompanying capital inflows, which reverse once the economy weakens. Trade deficits therefore tend to be pro-cyclical and to reinforce the cycle rather than being used to absorb shocks and smooth output, consistent with the findings in Kaminsky & Reinhart (1999) and Aguiar & Gopinath (2007). We will return to this theme in the context of our discussion of currency crises below.

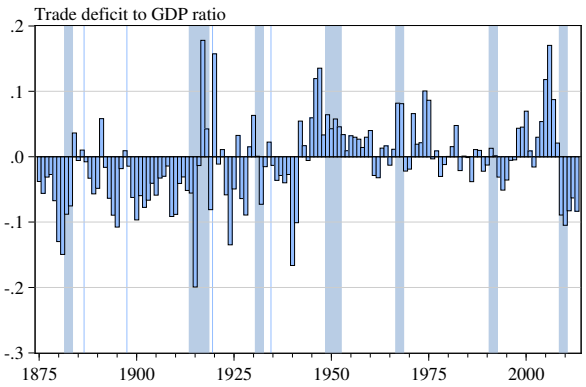
2.3 Exchange rate, terms of trade, and inflation

Another way for a small open economy to absorb external shocks is through adjustments in its exchange rate. Thus, the currency depreciates in bad times and supports net exports and reduces real economic volatility. At the same time, the results from Breedon et al. (2012) suggest that exchange rates in very small open economies such as Iceland have

[5] Aguiar & Gopinath (2007) find that this emerging market phenomenon is strongly linked to an unusually high ratio of permanent to temporary shocks. As Reinhart & Rogoff (2009) argue, policymakers in these countries seem to have a tendency to interpret favourable shocks as being permanent, leading to spending sprees and borrowing binges that ultimately lead to sudden stops in funding and a sharp recessions and a reversal in the current account.

[6] In Section 2.6 below, we also consider gross capital flows in the form of cross-border banking liabilities, which Borio et al. (2014) emphasise in relation to systemic banking crises.

Figure 2 Trade balance
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

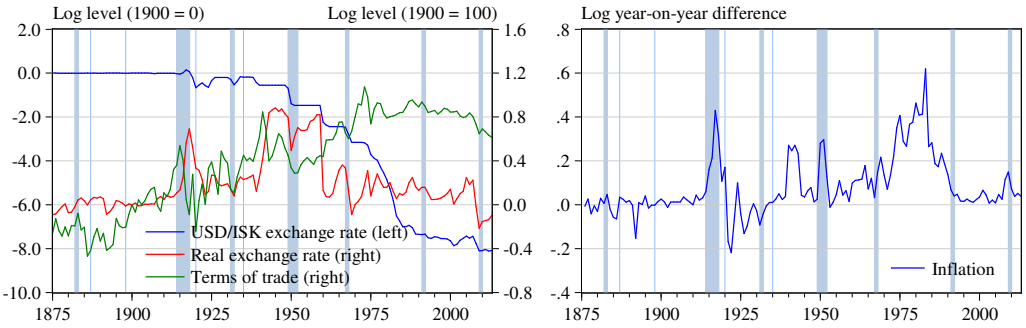
in fact not served as a shock absorber but rather as an important source of shocks and therefore as an amplifier of the business cycle. The exchange rate cycle is also of interest in our analysis of the financial boom-bust cycle as a number of studies have found the real exchange rate to be a leading indicator of currency and banking crises (cf. Kaminsky et al., 1998, Kaminsky & Reinhart, 1999, Goldstein et al., 2000, and Gourinchas & Obstfeld, 2012). Bruno & Shin (2014) provide a model consistent with these finding and emphasise the interactions between currency appreciations, borrowers' balance sheet strength, and greater risk-taking by banks in driving financial cycles in small open economies (see also Korinek, 2011).

Figure 3 shows the development of the nominal (number of US dollars per 1 unit of Icelandic króna) and real exchange rate together with the business cycle downturns from above (data sources and how the data is constructed is described in Appendix 3). The nominal exchange rate remains tightly pegged to the US dollar up to WWI within the gold standard regime through Iceland's monetary union with Denmark and the rest of the Nordic countries within the Scandinavian Monetary Union. This breaks down during the war and in 1922 Iceland exits the monetary union with Denmark and establishes its own currency, which starts its long and arduous downward slide to its most recent collapse in 2008.[7] As shown in Table 1, this depreciation bias has been particularly strong in the post-WWII period with exchange rate volatility also increasing – in part reflecting the greater exchange rate flexibility over the last two decades. The real exchange rate has remained more stable around a broadly fixed level, notwithstanding some extreme real exchange rate adjustments, in particular during the two World Wars, the start of the 1950s and 1960s, and the financial crisis in 2008-9.

While exchange rate volatility has increased in the post-WWII period, terms of trade shocks (a key driver of the Icelandic business cycle as one can gather from Section 2.1)

[7]See Gudmundsson et al. (2000) for a description of the history of Icelandic exchange rate regimes leading up to the country's adoption of a floating exchange rate regime with an explicit inflation target in 2001.

Figure 3 Exchange rate, terms of trade, and inflation
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

have in fact been more moderate as shown in Table 1 and Figure 3 (data sources described in Appendix 3). Improvements in terms of trade played an important role in the previously discussed modernisation and catch-up of the Icelandic economy relative to other advanced economies, with terms of trade improving by no less than 274% over the period 1886-1915. After a sharp deterioration during WWI and again after WWII, terms of trade improved again and peaked in the early 1970s. They remained relatively stable up to the recent global crisis which has seen terms of trade deteriorate by 20% from its 2006 peak.

Finally, Figure 3 reports the development of inflation (data sources described in Appendix 3), highlighting some wild fluctuations in the rate of price changes, both during deflationary periods in the pre-WWII period (in particular the years following WWI) and frequent inflationary bouts, especially during the World Wars and in the post-WWII period (in particular in the 1970s and 1980s). The high and volatile inflation is much more apparent in the latter half of the sample period, as reflected in the nominal exchange rate developments. These exchange rate and inflation developments will be revisited in our discussion of currency and inflation crises below.

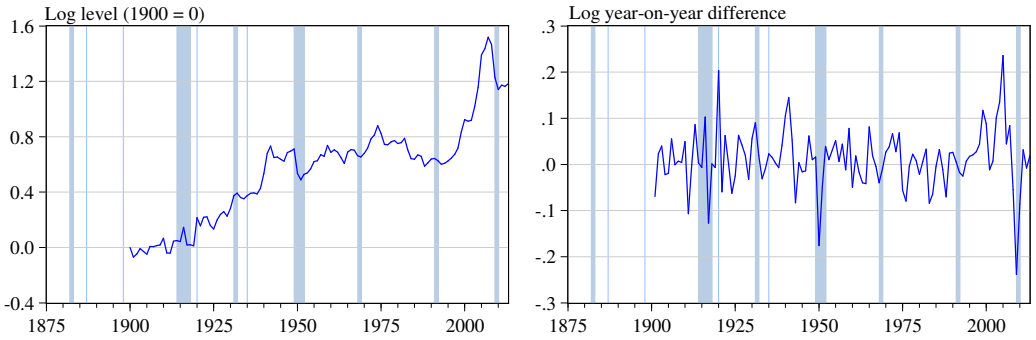
2.4 Residential house prices

Residential house price cycles are usually at the centre of any financial boom-bust cycle. In fact a number of studies have established the prominent role of house prices in the run-up to and aftermath of banking crises, with a house price boom leading into the crises (particularly if its debt-driven), followed by a substantial and persistent decline after the bust (see e.g. Bordo & Jeanne, 2002, and Reinhart & Rogoff, 2008). Furthermore, Reinhart & Rogoff (2009) find that real house prices are a robust leading indicator of financial crises, banking crises in particular.

As Reinhart & Rogoff (2009) argue, large house price declines can have marked real economic consequences even if they do not coincide with banking crises, and indeed this is borne out by the Icelandic data (see Figure 4):[8] while the large declines in real house

[8]House price data (described in Appendix 3) is only available from 1900, which coincides with the

Figure 4 Real house prices
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

prices in 1917-19 (cumulative decline of 12.5%) and 2008-10 (cumulative decline of 31.5%) coincide with systemic banking crises (see the discussion on banking crises below), the sharp decline in 1950-51 (cumulative decline of 20%) did not, although all three coincide with a cyclical downturn and a demand disaster (see Table 2 above). The figure also clearly shows the pro-cyclical nature of real house prices in Iceland, with booms in the run-up to recessions followed by declines just before, during or shortly after the business cycle turns. Interestingly, unlike inflation and the exchange rate, the comparison of real house prices over the two subsamples in Table 1 does not suggest that real house prices have become more volatile in the post-WWII period. We will discuss this house price cycle in more detail in Section 4.2.

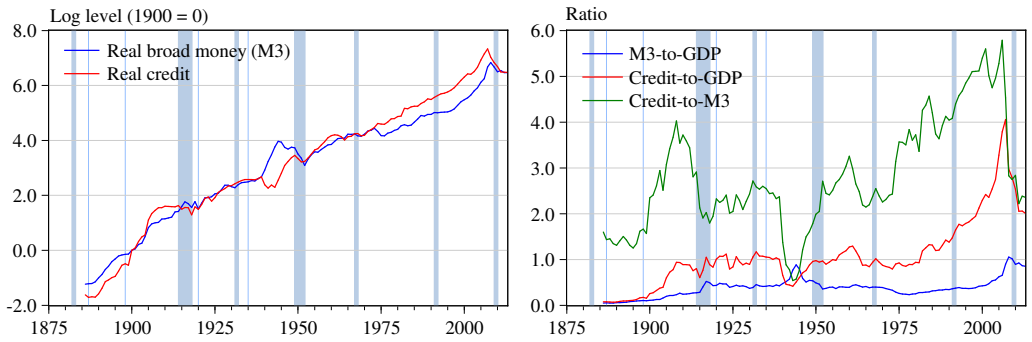
2.5 Money and credit

Credit aggregates are the measurable results of the credit creation process where liquidity conditions and perceptions of value and risk interact and lead to changes in exposure and financing capacity. Surges and shortfalls of liquidity and their accompanying balance sheet expansions and deleveraging can have severe repercussions for economic activity and overall macroeconomic stability.[9] Hence, studies of financial boom-bust cycles logically include credit aggregates as one of the key elements capturing the nexus between the financial system and the real economy (Claessens et al., 2011, 2012, Drehmann et al., 2012, and Aikman et al., 2015). Other studies examine to what extent monetary aggregates, or the ratio of total credit to money (which captures the extent of non-monetary funding of credit creation), can serve as indicators for the state of the financial cycle or signal increasing vulnerabilities in the latter stages of financial cycle upswings (Borio & Lowe, 2004, and

beginning of commercial bank mortgage lending in Iceland (Björnsson, 1961).

[9] Liquidity is an unobservable property of the financial system and refers to the ease of financing in financial markets and encompasses both funding liquidity (the ease of raising cash by selling new obligations to investors) and market liquidity (the ease of raising cash by selling assets). Liquidity depends on actions of private investors, financial institutions, and monetary authorities, and is best understood as a flow variable, which can disappear altogether, rather than a stock of available funding which can be redistributed in a time of crisis.

Figure 5 Money and credit
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

Shin & Shin, 2011).

To capture these aspects of the financial cycle and its link to financial crises we consider both credit and broad money measures. Our credit aggregate is based on data on total lending and bond holdings of the credit system. We use total credit as data availability does not allow us to focus solely on credit to the non-financial private sector over such a long period. Our broad money measure is M3. The data is available from 1886 when the first commercial bank (the state-owned Landsbanki) was founded. Hence, our series extend back for 128 years (further details are in Appendix 3).

Figure 5 shows credit and money in levels (in real terms), their shares in nominal GDP, and the money-to-credit ratio. As Table 1 shows, average annual real credit and money growth has been similar over the whole sample although money growth was considerably higher in the first half of the sample than in the post-WWII period, mainly due to high growth during the two World Wars. The credit-to-money ratio decreased sharply during the occupation of Iceland in WWII when cash holdings rose considerably following a large influx of foreign soldiers, while lending remained weak.

Iceland's rapid financial catch-up is also evident in Figure 5 in the marked rise in money and credit relative to GDP, especially after the creation of the country's first and only foreign-owned commercial bank in 1904 (Íslandsbanki). The money-to-GDP ratio remained within 40-50% range from 1916-40, which is close to the average ratio reported for developed economies in Schularick & Taylor (2012). The credit ratio settled at an even higher level, or approximately 100% of GDP, which in part reflected the important role of non-money financed bank credit in Iceland and the importance of credit extension by investment credit funds at the time.

Iceland's financial catch-up proved short-lived, however, and the financial system deteriorated consistently until the end of the 1970s due to chronic macroeconomic instability and mismanagement of the then almost fully state-owned banking system. This is apparent in the steady decline of savings in the chronic high inflation era when real interest rates were negative for years and the money-to-GDP ratio reached a low of 23½% in 1978.

Credit remained close to 100% of GDP on average, however, so the credit-to-money ratio was increasing and bank credit extension relied on increased leverage within the banking sector, as will be discussed in the next section. Widespread indexation of savings and loans to inflation was formally introduced in 1979 and this marked the beginning of a new catch-up phase where credit and money began to recover. In the subsequent two decades, the domestic financial system was liberalised and integrated with international financial markets. Finally, the run-up to and aftermath of the financial crisis in 2008 is clearly evident from the break-neck pace in pre-crisis credit expansion, with the credit ratio peaking at a whopping 400% of GDP in 2007, and the accompanying large post-crisis deleveraging, with the credit-to-GDP ratio collapsing by half and the credit-to-money ratio by almost two-thirds.

2.6 Banking system balance sheet

Financial boom-bust cycles reflect changes in the ease of managing balance sheets, in particular those of financial intermediaries. During boom phases, economies often experience a self-enforcing feedback loop of increased capital inflows, appreciating exchange rates, asset price surges, and apparently strengthening balance sheets – all of which contribute to boosting economic activity. Market participants are often inclined to take on too much debt and rely on excessively risky form of finance during such episodes, giving rise to excessive levels of financial fragility. These individual agents do not internalise the overall effects of their borrowing decisions through exchange rate and asset price changes, making financial fragility a by-product of external borrowing in small open economies with imperfect financial markets. During busts, adverse spirals kick in and induce deleveraging in the financial sector: obtaining funding becomes more difficult, capital inflows turn to outflows, exchange rates depreciate, currency mismatches increase, and asset price booms unwind; all of which can lead banks and other market agents to respond by fire-selling their assets, which reduces their net worth further, and reinforces the balance sheet constraints. These amplification effects lead to pecuniary externalities as the destabilising macroeconomic conditions cause adverse effects for the whole economy (e.g. Brunnermeier et al., 2009, Bianchi, 2011, Jeanne & Korinek, 2010, and Korinek, 2011). We therefore want to look beyond the traditional financial variables analysed in the literature, i.e. credit, money, and asset prices, and analyse the role of the entire banking system balance sheet (total assets, leverage, and the composition of liabilities) in the build-up of financial imbalances and their subsequent unwinding.[10]

First, we construct a measure of the size of the banking system relative to GDP to capture systemic risk arising from mismatches between the domestic authorities' capacity and the banking system's possible need for support in times of financial stress. This measure can also function as a proxy for market liquidity of the asset side of the banks' balance sheet, as assets may become more difficult to sell with limited price impact once

[10]See Pálmason (1994) for a brief history of the development of Iceland's banking system since the late 19th century to the mid-1990s.

the banking sector becomes very large relative to the economy. This variable can therefore be an important part in the financial boom-bust cycle and in determining the economic impact of the crisis (as found by Ólafsson & Pétursson, 2011, in a cross-country analysis of the latest global financial crisis).

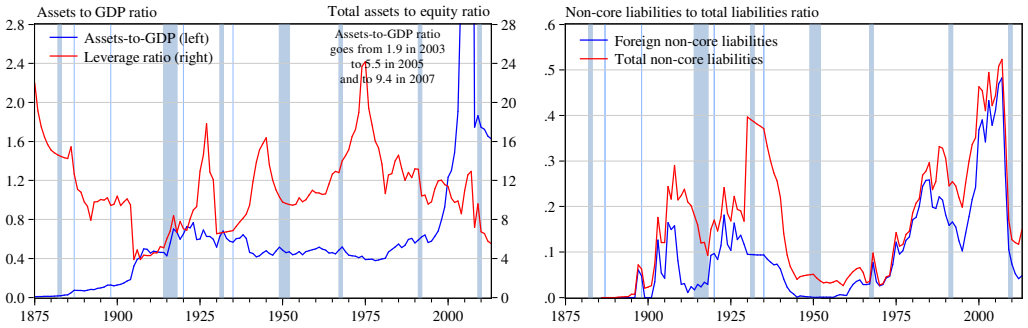
The second balance sheet variable we construct is a measure of banking system leverage (the ratio of banking system assets to book-value equity) to capture to what extent assets are being financed with debt. This variable is often emphasised but missing in the literature due to limited data availability over sufficiently long periods (cf. Drehmann et al., 2012). This leverage measure is more general than the credit-to-money ratio discussed above as it encompasses a greater number of assets and liabilities, and can therefore provide additional information for analysing the financial boom-bust cycle.

Our final banking system balance sheet variable is the ratio of non-core liabilities to total liabilities, which reflects the claims on the domestic banks not held by the ultimate domestic creditors. This measure is a proxy for the funding liquidity position of the banking system and aims to capture to what extent banks shift towards more unsustainable funding sources as the traditional (monetary) ones are exhausted in financial booms. This measure has been emphasised by Hahm et al. (2013) and Borio et al. (2011) but their studies cover a much shorter time period than ours. We also distinguish between foreign and total non-core liabilities to capture the possible distinctive vulnerabilities of relying on cross-border funding and their relation to banking and currency crises which could play an important role in the financial boom-bust cycle of a small open economy, such as Iceland. A particular benefit of the length of our data series is that it allows us to analyse cross-border funding during the first phase of globalisation in the pre-WWII period (see discussion in Borio et al., 2014).[11]

As shown in Table 1, the size of the banking system increased almost threefold in terms of GDP to roughly one times GDP in the post-WWII period. The leverage ratio shows that this expansion was largely accomplished through borrowing rather than increased equity, while the non-core financing ratio suggests that an important source of this funding was through foreign borrowing. The different development phases of Iceland's banking system, discussed in the previous section are also apparent in Figure 6 in the evolution of the size of the banking system: the financial catch-up early on when bank assets reached a level of over 75% of GDP, followed by a lengthy stagnation and deterioration until 1978 when assets reached a post-WWII trough below 40% of GDP. In fact, the bank asset-to-GDP ratio was similar in Iceland as the median case documented in Schularick & Taylor (2012) from 1920 to the late 1960s, but the rate of balance sheet expansion was very different from 1970-1995 and the asset ratio did not reach its pre-WWII peak until 1998. However, the balance sheet expansion reached an unprecedented level following the liberalisation of capital flows and privatisation of the state-owned banks, resulting in bank assets peaking at

[11] Our four balance sheet measures are based on various sources of balance sheet data for commercial banks and savings banks, with banking system assets and leverage available from 1875 while the two non-core liability measures are available from 1886 (see Appendix 3 for details).

Figure 6 Banking system balance sheet
Business cycle downturns shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

close to a staggering 940% of GDP in 2007 with cross-border assets and liabilities making up a large share of the balance sheet. Hence, this is an example of total banking system assets far exceeding the domestic credit-to-GDP ratio due to cross-border activities and asset holdings.

Another noteworthy feature of Figure 6 is that during the post-WWII period, leverage has peaked at times of balance sheet stagnation or reduction, rather than expansions. Hence, changes in leverage over this period may to a larger extent reflect the banks' response to declining deposit funding (discussed above) rather than increased willingness to expand and take on more risk.[12] This comes with a caveat: although the sharp expansion in the run-up to the financial crisis in 2008 was not reflected in large increases in leverage based on book value, de facto quality and quantity of bank capital in this period has been seriously questioned (Rannsóknarnefnd Althingis, 2010).

Finally, Figure 6 shows the evolution of non-core liabilities, which mainly consist of bond issuance and credit from other financial institutions, both domestically and on foreign wholesale markets.[13] The two phases of financial globalisation are apparent as cross-border funding plays an important role prior to the Great Depression and again from the 1970s and onwards. In 1906-08, approximately 15% of the banking system's borrowings came from abroad but the scale of foreign funding was actually larger as Íslandsbanki had foreign equity amounting to close to 10% of GDP. Access to foreign funding became more restricted following the global bank panic in 1907 and during WWI, but opened up again after WWI reaching a pre-WWII peak of 18% of total liabilities in 1923, but only after the government had intermediated state-guaranteed foreign funds to the banking system following the foreign liquidity crisis in 1920-21. After the collapse of Íslandsbanki

[12]The peak in leverage in the 1920s is different, however, as it was driven by the Icelandic authorities' efforts to expand the poorly capitalised state-owned Landsbanki and dismantle the foreign-owned Íslandsbanki after the latter experienced foreign-currency shortages in 1920-21 (see the discussion in Section 3.2). Following a change in law in 1921 forcing Íslandsbanki to sell its base metal reserves to Landsbanki at a discount, the state-owned bank expanded and became the country's central bank with a further capital injection, and an explicit state-guarantee on all its liabilities in 1927 and 1928 (Björnsson, 1961, 1981).

[13]The split between domestic and foreign is not clear-cut in the pre-WWII period as some foreign borrowing may have been categorised as domestic in the bank's accounts (Björnsson, 1981).

in 1930 (see Section 3.2), a state-controlled banking system was resurrected, although only after foreign creditors agreed to swap a share of their claims into bank equity which was subsequently paid down. From WWII and until the mid-1970s, non-core liabilities played a limited role in the banks' funding.

Access to foreign funding increased again in 1970 after Landsbanki joined a cross-national consortium of Nordic banks to gain an easier access to global wholesale markets (Jacobsen & Tschoegl, 1999). A short-lived decrease in cross-border funding took place following the Nordic banking crisis in the early 1990s, only to skyrocket after the liberalisation of capital flows in 1995 and Iceland's participation in the European "passport" system through its membership in the European Economic Area, which enabled the recently privatised commercial banks to expand their cross-border operations and thus sow the seeds of their own destruction (Gudmundsson, 2013). Non-core banking liabilities peaked at over 50% of total banking system liabilities prior to the latest financial crisis (the bulk of it being in foreign currency) before collapsing to its 1970s level of 4% in 2012.

3 Different types of financial crises

Although financial crises come in many shapes and forms, and can be defined in several ways, they share a number of commonalities that allow us to define them as episodes involving, inter alia, severe disruptions in financial intermediation that typically include large collapses in asset prices and credit volumes, serious strains on balance sheets, and collapses of financial institutions. Government intervention is often required in an attempt to contain these disruptions which often involves the use of fiscal resources and central bank balance sheets. These events can often spread over national borders and become global, either through common sources or through contagion across countries.

The fact that financial crises can take on many guises requires an identification of different types of financial crises. In this section we therefore aim to identify the most common types: currency crises (and their close relatives, inflation crises) and banking crises.[14] As financial crises often come in waves, we also construct a "multiple financial crisis indicator" in Section 4 to capture the clustering nature of the most severe crisis episodes in a single indicator.

3.1 Currency and inflation crises

Currency crises usually involve a speculative attack that can lead to a large devaluation or depreciation of the currency. They can also involve large interest rate hikes, a rapid

[14]The literature has identified other types of financial crises, mainly stock market, debt, and sudden-stop crises (cf. Reinhart & Rogoff, 2009, and Claessens & Kose, 2014). We do not cover stock market crises in Iceland as stock market data does not extend further back than the mid-1980s, while no incidences of sovereign debt crises are recorded for Iceland (see Reinhart & Rogoff, 2011), although the introduction of capital controls and frequent inflationary bouts are certainly versions of default – although default through inflation holds less clout for Iceland as a significant chunk of government debt is indexed to inflation. Sudden-stop crises are discussed in the main text in the context of other crises, mainly currency and banking crises, as these tend to be closely intertwined in such a small economy like Iceland.

Table 3 Currency and inflation crises in Iceland

Currency crises				Inflation crises		
Date	Duration (in years)	Cumulative depreciation	Average depreciation per year	Date	Duration (in years)	Average inflation per year
1919-20	2	0.526	0.263	1916-18	3	0.383
1932	1	0.219	0.219			
1939	1	0.211	0.211	1940-43	4	0.291
1950	1	0.508	0.508	1950-51	2	0.335
1960	1	0.535	0.535			
1968-69	2	0.497	0.248	1969	1	0.241
1974-85	12	0.978	0.082	1973-89	17	0.392
1988-89	2	0.324	0.162			
1993	1	0.151	0.151			
2001	1	0.194	0.194			
2008-9	2	0.482	0.241			
			Averages			
11 episodes	2.4	0.420	0.256	5 episodes	5.4	0.328

The table reports the dates of currency and inflation crises as identified by the numerical thresholds suggested by Reinhart & Rogoff (2009, 2011): exchange rate crises are defined as episodes where annual depreciations is greater than 15% per annum and inflation crises as episodes where annual inflation is in excess of 20% per annum (there are a few exceptions though explained in the main text).

Source: Authors' calculations (data sources described in Appendix 3).

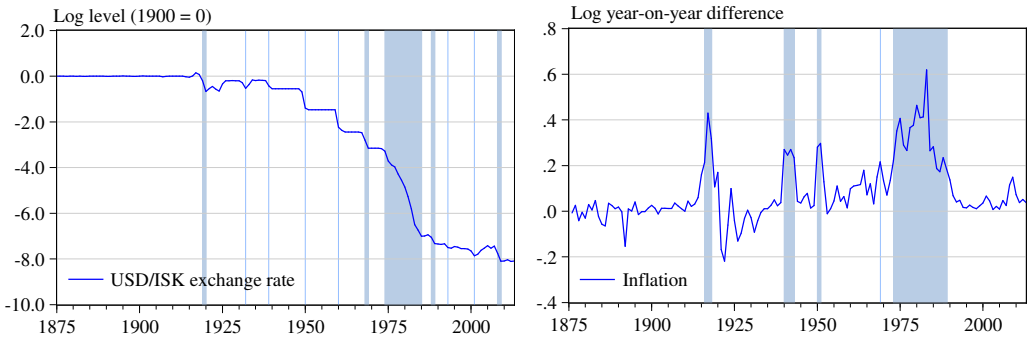
depletion of foreign reserves, or restrictions on capital outflows as the authorities attempt to halt the collapse of the currency. These crises are often triggered by unsustainable economic fundamentals, but can also be triggered by a self-fulfilling panic in a multiple equilibria context or arise due to serious balance sheet mismatches (see Claessens & Kose, 2014, for an overview).

To identify currency and inflation crises, we adopt the numerical criteria suggested by Reinhart & Rogoff (2009, 2011): for currency crises the threshold value is an annual depreciation of more than 15% per annum, while the threshold for inflation crises is an annual inflation rate of more than 20% per annum.[15] This criteria gives eleven episodes of currency crises in Iceland in our sample period with an average duration of 2.4 years (see Table 3 and Figure 7).[16] As can be seen, most of the currency crises identified are

[15]The currency threshold is similar to the 25% threshold proposed by Frankel & Rose (1996) but the inflation threshold is somewhat lower than what is sometimes used in similar studies (with 40% a common threshold), but as Reinhart & Rogoff (2009, 2011) point out inflation is usually well below the 20% during the gold standard period and a higher threshold would lead us to miss some potentially important crisis episodes. The threshold chosen is also well below standard definitions of hyperinflation but our interest goes beyond such extreme episodes. In fact, the use of standard definitions of hyperinflation would turn up zero events for Iceland. In Appendix 2 we analyse how sensitive our dating results are to variations in the threshold levels for currency and inflation crisis. Unsurprisingly, we find that the number of crisis episodes declines when the threshold level is increased: for currency crises the number of episodes falls to seven or eight when the threshold is raised to 30-50%, while the number of inflation crises falls to three when the inflation threshold is doubled to 40%.

[16]Although the average currency depreciation falls just short of the 15% threshold in 1974, we decide to start the currency crisis in that year rather than in 1975 as the currency was already depreciating by 20-40% in the latter half of 1974. For the same reason we decide to start the crisis in 1988 rather than in 1989 (with the currency already declining by 20% in the latter half of 1988). With the average depreciation

Figure 7 Currency and inflation crises
Currency crises (left) and inflation crises (right) shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

short-lived with more than half of the episodes lasting a year. One episode stands out in terms of its longevity: the currency crisis starting in the mid-1970s which lasts for more than a decade with a cumulative depreciation amounting to almost 98%. Some of the shorter crisis episodes are also nastier than others: the crises in the early 1920s, in 1950, the two crises in the 1960s, and the latest one, all saw a collapse of close to 50%.

Another noteworthy feature is that all but the last episode occur during a period which Iceland was following some type of an exchange rate peg (see Gudmundsson et al., 2000). Many of these episodes reflect attempts to depreciate an overvalued currency following a sharp deterioration of terms of trade or a collapse in export demand (1950, 1960, 1968-69, and 1993), while some also reflect capital flow reversals and foreign currency shortages (1919-20, 1932, and 2008-09). In all too many of these cases the peg proved unsustainable, with monetary policy too accommodative, fiscal policy too expansive, and domestic demand unsustainably high. A clear example of this is the chronic crisis episode in the mid-1970s to late 1980s, and the episode culminating in a currency attack on the fixed exchange rate regime in 2001 that finally brought an end to any attempt to peg the currency. Although the latest currency crisis occurs within a floating exchange rate regime, most of the characteristics described above also came together during this crisis: unsustainable level of demand and a large current account deficit, a sharp deterioration of external conditions following the global financial crisis, and large and vulnerable balance sheets following the enormous asset price and credit booms in the preceding years. We will return to this theme in our discussion of multiple financial crises in Sections 4 and 5.

Not surprisingly, the dating of inflation crises closely follows those of currency crises.[17]

in 1977 just shy of 10%, the simple threshold criteria suggests that the crisis ends in 1976 and resumes in 1978, but we decided to include 1977 as well.

[17]The simple correlation between these two types of fiat-money crises is 0.51, while the concordance index (see Table 5 below), which measures the relative frequency of both indicators giving the same signal, is 0.85. A close connection between inflation and currency crises is also found in Reinhart & Rogoff (2009). As with the currency crisis dates, we also need to make a judgement call on the inflation crisis dates as average inflation for 1987 falls just below the 20% threshold (measures 18.9%), but we decided to include that year in our chronic inflation crisis episode in the 1980s rather than having the crisis end in 1986 and resume in 1988 (with inflation ranging between 12% and 18% in the first half of 1987 and above 20% in

Our criteria gives five inflation crisis episodes with an average duration of 5.4 years. All the inflation crisis episodes coincide with currency crisis episodes, with the temporal sequence usually from a currency crisis to an inflation crisis, although it can be argued that the key source for the high real exchange rate and its subsequent correction is usually to be found in the chronic inflation throughout a large part of the period.

Currency crises and sudden stops

Currency crises frequently occur during periods of sharp current account reversals as funding of large current account deficits suddenly halts and capital starts flowing out of the country leading to strong pressures on the currency. Sudden stop crises (or balance of payment or capital account crises) therefore often go hand in hand with currency crises (see Claessens & Kose, 2014, for an overview). Although we do not have data on aggregate capital flows for the whole sample period, we see this pattern clearly in the trade balance data discussed previously (see Figure 8). All of the currency crisis episodes coincide with an improvement in the trade balance and seven of the eleven currency crises coincide with relatively large improvements (more than one standard deviation): the three first episodes in the 1920s and 1930s, the one in the late-1960s, the chronic episode in the 1970s to 1980s, the 2001 episode, and the latest 2008-9 crisis.

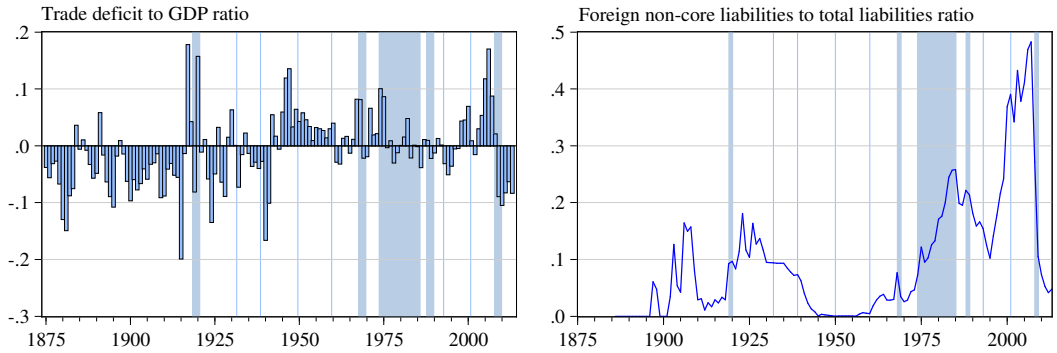
Sudden stop crises are commonly defined as episodes where large capital flow reversals (using a threshold value of two standard deviations) coincide with output collapses (cf. Calvo et al., 2008, and Forbes & Warnock, 2012). Applying this definition to our trade balance data narrows this down to two episodes: the 1919-20 crisis and the most recent 2008-9 crisis. Both led to a very large depreciation of the currency and a reversal of the trade balance amounting to 20-30% of GDP from peak to trough. It is also interesting that widespread capital controls were introduced in both instances: temporary controls on current account and capital account movements in the first episode, while widespread capital account restrictions were introduced in the most recent crisis in 2008-9, which have yet to be fully abolished. Widespread current and capital account controls were also introduced in the early 1930s, but that episode falls just shy of the two standard deviation threshold.[18]

This pattern of currency crises and sharp capital flow reversals is less clear when looking at foreign currency funding of local banks (Figure 8): although the foreign funding share usually declines following a financial crisis, these are usually relatively small and only in the last episode do we see a clear reversal when the foreign currency share plummets from a historical record high of 48% of total banking liabilities in 2007 to 7% in 2010. The domestic banks nevertheless faced severe foreign funding pressures in the crises in the 1920s and 1930s, but in both instances the government intervened and foreign funding was maintained. Despite the sequence of currency crises in the 1970s, the banks' foreign

the latter half of the year).

[18]The 1939 crisis also sees a trade reversal that exceeds the two standard deviation threshold but in that case we observe a large increase in domestic demand and output rather than a contraction due to the positive effects from the outbreak of WWII on the Icelandic economy.

Figure 8 Trade balance and foreign funding of domestic banks
Currency crises shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

funding rose throughout this period. This probably reflects Landsbanki's membership of a cross-national consortium of Nordic banks, which was discussed in Section 2.6.

3.2 Banking crises

Banking crises are the type of financial crises which often have the most profound effects on the real economy in terms of lost output and jobs (see e.g. Kaminsky & Reinhart, 1999, and Frydl, 1999). They can arise for a multitude of reasons through weaknesses on either the asset or liability sides of bank's balance sheets (Claessens & Kose, 2014, give an overview of the literature). These weaknesses can be system-wide or start in an individual bank and spread through panic to a significant part of the banking system. They can end with outright failures of banks or a significant restructuring – often through costly government interventions.

Unlike the numerical criteria for dating currency and inflation crises, the criteria for identifying banking crises is more subjective which often makes the specification of the exact start and finish of the crises elusive. This reflects the fact that a specific and unified numerical measure to signal an onset of a banking crisis is hard to come by as they tend to vary in how they develop. We therefore follow the standard practice in the literature in basing our event criteria on identifying dates were there are significant signs of financial distress in the banking system, as reflected in large-scale bank runs (be that a conventional run on deposits or a more "modern" run on wholesale funding) that lead to the closure, merging, or public sector takeover of a significant share of the banking system (see e.g. Reinhart & Rogoff, 2009, and Laeven & Valencia, 2013). We also identify the less onerous banking crises that do not lead to large-scale banking collapses but still require some type of restructuring and capital injection from the public sector to some important financial institution as being non-systemic. The fact that banking crises in Iceland from the 1970s to the present day have already been identified by Caprio & Klingebiel (2003), Reinhart & Rogoff (2009) and Laeven & Valencia (2013) makes life somewhat easier for us. Our task therefore basically involves extending the already existing dates back to the start of our

Table 4 Banking crises in Iceland

Date	Type	Duration (in years)	Market share of distressed institutions[1]	Change in real credit[2]	Change in fiscal balance[3]	Increase in government debt[4]
1920-21	Systemic	2	0.798	-0.172	-0.033	0.136
1930-31	Systemic	2	0.664	-0.097	-0.028	0.115
1985-86	Non-systemic	2	0.074	0.091	-0.053	0.039
1993	Non-systemic	1	0.172	0.015	-0.009	0.088
2008-10	Systemic	3	0.935	-0.813	-0.160	0.640
Average		2.0	0.529	-0.195	-0.057	0.204

The table reports the dates of banking crises used in this study. The dates identified for the 1985-86 and 1993 crises are obtained from Caprio & Klingebiel (2003) (also used by Reinhart & Rogoff, 2009, 2011), while we use Laeven & Valencia (2013) to date the start of the latest crisis. To date the two pre-WWII crises we used archived documentation (see the main text). 1. Share of distressed financial institutions in total credit by deposit money banks and other lending institutions in year $T-1$, where T is the starting year of the banking crisis. 2. Change in total real credit between year $T-1$ and T. 3. Change in central government fiscal balance between year $T-1$ and the post-crisis trough in years T to $T+3$ (ratio to GDP). 4. Change in central government debt between year $T-1$ and the post-crisis peak in years T to $T+3$ (ratio to GDP).

Source: Authors' calculations (data sources described in Appendix 3).

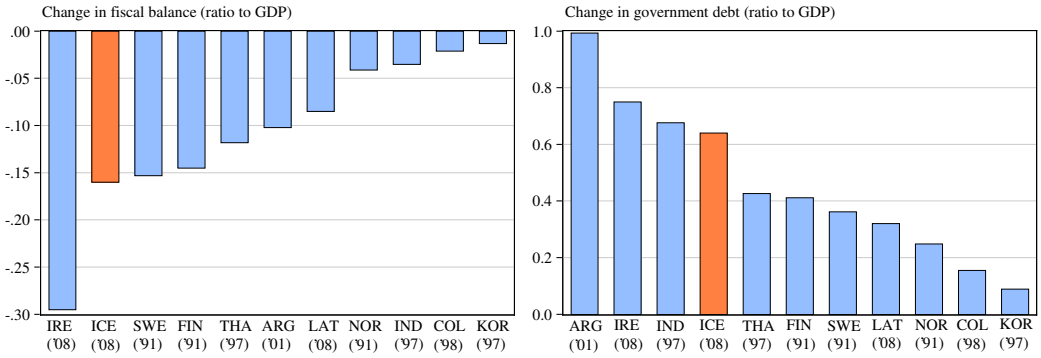
sample period in 1875.

Using these criteria, we identify five banking crisis episodes, covering 10 years (or 7.2%) of our 139 year sample period. Thus, banking crises occur on average every 22 years and last for 2 years (see Table 4). The 7.2% share of years in a banking crisis is very close to the average share found in Reinhart & Rogoff (2009, Table 10.5) for other European countries (6.3%) and advanced economies in general (7.2%) for the period 1800 to 2008. The average duration of 2 years also closely matches what they find for other European countries and advanced economies in general (2.1 and 2.2 years, respectively).

We follow Caprio & Klingebiel (2003) in defining two of these as non-systemic (see also Reinhart & Rogoff, 2009, 2011). The first of the two occurs in 1985-86 when one of the three state-owned banks (Útvegsbanki), with a market share of roughly 7% of total lending at the time, became insolvent following a bankruptcy of a major borrower, eventually leading to a government-led merger of the bank with three private banks in 1990. The second non-systemic banking crisis occurs in 1993 when the larger of two state-owned banks (Landsbanki), with a market share of roughly 17% of total lending at the time, needed a capital injection amounting to 1% of GDP due to large loan losses following the recession in the years leading up to the crisis. As Table 4 shows, neither of these two non-systemic banking crises led to a contraction in the aggregate supply of real credit to the economy or had a very large impact on government finances.

The three remaining crises were much more serious and left larger footprints on the real economy and none more so than the latest one, which hit in late 2008. Iceland's three large cross-border commercial banks collapsed following Lehman Brothers' bankruptcy in the autumn of 2008 (amounting to roughly 85% of the financial system), shortly followed by the failure of most of the smaller saving banks and other financial institutions, eventually leading to failure of more than 90% of the total financial system. We follow Laeven &

Figure 9 Fiscal impact of selected banking crises



Change in government fiscal balance between year $T-1$ and the post-crisis trough in years T to $T+3$ (ratio to GDP) and change in government debt between year $T-1$ and the post crisis peak in years T to $T+3$ (ratio to GDP). The countries are Argentina (ARG), Columbia (COL), Finland (FIN), Iceland (ICE), Ireland (IRE), Indonesia (IND), Korea (KOR), Latvia (LAT), Norway (NOR), Sweden (SWE) and Thailand (THA). Year of start of crisis in parenthesis.

Sources: International Monetary Fund (WEO database), Laeven & Valencia (2013) and Table 4.

Valencia (2013) and date the start of the crisis in 2008 rather than a year earlier as in Reinhart & Rogoff (2009, 2011). As in all of these studies, the crisis is assumed to end in 2010 with the completion of bank failures when the three largest savings banks were taken over by the financial supervisory authorities. The macroeconomic consequences of the crisis were huge: per capita domestic demand collapsed by almost 28% and GDP lost 8% from 2008 to 2010. The fiscal impact was also enormous: the fiscal balance deteriorated by 16% of GDP and central government debt rose by 64% of GDP.

The other two systemic crises were not as severe and fell upon a banking system that was dwarfed in terms of sheer size compared to the latest episode, but would still register on any banking crisis barometer. The former occurred in the start of the 1920s when the banking system ran into loan losses and foreign currency shortages that led to a seizure of cross-border payments for some months. The government eventually bailed out the two large commercial banks (Íslandsbanki and Landsbanki), suppliers of almost 80% of total lending, by guaranteeing a large foreign loan amounting to 8% of GDP (see Ísleifsson, 1986, Nordal, 1997, and Jónsson, 2009).[19] The fiscal impact is sizeable, with government debt rising by almost 14% of GDP. The second crisis takes place in the early 1930s and is slightly smaller than the previous one. It starts when Íslandsbanki (with a market share of 30%) again ran into loan losses and foreign currency liquidity problems, which eventually led to its bankruptcy in 1930. Landsbanki (with a market share of roughly 35%) also experienced severe foreign currency shortages in 1931, which led to the introduction of limits to current account trades and related foreign exchange transactions (see Björnsson, 1961, and Nordal, 1997).

The average share of roughly half of the financial system in distress over the five episodes is slightly higher than the 40% share that Caprio et al. (2005) find for banking crises since

[19]This also coincided with a number of bank collapses in Scandinavia during the 1920s, including some of the main creditors of the Icelandic banks (see Cohn, 1958, and Wetterberg, 2009).

1970 among medium and high income countries. The average increase in government debt of 20% of GDP is also comparable to the 24% increase Laeven & Valencia (2013) find for advanced economies for the period 1970-2011. Comparing average values, however, masks how the latest episode stands out in terms of severity. Caprio et al. (2005) record only seven instances where 90% or more of the banking system fails (Bangladesh, Cote d'Ivoire, Guinea and Tanzania in the late 1980s, and the Central African Republic, Costa Rica and Poland in the early 1990s), while very few financial crises have left a larger hole in government finances as seen in Figure 9.

4 Multiple financial crises

4.1 Identifying multiple crises

In Table 5 we summarise the key statistical properties of the indicator variables we have constructed to capture the dates of different types of financial crises and economic downturns (both regular cyclical downturns and the more serious demand disaster episodes). We report the number of years in a given crises, the number of crisis episodes, and the average duration of each crisis for the whole sample period and for the two subsamples. The first thing to notice is that the incidence of currency and inflation crises is mostly concentrated in the post-WWII period, both in terms of number of episodes and the number of years in a state of crisis. Currency and inflation crises have also tended to last longer in the second period, but no such difference is apparent for banking crises, whose relative incidence and duration is very similar across the two subsamples. The table also shows that while regular cyclical downturns have become slightly less common in the post-WWII period (albeit lasting longer) in line with declining economic volatility reported in Table 1, the incidence of the more catastrophic demand disaster has actually increased.

Finally, Table 5 reports the concordance index originally suggested by Harding & Pagan (2002) adopted here to capture the co-movement of any two crisis indicators (i.e. the relative number of years when a pair of two indicators gives the same signal). Thus, the currency and inflation crisis indicators give an identical signal in 85% of the time, with the index in general ranging from 0.7-0.9 for other indicator combinations, suggesting that the indicators tend to give the same signal most of the time. This measure, however, overstates the coincidence of our crisis signals as the relatively frequent "no crisis" signal inflates the statistics.

At the same time, the concordance index may provide a too narrow measure for capturing the typical clustering behaviour of different types of financial crises (a common finding in the literature, see Reinhart & Rogoff, 2009, for an overview) as it only captures crisis episodes occurring within the same year. The concordance index therefore does not capture the possibility of crises that come in a sequence over a period of some years. For example, Kaminsky & Reinhart (1999) find that currency and banking crises often go hand in hand (a so-called twin crisis) with problems in the banking sector usually predating the currency

Table 5 Summary statistics for crises and downturns

	Currency crises	Inflation crises	Banking crises	Multiple financial crises	Cyclical downturns	Demand disasters
			Total sample (1875-2013)			
Number of years	26	27	10	22	23	25
Share of sample	0.19	0.19	0.07	0.16	0.17	0.18
Number of episodes	11	5	5	6	11	9
Duration (in years)	2.4	5.4	2.0	3.7	2.1	2.8
			First subsample (1875-1944)			
Number of years	4	7	4	10	13	7
Share of sample	0.06	0.10	0.06	0.14	0.19	0.10
Number of episodes	3	2	2	2	7	4
Duration (in years)	1.3	3.5	2.0	5.0	1.9	1.8
			Second subsample (1945-2013)			
Number of years	22	20	6	12	10	18
Share of sample	0.32	0.29	0.09	0.17	0.14	0.26
Number of episodes	8	3	3	4	4	5
Duration (in years)	2.8	6.7	2.0	3.0	2.5	3.6
			Concordance index (total sample)			
Currency crises	1.00	0.85	0.81	0.78	0.72	0.79
Inflation crises		1.00	0.76	0.73	0.71	0.74
Banking crises			1.00	0.87	0.82	0.82
Multiple financial crises				1.00	0.91	0.91
Cyclical downturns					1.00	0.84
Demand disasters						1.00

The table reports the number of years in a given crisis and the relative share of years in a crisis state (the number of years in crisis divided by total or subsample size). The table also reports the number of crisis episodes and the average duration of each crisis in years. The dates for currency and inflation crises can be found in Table 3, while the dates for banking crisis can be found in Table 4 and dates for the multiple financial crises indicator in Table 6 below. Dates for cyclical downturns and demand disasters are reported in Table 2. The table reports summary statistics for the total sample from 1875-2013 (139 years) and for two subsamples: the period 1875-1944 (70 years) and the period 1945-2013 (69 years). The concordance index of Harding & Pagan (2002) measures the fraction of time each pair of indicators gives the same signal.

Source: Authors' calculations (data sources described in Appendix 3).

crisis, as problems in the banking system lead to a collapse in overall confidence in the economy and a run on the currency. An inflation crisis would typically follow the currency crisis, especially in small open economies with poorly anchored inflation expectations. The alternative sequence is of course also possible, with a currency collapse wreaking havoc in private non-financial sector balance sheets (especially if they are characterised by currency mismatches), leading to large loan losses and eventually to bank collapses.[20] Finally, financial turbulences can also be triggered by adverse events in the real economy, such as a sharp deterioration of terms of trade and a marked slowdown of growth. The financial crisis can therefore amplify the economic downturn instead of triggering it. Indeed, Reinhart & Rogoff (2009) find that this amplifying nature of financial crises is quite common. Furthermore, these crisis clusters typically lead to deeper and longer recessions (see also

[20] A currency crisis that goes hand in hand with loss of cross-border funding and limited domestic lender of last resort capacity in foreign currency can also lead to a more rapid banking system collapse.

Table 6 Multiple financial crises in Iceland

Multiple financial crises		Cumulative contraction		Coinciding crises and economic downturns				
Dates	Dur.	Per cap. demand	GDP	Currency crises	Inflation crises	Banking crises	Demand disasters	Cyclical downturns
1914-21	8	0.127	0.086	1919-20	1916-18	1920-21	1914-15 1918 1923-24	1914-18 1920
1931-32	2	0.179	0.034	1932		1930-31	1931-32	1931-32
1948-51	4	0.309	0.043	1950	1950-51		1948-51	1949-52
1968-69	2	0.155	0.045	1968-69	1969		1968-69	1967-68
1991-93	3	0.075	0.023	1993	1973-89	1993	1988-93	1991-92
2008-10	3	0.266	0.069	2008-9		2008-10	2007-10	2009-10

The table reports the dates of multiple financial crises identified and the currency, inflation and banking crises, and demand disasters and cyclical downturns previously identified around these financial crisis episodes (see Tables 2-4). Also reported is the duration (in years) of these financial crises and the cumulative loss in per capita domestic demand and output in these episodes.

Source: Authors' calculations (data sources described in Appendix 3).

Bordo et al., 2001) and are usually associated with severe disaster episodes as defined by Barro & Ursúa (2008).

To capture this clustering nature of financial crises in a single "multiple financial crisis indicator", we apply a version of the Harding & Pagan (2006) non-parametric common cycle algorithm in an attempt to identify episodes where our different indicators signal a common crisis. Specifically, we calculate the end-date of a crisis for the three financial crisis indicators and our two macroeconomic measures capturing cyclical downturns and the more punishing demand disaster episodes, as we want to concentrate on the more severe crisis episodes. For each indicator we then calculate the minimum distance at each point of time to the end-date of the next crisis and from that we construct a single common end-date indicator as the median of the calculated distances for the five indicators. A common crisis is then identified when the following two conditions are fulfilled: (1) there is a local minimum in the common indicator; (2) there is as cluster of end-dates, identified when at least 4 of the 5 indicators have an end-date within two years from the common end-date. If the common end-date is not uniquely determined using the above algorithm we use the date which gives the lowest average distance to the end-date of the individual indicator, as in Drehmann et al. (2012).

This algorithm gives us six common crisis episodes with end-dates in 1918, 1932, 1951, 1969, 1993, and 2010.[21] We adopt these end-dates for the common multiple crisis indicator

[21]Thus, our algorithm excludes the currency and inflation crises in the 1970s and 1980s and the non-systemic banking crisis in the mid-1980s as output and domestic demand were actually growing robustly throughout most of the period. Extending the cluster width to 3 years as in Drehmann et al. (2012) does not alter our results. Neither does adding turning point censoring rules as suggested by Harding & Pagan (2006). We also tried specifying the algorithm in terms of common starting dates. This gave us the same six common crisis episodes, except that the one in the early 1990s becomes only weakly identified

(although extending the first one to 1921, as explained below), while looking at each episode in turn to define the start dates according to the corresponding start-dates of individual financial crisis episodes or a demand disaster (explained below). Table 6 summarises key statistics for the six episodes.

4.2 The anatomy of six multiple crisis episodes

In this subsection we discuss our six crisis episodes in more detail, both in terms of the exact timing of the crises and the sequence of events. We also discuss the development of our macroeconomic and financial variables, shown in Figure 10, in the run-up to and aftermath of each episode. To analyse their behaviour, we look at each variable relative to its long-term trend. The pattern we are interested in is whether our variables, the financial variables in particular, tend to grow faster than what is implied by their trend in the lead up to the crisis and fall below their trend once the crisis unfolds. If a set of particular variables shows such behaviour systematically in the run-up to financial crises, they might serve as useful early-warning indicators for future financial crises. Alternatively, we may find that each episode is different and that an alternative set of variables signals an upcoming crisis in each case.

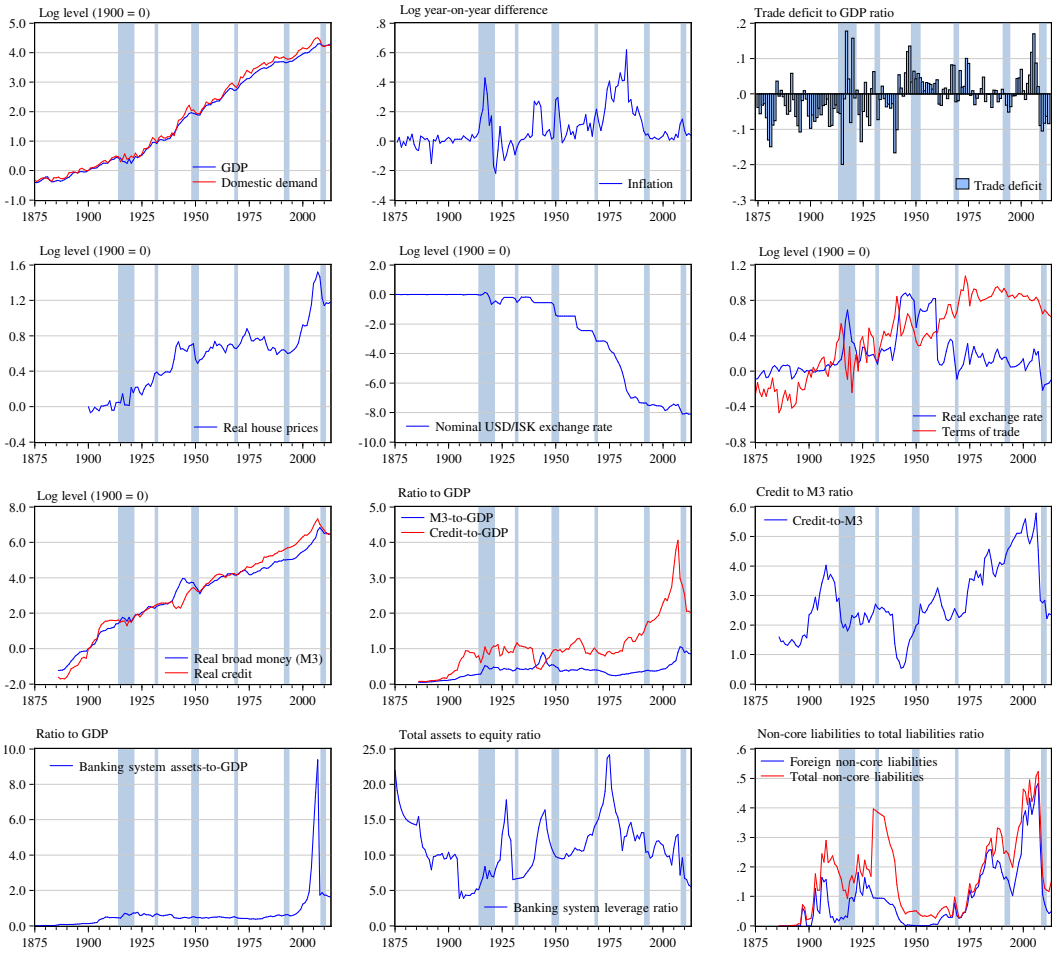
To estimate the long-run trend of each variable we need to strike a balance between allowing a relatively smooth trend that can still capture possible changes in the trend due to structural breaks over the long period we analyse, for example due to financial deepening and shifting degree of financial globalisation, against simply matching the actual variable too closely. We therefore use the Hodrick-Prescott (1980, 1997) filter, which is a standard method for estimating flexible trends in economic data. This approach has also been used for analysing financial cycles in a number of studies, such as Gourinchas et al. (2001) and Mendoza & Terrones (2008), and is recommended by the Basel Committee (2010) for estimating financial gaps for establishing capital buffers (see also Drehmann et al., 2010).

When using the Hodrick-Prescott filter, one must choose the value of λ, which determines how much weight to put on minimising the variability in the cyclical component of the series relative to the smoothness of the trend component (a higher value of λ imposes more smoothness on the estimated trend). Hodrick and Prescott recommend using $\lambda = 1,600$ for quarterly data, which has become a standard value for business cycle analysis with quarterly data and can be shown to correspond to a business cycle frequency of roughly 7.5 years. As financial cycles are thought to be longer than regular business cycles, the Basel Committee (2010) recommends using a higher λ value.[22] In particular,

(only identified by three of the five indicators or needing an extension of the window to 4 years). The common starting dates, although not as tightly identified as the common end-dates in the main text, are also very similar to those chosen. We also applied the algorithm exclusively to the financial crisis indicators where a cluster is identified when at least two of the three have an end-date within two years from the common end-date. This gave us the same six episodes with broadly the same end-dates but also included three additional end-dates (1941, 1986, and 1989). However, the first two additional dates can hardly be categorised as severe financial crises as they coincided with robust economic activity (average GDP growth ranged from 12% to 17% per year in 1940-1942 and was over 3% throughout the latter half of the 1980s).

[22] The properties of the financial cycle in Iceland is the topic of our companion paper (Part II).

Figure 10 Multiple financial crises in Iceland
Multiple financial crises shown as shaded areas



Source: Authors' calculations (data sources described in Appendix 3).

based on the results in Drehmann et al. (2010), they recommend using the value 400,000 for quarterly data which corresponds to a financial cycle that is four times longer than the regular business cycle [$\approx 4^4 \times 1,600$)]. To derive the corresponding weight for annual data, we follow Ravn & Uhlig (2002) who show that the optimal transformation involves multiplying the quarterly λ weight with the fourth power of the observation frequency ratio. This gives us a λ value of 1,563 [$= (¼)^4 \times 400,000$)] which we use in this paper.[23] Finally, as in Mendoza & Terrones (2008), we choose to base our trend estimate on the full sample estimate rather than using recursive estimate as in Gourinchas et al. (2001) or a fixed rolling window estimate in the run up to each crises as in Dell'Ariccia et al. (2012) as our annual observations would leave us with too few observations to estimate the trend

[23] For the regular business cycle weight of 1,600 for quarterly data this corresponds to a value of 6.25 [$= (¼)^4 \times 1,600$)] for annual data. This is a much lower than the value of 100 originally suggested by Hodrick and Prescott for annual data (obtained as $(½)^2 \times 1,600$, which Ravn and Uhlig show is a sub-optimal transformation). Our λ value is close to the λ value of 1,000 used by Gourinchas et al. (2001) but higher than the value of 100 used by Mendoza & Terrones (2008). We also tried using a value of 100 with broadly similar results.

with any precision in the early part of the sample or in the run-up to crisis that follow fast on the heels of one another.

Tables 7.a-c summarise the results in terms of heat maps for each of the six crisis episodes for the period $[T-5$ to $T+5]$, where T is the first year of the crisis. The upper panel of each table shows the financial variables included in our sample and the lower panel the macroeconomic variables. Each heat map shows the deviations of a given variable from its long-term trend in terms of the number of standard deviations of the cyclical component of each variable. Red colours denote that the variable is above trend, while blue colours denote that the variable is below trend, with darker shades denoting larger deviations from trend. We now proceed to discuss each episode in turn.

The 1914-1921 crisis

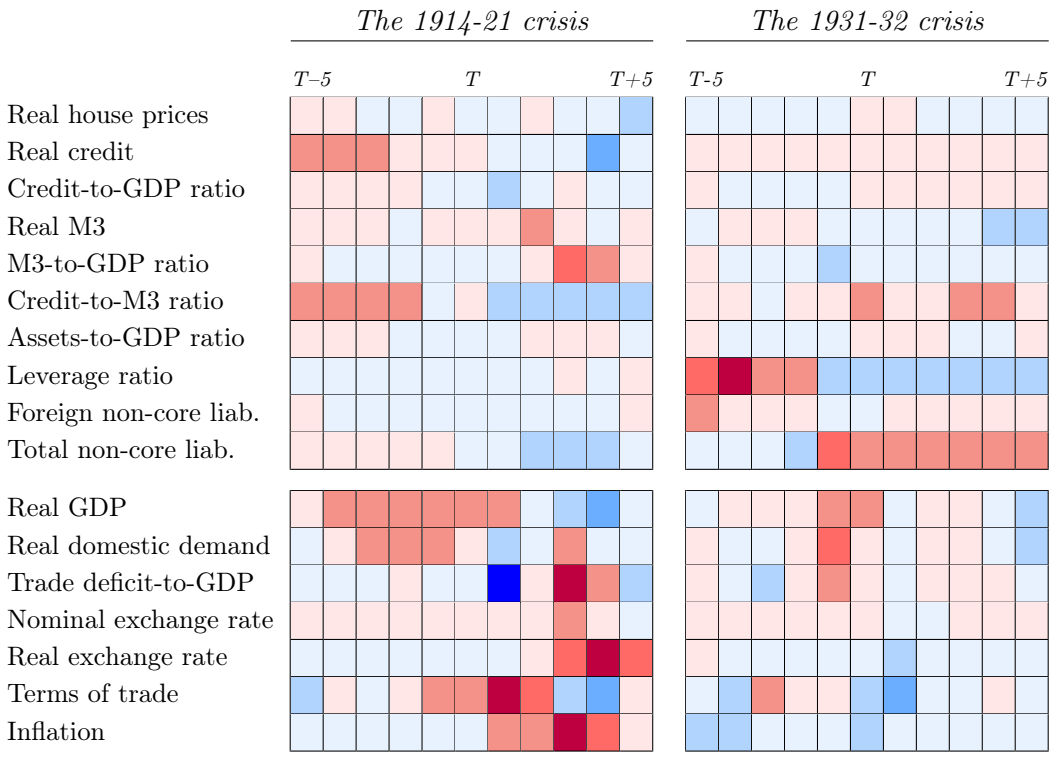
We assume that the first multiple financial crisis starts in 1914 with the onset of WWI, which marked the beginning of a period of prolonged economic hardship and a sequence of financial crises. The Icelandic economy was especially vulnerable to the outbreak of WWI due to its heavy reliance on foreign trade. The country's export ratio was among the highest in Europe and most manufacturing goods and approximately half of food consumption were imported (Jónsson, 2004). Trade restrictions and enforced trade agreements associated with WWI therefore caused widespread shortages of imported goods and loss of important export markets. These negative external shocks led to a collapse in domestic demand and output, as well as rampant inflation as import prices rose steeply and convertibility of the currency was suspended. As peace resumed and foreign trade was restored in 1919 the economy experienced a brief recovery, but havoc returned as export prices collapsed in the global post-WWI crisis, resulting in extensive bankruptcies of heavily indebted fisheries companies and the emergence of a black market for the overvalued domestic currency. Hence, the economy underwent a sudden stop and a currency crisis and eventually a systemic banking crisis in 1920. The end-date of this crisis episode is assumed to be in 1921 when the banking crisis was brought to an end with the government's foreign-funded bail-out of the two largest banks.[24] Over this 8 year period, output fell by 8.6% and per capita demand by just under 13%, and it took a staggering 11 years for output to reclaim its pre-crisis peak again (13 years for demand), making this the deepest and most protracted recession of the 20$^{\text{th}}$ century.[25]

As Table 7.a shows, it is mainly output and domestic demand, as well as credit and, to some extent, non-core banking liabilities, which were above their long-term trend in the run-up to the crisis and subsequently fall below trend. The pattern in the run-up to the crisis reflects the export-led growth period spurred by the adaptation of credit-financed advanced fishing technology. The Achilles' heel of this growth strategy was that it was

[24] We decided to date the end of the crisis in 1921 although demand contracted again in 1923-24, due to the strong growth recorded in output and demand in the intervening year.

[25] Kjartansson (2003) refers to the period 1914-1923 as "the long economic downturn in Iceland's 20$^{\text{th}}$ century history". Note that both output and, in particular, demand experience a few repeated relapses after temporary reclaiming their pre-crisis level, but here we refer to a more sustained recovery.

Table 7.a Financial and macroeconomic variables in the 1914-21 and 1931-32 crises



The table shows the development of each variable compared to its long-term trend for the five years in the run-up to and in the aftermath of a financial crisis, where T indicates the first year of the crisis. The long-term trend is estimated for the whole sample period using the Hodrick-Prescott filter with a smoothing parameter equal to 1,563 (see the main text for explanation). Red cells indicate that a variable was above trend in a given year with darker red cells indicating ever larger deviations above trend (■ indicates more than 1 standard deviation above trend, ■ more than 2 standard deviations above trend, and ■ more than 3 standard deviations above trend). Blue cells indicate that a variable was below trend in a given year with darker blue cells indicating ever larger deviations below trend (■ indicates more than 1 standard deviation below trend, ■ more than 2 standard deviations below trend, and ■ more than 3 standard deviations below trend).

Source: Authors' calculations (data sources described in Appendix 3).

based on a narrow export base, concentration of credit risk, and the presence of liberalised cross-border flows of goods and capital. All of these factors were tested during WWI and these macro-financial linkages remained strong throughout this period. This is, for instance, reflected in real credit remaining below its trend for 11 years after the onset of the crisis and output for even longer.[26] Hence, real credit only returned to its trend 5 years after the banking crisis was resolved and even then it was based on bank leverage rising significantly above trend, which played a role in the next crisis in the early 1930s.

The 1931-1932 crisis

The Great Depression did not make its mark on economic growth in Iceland until 1931 when

[26]The credit-to-money ratio, as well as the total non-core financing ratio, also remained below trend for 8 and 9 years, respectively, as money financing increased during this period after convertibility of the currency was suspended. The terms of trade deterioration, the rise in inflation and the accompanying real exchange rate appreciation and worsening of the trade balance during the crisis are also evident from the heat map in Table 7.a.

export prices collapsed. This year marks the beginning of our second multiple financial crisis, which is much shorter than the previous one, lasting only from 1931-32.[27] Although short, it includes both a systemic banking crisis and currency crisis and its macroeconomic consequences are large: per capita demand falls by almost 18% and output by more than 3%. The effects of the crisis (and its resolution) are even to a larger degree reflected in the weak recovery in its aftermath with 11 years passing before per capita domestic demand reaches its pre-crisis level.

The macro-financial linkages at work in the run-up to and aftermath of this crisis seem broadly similar to the previous one. Just as in the run-up to the 1914-21 crisis, output and demand were above their long-term trend levels (see Table 7.a) supported by robust export growth related to credit-financed technological improvements in the fisheries sector, reflected in real credit rising above its long-term trend. Iceland's golden age as world-leading salt fish supplier reached its peak in the late 1920s, but following the outbreak of the Great Depression, fish prices collapsed, tariffs were introduced, followed by the collapse of the important export market in Spain during its civil war. Widespread financial distress and a series of bankruptcies followed. Hence, the narrow export base, concentration of credit risk, and reliance on foreign trade (and funding) proved a precarious combination once again.

Financial stability was further undermined this time around by the fact that the banking sector had not been put on a firm footing in the 1920s: many of the banks' borrowers remained in financial distress (due to a difficult mix of high debt, price deflation, high real interest rates, and the revaluation of the króna), the banks' equity position deteriorated (as reflected in bank leverage rising markedly above trend in Table 7.a). Hence, a twin currency and banking crisis occurred shortly after the effects of the Great Depression hit the domestic economy.

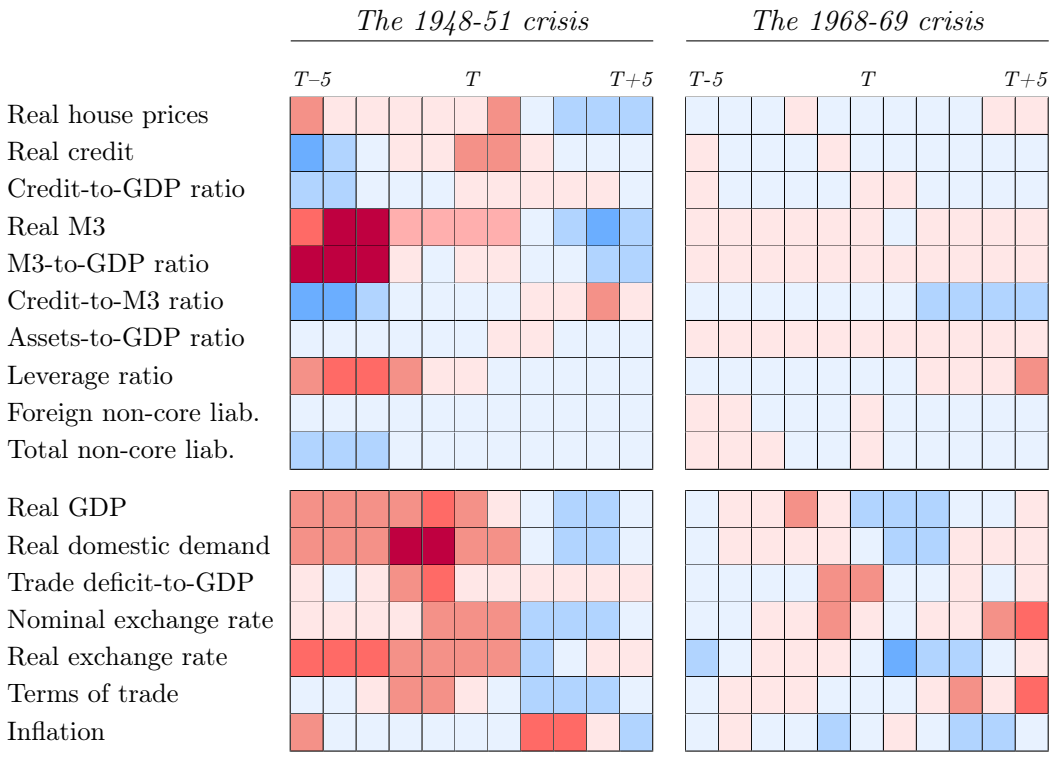
Just as in the previous crisis, the immediate policy response neither included a change in interest rates nor the abandoning of the fixed exchange rate peg, but relied instead on the introduction of capital and current account restrictions and a government-led intervention in the banks' foreign funding (the króna depreciated against the US dollar but remained fixed against the pound sterling until 1939). However, the restrictions were not short-lived this time around and the financial restructuring resulted in a state-controlled banking (and corporate) sector – both of which proved to be much more enduring in Iceland than in most other advanced economies.

The 1948-1951 crisis

Our third multiple financial crisis follows the demand collapse in 1948 related to a negative terms of trade shock and loss of market share as European fisheries recovered after WWII. The weakening real economy eventually led to currency and inflation crises in 1950 and

[27] We choose to start this financial crisis in 1931 although we have previously dated the start of the banking crisis in 1930. The reason is that 1930 shows very strong growth in output and demand (well above 10%).

Table 7.b Financial and macroeconomic variables in the 1948-51 and 1968-69 crises



The table shows the development of each variable compared to its long-term trend for the five years in the run-up to and in the aftermath of a financial crisis, where T indicates the first year of the crisis. The long-term trend is estimated for the whole sample period using the Hodrick-Prescott filter with a smoothing parameter equal to 1,563 (see the main text for explanation). Red cells indicate that a variable was above trend in a given year with darker red cells indicating ever larger deviations above trend (■ indicates more than 1 standard deviation above trend, ■ more than 2 standard deviations above trend, and ■ more than 3 standard deviations above trend). Blue cells indicate that a variable was below trend in a given year with darker blue cells indicating ever larger deviations below trend (■ indicates more than 1 standard deviation below trend, ■ more than 2 standard deviations below trend, and ■ more than 3 standard deviations below trend).

Source: Authors' calculations (data sources described in Appendix 3).

a further collapse of demand lasting into 1951. Per capita domestic demand fell by a staggering 31% (the largest contraction in per capita demand recorded in Iceland) while output fell by just above 4% – with output taking 6 years to reclaim its pre-crisis level and per capita demand an eye-popping 16 years to reclaim its pre-crisis level.

The crisis must be but into context with WWII, which had profound effects on the Icelandic economy. Demand for exports was exceptionally strong during WWII and domestic demand was stimulated further by the presence of the occupation forces of 20-30 thousand soldiers (or approximately 20% of the total population at the time). Average annual GDP growth during the war period was 10%, with domestic demand growing even more rapidly, and inflation was rampant. At the end of WWII, income levels were at an all-time high, banking system foreign reserves amounted to almost 50% of GDP, and its liquidity position was strong. However, extensive macro-financial imbalances had built up and they increased considerably in the run-up to the crisis when a government-led investment boom took place, exhausting the foreign reserves by 1947.

Hence, once again, the conditions were ripe for a negative feedback loop between an external shock, an overextended domestic economy, and a banking system lacking the necessary resilience. These conditions are clearly evident in Table 7.b, for instance, in a significantly overvalued real exchange rate and a rapidly growing trade deficit. Warning signs are also clear in the financial system with money balances rising well above its trend level, bank leverage increasing in a poorly capitalised banking system, signs of overextension in the housing market, and credit rising above its long-term trend. Just as in previous crises, the authorities were reluctant to use the exchange rate and interest rate when responding to the crisis, but instead reinforced capital and current account restrictions, increased the government's role within the economy, and reintroduced substantial subsidies to the troubled export sector.

The 1968-1969 crisis

The fourth multiple financial crisis follows the natural resource crash in 1968 with collapsing demand and an onset of a currency crisis, leading to further collapse of demand and an inflation crisis in 1969. Per capita demand fell by almost 15.5% but output by less or 3%, while both took 4 years to reclaim their pre-crisis levels.

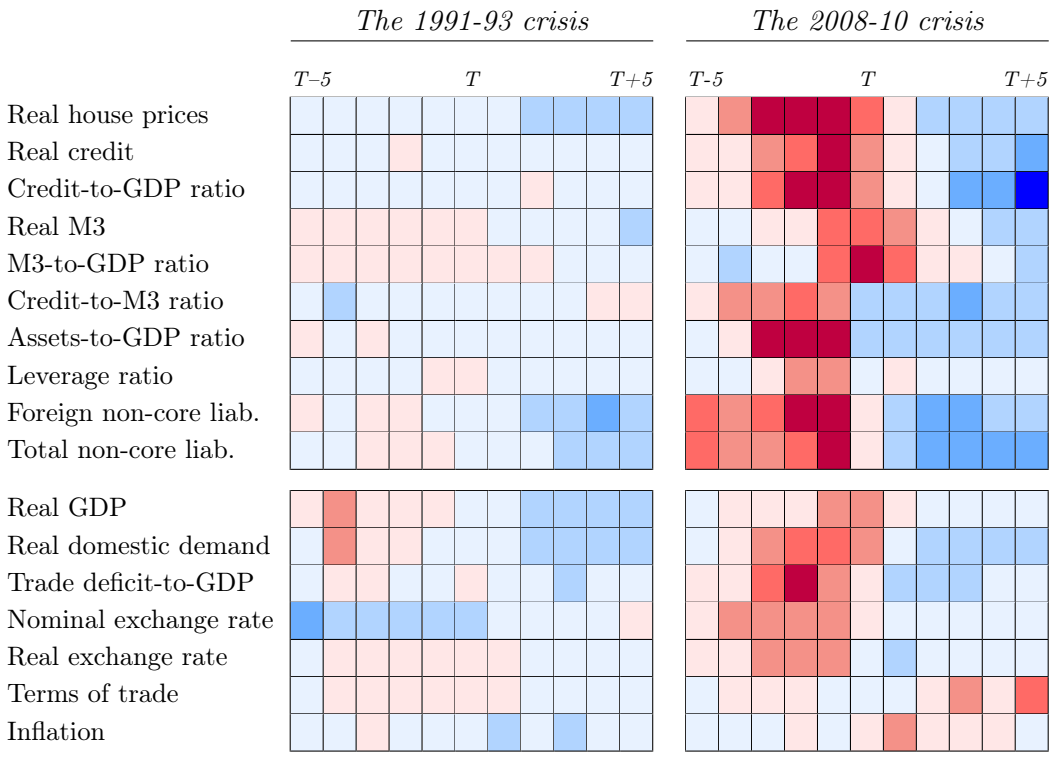
The negative (real) external shock to the economy was no less severe than in the previous crisis but the extent of macro-financial imbalances heading into the crisis were considerably smaller this time around as clearly reflected in Table 7.b. That probably played an important role in making this a relatively short-lived crisis compared to the previous ones.

The 1991-1993 crisis

The fifth multiple financial crisis is assumed to start in 1991 with a weakening of the real economy eventually leading to currency and non-systemic banking crises in 1993, with per capita demand falling by 7.5% and output by more than 2% – and taking 4 and 6 years respectively to reclaim their pre-crisis levels. Here, we needed to make a judgement call as the demand disaster identified in Section 2.1 is assumed to start earlier, or in 1988. That followed a sharp increase in real interest rates to bring the persistent inflation and currency crises discussed in Section 3.1 to a halt. However, we decided to date this crisis only from 1991 as output continued to grow until 1990 and only started to contract in 1991 when we assume the crisis starts. By then a global economic downturn reinforced the domestic disinflationary pressures resulting in a recession. But just as in the 1968-69, the extent of macro-financial imbalances heading into the crisis were limited (see Table 7.c) and the crisis proved relatively short-lived.[28]

[28]In both crises, though, the effects on the labour market were more severe and emigration to other countries increased considerably.

Table 7.c Financial and macroeconomic variables in the 1991-93 and 2008-10 crises



The table shows the development of each variable compared to its long-term trend for the five years in the run-up to and in the aftermath of a financial crisis, where T indicates the first year of the crisis. The long-term trend is estimated for the whole sample period using the Hodrick-Prescott filter with a smoothing parameter equal to 1,563 (see the main text for explanation). Red cells indicate that a variable was above trend in a given year with darker red cells indicating ever larger deviations above trend (■ indicates more than 1 standard deviation above trend, ■ more than 2 standard deviations above trend, and ■ more than 3 standard deviations above trend). Blue cells indicate that a variable was below trend in a given year with darker blue cells indicating ever larger deviations below trend (■ indicates more than 1 standard deviation below trend, ■ more than 2 standard deviations below trend, and ■ more than 3 standard deviations below trend).

Source: Authors' calculations (data sources described in Appendix 3).

The 2008-2010 crisis

The sixth and final multiple financial crisis in our sample is truly the perfect storm. We assume that it starts in 2008 with a sudden stop and twin currency and systemic banking crises, and a collapse in demand lasting into 2010. The economic consequences are devastating: per capita domestic demand falls by a whopping 26.6% and output by 8% (based on annual data). Although output had almost regained its pre-crisis level in 2013, per capita domestic demand remained almost 25% below its 2007-level and will take years to reclaim that level based on any reasonable growth assumptions.

The extent of financial imbalances in the run-up to the 2008-2010 crisis is unprecedented and red lights blink across the board well before the crisis hits: all financial variables examined in Table 7.c exceeded their long-term trend levels by multiple standard deviations and many do so already 4 or 5 years before the start of the crisis. For example, in the year before the crisis (in 2007), we find that house prices and non-core bank funding are almost 4 standard deviations above trend, the credit-to-GDP ratio almost 6 standard deviations

above trend, and bank assets-to-GDP a staggering 8 standard deviations above trend (the deviations of bank leverage from trend is smaller, or "only" just under 2 standard deviations above trend but that is probably due to an overvaluation of book-value equity as discussed in Section 2.6). The degree of (internal and external) macroeconomic imbalances are also evident from Table 7.c with output and demand well above trend, a very large trade deficit, and an overvalued currency. Hence, the severity of this crisis episode does not come as a surprise in light of these imbalances and the size of the external shock in the form of the global financial crisis and accompanying global recession.[29]

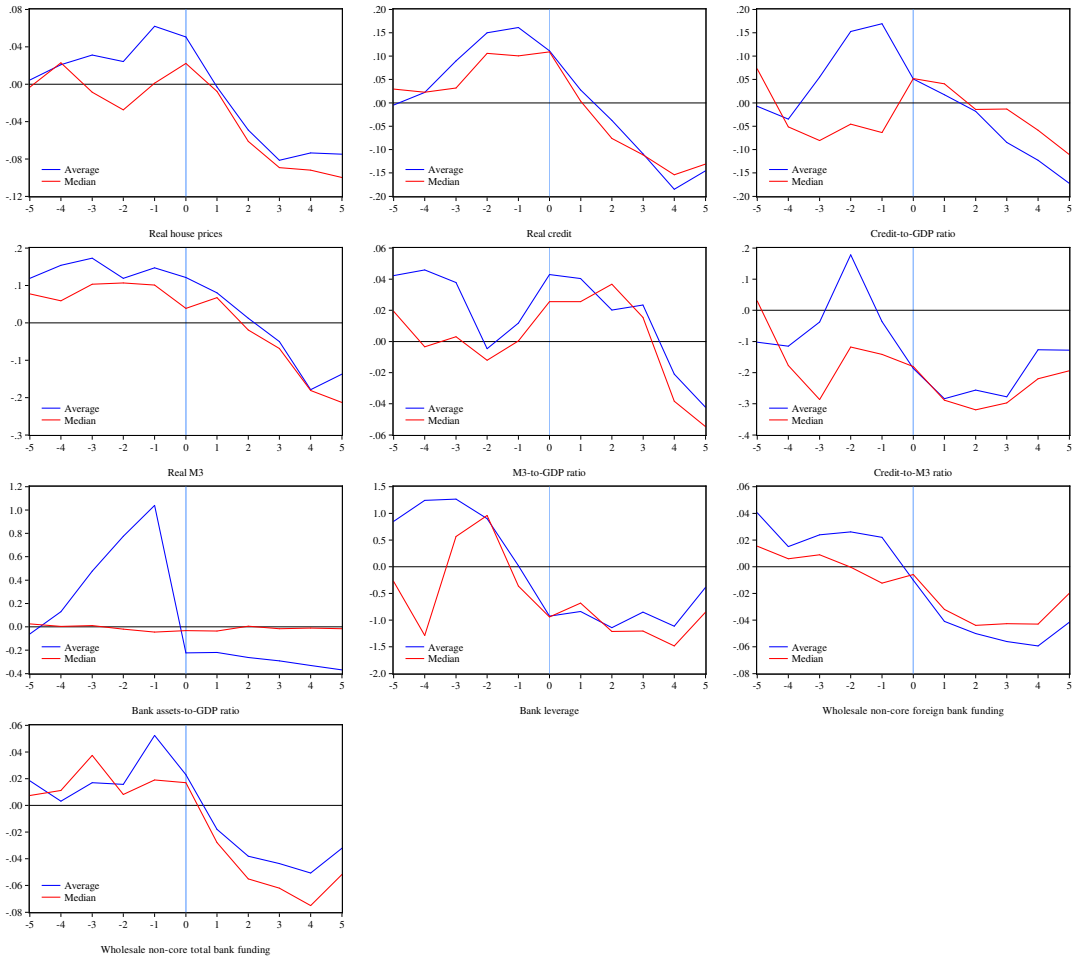
5 General properties of financial crises in Iceland

Although our identification of these six multiple crisis episodes involves some degree of judgement, it allows us to capture the clustering nature of these different types of financial crises while concentrating on the more serious ones. It also allows us to highlight some common features among these episodes. We see, for example, that a serious financial crisis occurs every 15½ years on average and although the incidence of these multiple crises is broadly the same in the two subsamples (see Table 5 above), the duration is greater in the first half of our sample period. We also note that all the episodes involve a demand disaster and in most cases this serves as a trigger for the ensuing financial crisis. Furthermore, all six cases involve a currency crisis that follows or coincides with the demand disaster. In all but two cases does a banking crisis emerge – usually towards the end of the crisis episode. We also note that three of the multiple crisis episodes involve a twin crisis with a currency crisis and a systemic banking collapse (two of which also involve a sudden stop crisis) and these lead to the largest output loss and take the longest time to recover from (this is less clear for demand due to the unusually large contraction in 1948-51). Interestingly, those episodes are concentrated in the two periods of financial globalisation where foreign funding pressures of the domestic banks coincided with similar problems among their main foreign creditors, while the two non-banking crisis episodes occur in periods where external funding of the domestic banking system was very limited.

Figure 11 summarises the typical behaviour of our financial variables in the run-up to and aftermath of the six multiple financial crises. On average we find that real house prices peak at 6% above trend a year before a crisis starts and then fall significantly below trend as the crisis unfolds. However, the average behaviour of real house prices is somewhat dominated by the latest crisis episode, as reflected in the median path. This also holds true for some of the other financial variables, such as the ratios of banking system assets, credit, and money to GDP and the credit-to-money ratio. For other financial variables, the average and median paths are more similar. Thus, we see imbalances consistently build up in real credit and money in the years leading up to a crisis, with rising bank leverage and

[29] An extensive literature on this crisis, its sources and how it spread world-wide has emerged in recent years, see Bordo & Landon-Lane (2012) and Reinhart & Rogoff (2009) to name but few. Many aspects of the Icelandic crisis are discussed earlier in this paper but also in papers such as Gudmundsson (2013), Rannsóknarnefnd Althingis (2010), and Ólafsson & Pétursson (2011).

Figure 11 Financial variables in the run-up to and aftermath of financial crises in Iceland



Deviations from long-term trend (estimated using the Hodrick-Prescott filter) for the period $[T-5$ to $T+5]$, where $T=0$ is the first year of the financial crisis. The figure shows the average and median values across the six financial crises in Table 6.

Source: Authors' calculations (data sources described in Appendix 3).

non-core funding. Real credit typically peaks shortly before the crisis, while real money and leverage peak 2-3 years prior to the crisis and non-core funding even earlier. The post-crisis pattern of the financial variables is even clearer: all (except bank assets perhaps) fall markedly below trend, thus magnifying the ensuing economic contraction. We will return to this issue in our comparison of economic consequences of financial crises and regular business cycle downturns in Section 5.2.

5.1 Early-warning signals

The analysis above suggests that no single financial indicator consistently warns of an ensuing financial crisis over all the crisis episodes. While there were clear warning signals across the whole spectrum of financial variables leading into the latest crisis, we find cases where each financial variable is relatively silent in the run-up to some of the earlier crises and, in two of the episodes (in the late 1960s and early 1990s) none of the financial

variables gave a clear warning signal heading into the crisis. A simple way to summarise the ability of our data to consistently give an early-warning signal of an upcoming financial crisis is the non-parametric signal extraction approach originally suggested by Kaminsky & Reinhart (1999), reported in Table 8. This approach is based on monitoring the evolution of a number of variables in the run-up to a financial crisis and interpreting a pattern of behaviour were a variable deviates sufficiently from its trend as a warning signal about an upcoming crisis within a specified period of time. A variable that frequently sends a correct signal about future crises, while seldom sending a false signal – either by signalling a crisis when no crisis follows or missing an upcoming crisis – is deemed as having good signalling properties.

To make this operational, we first define a signal indicator for each variable which is 1 when the variable deviates by more than 1.5 standard deviations from its long-term trend, defined by the Hodrick-Prescott trend previously discussed, and zero otherwise.[30] The use of a 1.5 standard deviation threshold is motivated by its common usage in defining credit booms (cf. Dell'Ariccia et al., 2012, and Mendoza & Terrones, 2008). A lower threshold would increase the frequency of crisis signals and thus increase the probability of an indicator signalling a crisis while increasing the risk of Type 2 errors (wrongfully signalling a crisis). A higher threshold would however increase the risk of Type 1 errors (failure to signal an actual crisis). Having defined the signal indicator for each variable, we judge a signal of 1 (0) to be correct if a crisis (no crisis) occurs any time within a three-year horizon (Drehmann et al., 2010, also use a three year horizon, while Kaminsky & Reinhart, 1999, use a two-year horizon in a data set of monthly frequency). Thus, signals that occur prior to the three-year window are not counted, nor are signals that occur once a crisis has started. Table 8 reports various measures of the signalling properties of our financial and macroeconomic variables.

First, the table reports the success of each variable in signalling crisis episodes, i.e. the relative success of signalling the six crises identified within the three year window. Second, the table shows the relative number of "good" signals, i.e. the fraction of crises predicted by correct signals – for a perfect signalling variable, this measure would be 1 (the variable would signal a crisis in all three years up to all the six crisis episodes). Third, the table shows the relative number of "false" signals, i.e. the fraction of time a crisis is signalled when no crisis occurs – for a perfect signal, this measure would be 0 (the variable would never signal a crisis that does not occur). The table also reports the noise-to-signal ratio, i.e. the ratio of the fractions of false to good signals. Although the best early-warning indicators are often chosen on the basis of minimising the noise-to-signal ratio, we also want variables that correctly signal an upcoming crisis, even though they would sometimes give a false signal: policymakers are likely to assign greater weight to the risk of missing a crises (Type 1 errors) than calling a crisis that does not occur (Type 2 errors), cf. Borio

[30] We use the year 1900 as our starting point as that is the first observation for house prices – the variable available over the shortest period in our sample.

Table 8 Early-warning signals for multiple financial crises

	Fraction of crises called	Fraction of good signals	Fraction of false signals	Noise-to-signal ratio	Difference between conditional and unconditional crises probabilities
Real house prices	0.167	0.167	0.031	0.188	0.342
Real credit	0.167	0.167	0.063	0.375	0.175
Credit-to-GDP ratio	0.167	0.167	0.000	0.000	0.842
Real M3	0.333	0.167	0.031	0.188	0.342
M3-to-GDP ratio	0.333	0.111	0.021	0.188	0.342
Credit-to-M3 ratio	0.167	0.111	0.052	0.469	0.128
Assets-to-GDP ratio	0.167	0.167	0.000	0.000	0.842
Leverage ratio	0.500	0.222	0.083	0.375	0.175
Foreign non-core liab.	0.167	0.167	0.063	0.375	0.175
Total non-core liab.	0.333	0.222	0.073	0.328	0.206
Real GDP	0.667	0.333	0.010	0.031	0.699
Real domestic demand	0.500	0.389	0.010	0.027	0.717
Trade deficit-to-GDP	0.500	0.333	0.000	0.000	0.842
Nominal exchange rate	0.167	0.111	0.083	0.750	0.042
Real exchange rate	0.333	0.278	0.052	0.188	0.342
Terms of trade	0.500	0.167	0.031	0.188	0.342
Inflation	0.000	0.000	0.073	–	-0.158
			Averages		
Financial variables	0.250	0.167	0.042	0.248	0.357
Macroeconomic variables	0.381	0.230	0.037	0.197	0.404
All variables	0.304	0.193	0.040	0.229	0.376

The table reports the signalling properties of each variable based on deviations from its Hodrick-Prescott trend that are larger than a threshold value of 1.5 standard deviations over a three-year window in the run-up to each of the six financial crises identified. The second column gives the fraction of crisis episodes correctly signalled by each variable. The third column reports the number of correct crisis signals as a fraction of years in which a crisis signal could have been issued (1 – Type 1 errors). The fourth column reports the number of false crisis signals as a fraction of years in which a no-crisis signal could have been issued (Type 2 errors). The fifth column reports the ratio between the fractions of good and false signals (the third column divided by the second column). The sixth column gives the difference between the conditional probability of a crisis (the fraction of signals issued that were followed by a crisis in the subsequent three years) and the unconditional probability of a crisis (i.e. the relative number of crisis years in our sample).

Source: Authors' calculations (data sources described in Appendix 3).

& Drehmann (2009).[31] Finally, the table compares the conditional probability of a crisis (i.e. the fraction of signals issued by the variable that were followed by a crisis in the subsequent three years) to the unconditional probability of a crisis (the relative number of years in crises identified in our sample). For a variable containing useful information, the conditional probability should be higher than the unconditional one while variables with poor signalling properties would record a low or even a negative value – indicating that they contain no useful information.

Not surprisingly, given the outcomes in Tables 7.a-c, we find that the financial variables have given relatively few good signals across the six crisis episodes and some of them have a relatively high noise ratio. At first sight, variables such as the bank assets-to-GDP ratio

[31] This is presumably why we value insights of people, such as one renowned economist who was once said to have foreseen ten of the last five financial crises.

may seem as a relatively good indicator, as it has a zero noise ratio, but at the same time it has a track record of only signalling one of the six crises. At a cost of a slightly higher noise ratio, the leverage ratio, total non-core bank funding and real money growth score higher on predicting future crises and might therefore prove more valuable as early-warning indicators despite some false signals.

While the financial variables seem somewhat underwhelming in their ability to consistently signal a crisis across the six episodes identified here, the macroeconomic variables, in particular output, domestic demand and the trade deficit, seem to do somewhat better: these three variables have a low noise ratio while being able to signal half to two-thirds of the crisis episodes and sending a correct signal 30-40% of the time. The real exchange rate and terms of trade also seem to contain some valuable information, while the nominal exchange rate and inflation do not seem to be very valuable early-warning indicators. It should be noted, that the trade deficit serves a dual role in our analysis as both an indicator of macroeconomic imbalances and financial fragility due to reliance on cross-border capital flows. Hence, its ability to warn of an ensuing crisis may reflect the fact that it captures the fragile reliance of booms being financed from abroad within such a small open economy.

Comparing the average scores across financial and macroeconomic variables suggests that while the frequency of false signals is roughly equal across both sets of variables, the main difference lies in the ability of the macroeconomic variables to correctly signal an upcoming crisis. This leads to a lower noise ratio for the macroeconomic variables and ties in well with the analysis above on their importance in triggering a crisis. The financial variables then play an important role in amplifying the crisis and the ensuing contraction (see the discussion below).[32] But as the latest episode so clearly shows, the financial variables can also serve as early-warning signals, especially when so many of them send an identical signal over such an extended period. It is also important to note that the latest episode is the only financial crisis in Iceland's history where both the real economy and the financial system are relatively advanced and modern. The latest episode might therefore be of more relevance than past episodes in constructing early-warning indicators to warn against possible future financial crises.[33]

[32]The importance of macroeconomic variables as early-warning indicators is also found in other studies, see for example Davis & Karim (2008) and the summary in Reinhart & Rogoff (2009). See, for example, Rose & Spiegel (2009) for a sceptical view on the ability of these early-warning methods in consistently predicting financial crises.

[33]The robustness analysis in Appendix 1 suggests that this overall finding of somewhat underwhelming success of giving early-warning signals of financial crises continues to hold when looking at the currency and banking crises separately. The ability to signal an upcoming crisis tends to deteriorate compared to what we find for the multiple financial crises, in particular the ability of the macroeconomic variables to predict an upcoming banking crisis. The robustness analysis in Appendix 2 also shows that the early-warning ability of the financial and macroeconomic variables continues to be somewhat underwhelming when the multiple financial crises that some might argue are real economic shocks rather than true financial crises are excluded from the analysis. The signalling performance tends to improve marginally when crises episodes that our variables fail to flag are left out, but the relative performance of the two set of variables tends to remain the same.

5.2 Real effects of multiple financial crises

The discussion above suggests that financial crises in Iceland have been costly in terms of lost economic activity. But as crises usually coincide with "regular" business cycle downturns (and are indeed often triggered by these as discussed above), we also want to establish whether they simply reflect output losses related to the business cycle downturns or whether financial crises actually make the associated recessions more severe. Failure to distinguish between output losses in financial crises to those in regular business cycle downturns would suggest that financial crises are not that special in terms of economic consequences. Larger output losses in financial crises would, however, suggest that they trigger some macro-financial linkages that amplify the hardship of the recession (e.g. leading to financial disintermediation, liquidity spirals, rising risk premia, reducing access to working capital and external finance in general). Indeed, this is what is commonly found in the literature (cf. Bordo et al., 2001, Bordo & Landon-Lane, 2012, and Claessens et al., 2012) and is clearly visible in our data too, cf. Table 9.

First, the table reports the average cumulative contraction in GDP during business cycle downturns and in per capita demand during demand disasters from Table 2: the average contraction is 7.6% in GDP and 18.4% in per capita demand, respectively, with the downturns lasting for roughly 2-3 years. It is clear, however, from the table that downturns that overlap with financial crises are worse both in terms of accumulated losses and duration: output and demand contract by roughly 1½ times more on average during financial crises than during downturns that do not coincide with financial crises and these downturns last for about a year longer on average.

The table shows that most of the eleven business cycle downturns and nine demand disasters previously identified coincide with financial crises: business cycle downturns that coincide with financial crisis account for roughly two-thirds of all business cycle downturns. This is somewhat higher than the 50% share reported by Claessens et al. (2012) for a sample of 61 countries over the period 1960-2011 and may reflect the fact that our criteria for identifying business cycles possibly leaves out some of smaller downturns that have less to do with financial crises. Not surprisingly, the share in demand disasters is even higher, or almost 80%, creating some potential problems in comparing average outcomes over the two types of episodes due to the small number of observations in the case where no financial crises take place. The lower panel of Table 9 therefore also compares outcomes for the average of all contractions in both series and the cumulative contraction and duration in years of subsequent contractions. Again, the data suggests that financial crises are particularly nasty: the average per-year contraction is 1½-2½ times larger while the cumulative contraction is roughly 3 times larger and the contractions last for up to a year longer on average. In Appendix 2 we show that these results continue to hold when the multiple financial crises that some might argue are real economic shocks rather than true financial crises are excluded from the analysis.

Table 9 Comparison of recessions with and without financial crises

Business cycle downturns and demand disasters

	GDP			Per capita domestic demand		
	All	With financial crises	Without financial crises	All	With financial crises	Without financial crises
Cumulative contration	0.076	0.087	0.059	0.184	0.202	0.121
Average duration	2.1	2.6	1.3	2.8	3.0	2.0
Frequency	11	7	4	9	7	2

Yearly contractions

	GDP			Per capita domestic demand		
	All	With financial crises	Without financial crises	All	With financial crises	Without financial crises
Average contraction	0.032	0.037	0.025	0.057	0.094	0.039
Cumulative contraction	0.052	0.084	0.027	0.092	0.162	0.060
Average duration	1.7	2.3	1.3	1.7	1.9	1.6
Frequency	30	16	14	50	16	34

The upper panel of the table reports outcomes for the identified business cycle downturns and demand disaster episodes (see Table 2). Reported are the average cumulative contraction in GDP and per capita demand during these episodes, their average duration (in years) and the number of episodes. The table also compares episodes that coincide with multiple financial crises (see Table 6) and those that do not. The lower panel of the table similarly reports the outcomes for all contractionary years in GDP and per capita demand. Reported are the average yearly contractions and the average cumulative contractions over years of subsequent contractions, the average duration of periods of subsequent contractions (in years) and the number of years of contraction for the whole sample and years that coincide with multiple financial crises and years that do not.

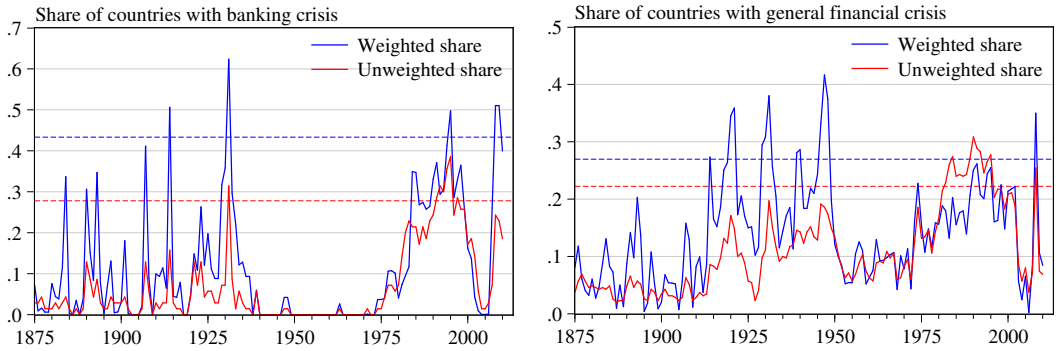
Source: Authors' calculations (data sources described in Appendix 3).

5.3 Are there important spillover effects of global financial crises to Iceland?

It is well known that financial crises often have an important international dimension of some kind, be that due to common sources of vulnerability in a financially integrated global economy, such as the credit and asset price bubbles experienced by many advanced economies in the run-up to the most recent crisis, or due to the transmission of crises from one country (often a global financial centre) to another as a result of cross-border contagion working through both financial and trade channels (see, for example, Kaminsky et al., 2003, and Borio et al., 2014). Both types of channels were at work in the recent global crisis but also played a part in many earlier episodes (cf. Bordo & Murshid, 2001). Not surprisingly, these global crises tend to be more severe and harder to recover from as the rest of the world is also suffering.

To measure the global incidence of financial crises, we use the aggregate indices for 70 countries constructed by Reinhart & Rogoff (2011) for banking crises and for general financial crises which also include currency, inflation, debt, and stock market crises (with equal weights for each indicator). Figure 12 shows the data for the period 1875-2010 (the

Figure 12 International banking and general financial crises



Share of 70 countries in a given crisis from Reinhart & Rogoff (2011). The weighted series use each country's average 1950-2010 share in total GDP using PPP-adjusted nominal GDP in Geary-Khamis US dollars (from Penn World Tables). The multiple global financial crisis measure is obtained as the sum of currency, inflation, sovereign external debt, banking, and stock market crises indicators in Reinhart & Rogoff (2011). Horizontal broken lines denote 3 standard deviations from the whole-sample average share.

Sources: Reinhart & Rogoff (2011), Penn World Tables, and authors' calculations.

last observation in Reinhart's and Rogoff's sample). To reflect the fact that a crisis in a large economy is more likely to resonate on a global scale than a crisis in a small economy, we also construct GDP-weighted indicators using PPP-adjusted GDP weights.[34]

The figure also shows horizontal lines representing 3 standard deviations from the sample average of the country shares to capture the most serious global crises (see also Bordo & Landon-Lane, 2012). Looking at the GDP-weighted series, this allows us to identify four severe global bank-specific crises and six others of a more general nature.[35] The first crisis occurs in 1914 with the outbreak of WWI which led to a global liquidity crisis, stock market closings and widespread banking collapses. Another global financial crisis follows soon at the start of the 1920s with widespread currency crises and a global recession when international monetary conditions were tightened to rein in the inflation that had built up following WWI, with banking crises occurring in many small European countries (including the Scandinavian countries). This crisis was, however, dwarfed by what followed by the end of the decade with the onset of the Great Depression triggered by the stock market collapse in the US. Soon other market collapses followed, with a record

[34] As weights, we use each country's average 1950-2010 share in PPP-adjusted nominal GDP in Geary-Khamis US dollars from the Penn World Tables using Reinhart & Rogoff's (2011) 70 country sample to proxy world output (the total share amounts to 82% of world output over the period 1950-2010). This is a slightly different weighting system from what Reinhart & Rogoff (2009, 2011) use but the difference should by minor. The index for overall global financial crises should therefore closely match the BCDI+-index constructed by Reinhart & Rogoff (2009).

[35] The banking panic of 1907 that began in the US following the San Francisco earthquake in 1906 and quickly spread out to a number of other industrial countries comes close to exceeding the threshold but just misses out. The Barings Bank crisis in the early 1890s and the Latin America debt crisis in the mid-1980s also come close. The higher values for the GDP-weighted series than the unweighted series over most of the sample period reflects the relative concentration of crisis episodes among the larger economies. The exception is the financial crisis in the late 1980s and early 1990s, which was more concentrated among smaller, emerging market economies. See Kindleberger & Aliber (2011), Eichengreen & Bordo (2003), Reinhart & Rogoff (2009) and Bordo & Landon-Lane (2012) for a more detailed description of these and other global financial crisis episodes discussed in this paper.

Table 10 International financial crises and the probability of a financial crisis in Iceland

	Different types of financial crises in Iceland							
	Curr-ency	Infl-ation	Bank-ing	Mult-iple	Curr-ency	Infl-ation	Bank-ing	Mult-iple
	Using the share of countries in banking crises				Using the share of countries in general financial crises			
Constant	*-1.35*	*-1.57*	*-2.49*	*-2.08*	*-1.66*	*-1.85*	*-2.24*	*-2.83*
	(0.19)	*(0.26)*	*(0.37)*	*(0.31)*	*(0.27)*	*(0.30)*	*(0.37)*	*(0.60)*
Lagged dependent variable	*1.44*	*2.61*	0.96	*2.44*	*1.41*	*2.55*	*1.66*	*2.39*
	(0.30)	*(0.36)*	(0.53)	*(0.42)*	*(0.31)*	*(0.35)*	*(0.53)*	*(0.42)*
Share of countries in crises	0.62	-1.38	*4.48*	*2.74*	2.54	1.16	3.07	*6.69*
	(0.94)	(1.17)	*(1.32)*	*(1.22)*	(1.54)	(1.64)	(2.04)	*(2.51)*
Marginal effects	–	–	0.056	0.049	–	–	–	0.069
Pseudo R^2	0.197	0.516	0.394	0.482	0.214	0.511	0.271	0.528
LR test (p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

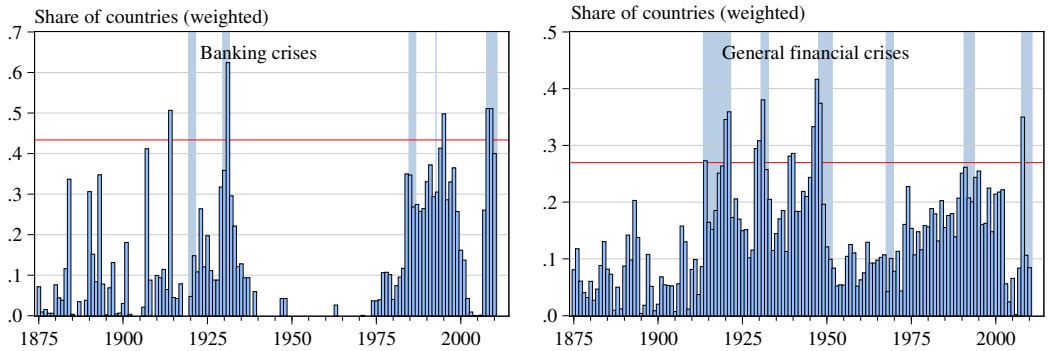
The table reports the outcomes of probit regressions of different financial crisis indicators for Iceland (see dates in Tables 2-4, 6) on its own one-year lag and the GDP-weighted share of countries in banking crises and general financial crises, respectively, from Reinhart & Rogoff (2011) (see note to Figure 12). The estimation period is 1875-2010 (135 observations). Numbers in parenthesis are robust (Hubert-White) standard errors and parameters significant at the 5% critical level are in italics. The LR test reports the p-value for the null hypothesis that the parameters (except the constant) in the probit regression equal zero. The table also reports the marginal effect of increasing the share of countries in crises by one standard deviation, evaluating the regressors at their sample mean. The table only reports the marginal effects where the global share is found to be statistically significant from zero.

Source: Authors' calculations (data sources described in Appendix 3).

number of bank failures and a sharp increase in sovereign defaults. There is another cluster of crises around the start and end of WWII, and extending into the late 1940s – mostly related to sovereign defaults and inflation crises (the latter period has also been identified as a global financial crisis episode by Kindleberger & Aliber, 2011, and Reinhart & Rogoff, 2009, 2011). The next episode relates to the banking crises of the early 1990s starting with the Scandinavian and Japanese crises at the beginning of the decade, followed by the Tequila crisis in 1994 and Asian crisis in 1997-98. The final episode is the most recent global crisis starting in the US but spreading rapidly throughout most of the world, in particular through widespread funding and asset market collapses and bank panics. In terms of its impact on real economic activity and asset markets and the ferocity with which it spread globally it stands out as the most serious global financial crisis since the Great Depression.

A quick comparison of the dates of these global episodes and the crisis dates for Iceland identified in Sections 3 and 4 suggests an important contagion effect from the global episodes to Iceland and this is further highlighted by the simple regression results shown in Table 10. The probit estimates suggest strong international contagion effects in the case of banking and multiple financial crises but less so for currency and inflation crises. Icelandic banking and general financial crises therefore seem to have a strong international component while domestic currency and inflation crises seem to be dominated by local factors (a common finding in the literature, cf. Joy et al., 2015). The significance of the

Figure 13 International spillover of global financial crises to Iceland
Banking crises (left) and multiple financial crises (right) in
Iceland shown as shaded areas



Share of 70 countries in a given crisis from Reinhart & Rogoff (2011) weighted by their average 1950-2010 share in total GDP of these countries using PPP-adjusted nominal GDP in Geary-Khamis US dollars (from Penn World Tables). The multiple global financial crisis measure is obtained as the sum of currency, inflation, sovereign external debt, banking, and stock market crises indicators in Reinhart & Rogoff (2011). Horizontal lines denote 3 standard deviations from the whole-sample average share.

Sources: Reinhart & Rogoff (2011), Penn World Tables, and authors' calculations.

lagged dependent variable, suggests furthermore that financial crisis in Iceland tend to be highly persistent.[36]

The estimation results suggest that a one standard deviation increase in the share of countries in a financial crisis (which represents roughly a doubling of the share of countries in a crisis) increases the probability of a financial crisis in Iceland by 5-7 percentage points.[37] Since the sample frequency of these crises in Iceland is relatively low (just above 7% for banking crisis and just under 16% for multiple financial crisis), this represents a significant increase in crisis probabilities within a range of plausible shocks to the global share of countries in a crisis. A more extreme shock of three standard deviations (our criteria for identifying the most serious global episodes) would correspondingly lead to a sharper rise in the crisis probability: the probability of a banking crisis in Iceland would rise by 17 percentage points, while the probability of a multiple financial crisis would rise by more than 20 percentage points, thus leading to a two- to threefold increase in the probability of a financial crisis in Iceland.[38]

Finally, Figure 13 compares the dates of banking and multiple financial crises in Iceland discussed previously to their global counterparts, again confirming visually how strongly linked most of the Icelandic crises are to the above global events. In fact, it can be argued that the only true Iceland-specific crisis is the 1968-69 episode, which does not seem to

[36]Thus, for any given year the probability of a crisis increases by about 50-75% if there is a crisis in the preceding year compared to if there is no crisis in the preceding year, other things kept constant. This persistence of financial crises is commonly found in the literature, cf. Reinhart & Rogoff (2009).

[37]A one standard deviation increase in the share of countries in a banking crisis represents an increase from the average share of 11.3% to 25.7%. A similar rise in the share of countries in a general financial crisis represents an increase from the average share of 14.1% to 23.1%.

[38]The robustness analysis in Appendix 2 shows that these results continue to hold when the multiple financial crises that some might argue are real economic shocks rather than true financial crises are excluded from the analysis. Appendix 2 also shows that our findings that global factors play less of a role for currency and inflation crises are found to be robust to variation in the currency and inflation crisis dates.

have an international counterpart. The others can, to a different degree, all be linked to some international crisis episode: the impact of WWI; the financial crisis of 1920-21 and the Scandinavian banking crisis of the same period; the Great Depression; the global trade collapse and the Korean war by the end of the 1940s; the numerous financial crises of the early 1990s; and the latest global financial tsunami.[39]

6 Conclusions

In this paper we analyse financial crises in Iceland over a period spanning almost one and a half century. For this purpose, we construct a dataset that includes measures of overall economic activity (output and domestic demand) and macroeconomic variables capturing the small, open, commodity-based nature of the Icelandic economy (trade balance, nominal and real exchange rate, and terms of trade) for the period 1875-2013. We also include inflation to take account of the chronic inflation crises of the Icelandic economy. From our data on output and domestic demand we identify dates of regular business cycle downturns and the more punishing episodes of large collapses in per capita domestic demand (identified in the same way as Barro & Ursúa, 2008, define consumption disasters) which we use to analyse the interaction of economic downturns and financial busts.

Our dataset includes several financial variables as well. The key variables in any analysis of financial booms and busts: money, credit, and house prices, are included but also variables reflecting the banking system balance sheet to uncover additional sources of financial imbalances. On the asset side, we include banking system total assets relative to GDP as a general measure of financial vulnerabilities (reflecting both systemic risk and market liquidity). On the liability side, we include the banking system leverage ratio to capture the extent to which bank assets are being financed with debt, and the share of banking system non-core funding (both in foreign currency and in total) in overall funding to capture the stability of the funding position of the banking system. Our dataset therefore includes macroeconomic variables that reflect the structure of the economy and some financial variables that are rarely found in the literature on financial crises due to lack of data availability over sufficiently long periods to be useful in analysing financial boom-bust cycles.

We identify three types of financial crises. First, we identify eleven currency crises, ranging from some short, but nasty, episodes in the early 1920s, in 1950, 1960, and 2008, to the chronic crisis lasting from the mid-1970s to the mid-1980s. Two of these episodes (the one in the early 1920s and the latest episode; with the one in the early 1930s coming close) involve a sudden stop of capital inflows that eventually leads to the introduction of capital controls. We also identify five episodes of the closely related inflation crises, all of which coincide with a currency crisis (either lead to or, more commonly, follow). Finally,

[39]Even the relatively small banking crisis of the mid-1980s has an international angle, with the Latin American debt crisis at the beginning of the decade followed by widespread banking problems, although it may not have reached the global proportions defined by the 3 standard deviation threshold used here.

we identify five banking crises – of which three are adjudged to be systemic (in the early 1920s, early 1930s and in 2008), while two are non-systemic and therefore leave smaller footprints on the real economy (in the mid-1980s and in 1993).

Recognising that different types of financial crises tend to come in clusters, we also construct a single "multiple financial crisis indicator" using a non-parametric common cycle algorithm. This allows us to identify six major financial crises occurring every fifteen years with each lasting almost four years on average. The first episode coincides with the outbreak of World War I and lasts into the early 1920s. The second crisis starts in the early 1930s, coinciding with the Great Depression. While the third crisis has a clear link with the global financial crisis in the late 1940s following the collapse of global trade and the Korean War, the fourth crisis in the late 1960s has almost exclusively Iceland-specific sources related to collapsing fish catch. The fifth crisis episode occurs in the early 1990s, coinciding with numerous financial crises abroad, and was related to falling economic activity following attempts to rein in the chronic inflation of the 1970s and the 1980s. The final episode starts in 2008 and coincides with a serious global financial crisis. It turns out to be the largest financial crisis in the country's history with over 90% of the financial system collapsing. All but one of these six episodes therefore coincide with a serious global financial crisis and our empirical results, indeed, suggest that the most serious global episodes coincide with a two- to threefold increase in the probability of a financial crisis in Iceland.

We find that these six crisis episodes have many things in common. All, for example, involve a serious demand disaster and in most cases this serves as a trigger for the ensuing financial crisis. In all six cases does the crisis also involve a currency crisis that follows or coincides with the demand disaster. In all but two cases does a banking crisis emerge – usually towards the end of the crisis. We also find that these crises tend to have serious economic consequences: economic contractions coinciding with these episodes tend to be about twice as deep as regular business cycle downturns and last almost twice as long.

But at the same time we also find that each episode is unique in some way. Financial imbalances played an important role in the first three financial crises, with broad money, credit and bank leverage (and to a lesser extent, house prices) rising markedly above trend in the run up to these episodes. No clear signs of financial imbalances in the build-up to the crises in the late 1960s and early 1990s can be detected, however, suggesting that these episodes had pure real economy sources. Finally, we see a build-up of financial imbalances leading into the latest crisis episode that are truly unprecedented: most of the financial variables rise above their trend level by an eye-popping 4-8 standard deviations, while we also detect a build-up of significant internal and external macroeconomic imbalances leading into the crisis. Due to the different importance of financial imbalances in these six crises, we are unable to find robust financial early-warning signals across all six episodes. However, we find that macroeconomic variables, such as output, domestic demand, the trade balance and, to a lesser extent, the real exchange rate, give a somewhat more robust warning signal.

Our analysis of financial crises naturally raises the question of whether our financial variables tend to move together in long "financial cycles", and if so, how these common cycles interact with regular business cycles and, more importantly, whether the peaks and troughs of these financial cycles tend to coincide with financial turbulences. This is the topic of the second part of our study, which also discusses the policy implications of our findings.

Appendix 1 Early-warning signals for currency and banking crises?

The results in Table 8 in the main text suggest that no single financial variable succeeds in providing an early-warning signal on a consistent basis for the six multiple financial crises we identify. However, our results suggest that some of the macroeconomic variables, such as output, domestic demand, the trade balance, and, to a lesser extent, the real exchange rate, do a somewhat better job. Here we redo our analysis separately for the currency and banking crises we identify in Section 3. Overall, we see no improvement in the signalling properties of our set of financial and macroeconomic variables compared to those reported in the main text. The noise ratio rises on average, especially for the macroeconomic variables in the case of banking crises. The somewhat underwhelming early-warning properties of our variables found in the main text for the six multiple financial crises therefore continue to hold for the currency and banking crises we identify.

Table A.1.1 reports the average signalling properties of the financial and macroeconomic variables for the eleven currency crises identified in Table 3. Compared to the results in the main text, we find that the signalling properties of individual financial variables deteriorate in most cases through a combination of a declining fraction of good signals and a rising fraction of bad signals. The same applies for the macroeconomic variables, except for the nominal exchange rate where the noise ratio declines. The overall signalling properties of both sets of variables tends to deteriorate but the relative success of the financial and macroeconomic variables remains unchanged.

Table A.1.2 repeats the exercise for the five banking crises in Table 4. For the individual financial variables we tend to see a slight improvement, mainly through a rising fraction of good signals, although the average noise ratio for the financial variables rises marginally compared to what we find in Table 8. The signalling power of most of the macroeconomic variables deteriorates significantly, however, mainly through a declining fraction of good signals. This is particularly striking for GDP, which loses most of its early-warning power, but can also be seen in domestic demand and the terms of trade. Although the signalling power of the trade balance deteriorates as well, it still retains some of its early-warning information. But the overall signalling properties of the macroeconomic variables deteriorate markedly and become poorer compared to the financial variables.

Table A.1.1 Early-warning signals for currency crises

	Fraction of crises called	Fraction of good signals	Fraction of false signals	Noise-to-signal ratio	Difference between conditional and unconditional crises probabilities
Real house prices	0.091	0.091	0.025	0.272	0.311
Real credit	0.091	0.091	0.074	0.815	0.044
Credit-to-GDP ratio	0.091	0.091	0.000	0.000	0.711
Real M3	0.091	0.030	0.062	2.037	-0.123
M3-to-GDP ratio	0.182	0.091	0.037	0.407	0.211
Credit-to-M3 ratio	0.091	0.061	0.037	0.611	0.111
Assets-to-GDP ratio	0.091	0.091	0.000	0.000	0.711
Leverage ratio	0.091	0.061	0.086	1.426	-0.067
Foreign non-core liab.	0.182	0.121	0.049	0.407	0.211
Total non-core liab.	0.273	0.182	0.062	0.340	0.256
Real GDP	0.273	0.121	0.049	0.407	0.211
Real domestic demand	0.273	0.152	0.025	0.163	0.425
Trade deficit-to-GDP	0.364	0.182	0.012	0.068	0.568
Nominal exchange rate	0.182	0.121	0.000	0.000	0.711
Real exchange rate	0.364	0.242	0.049	0.204	0.377
Terms of trade	0.182	0.061	0.086	1.426	-0.067
Inflation	0.091	0.091	0.062	0.679	0.086
			Averages		
Financial variables	0.127	0.091	0.043	0.631	0.237
Macroeconomic variables	0.247	0.139	0.041	0.421	0.330
All variables	0.176	0.111	0.042	0.545	0.275

The table reports the signalling properties of each variable based on deviations from its Hodrick-Prescott trend that are larger than a threshold value of 1.5 standard deviations over a three-year window in the run-up to each of the eleven currency crises identified in Table 3. The second column gives the fraction of crisis episodes correctly signalled by each variable. The third column reports the number of correct crisis signals as a fraction of years in which a crisis signal could have been issued (1 – Type 1 errors). The fourth column reports the number of false crisis signals as a fraction of years in which a no-crisis signal could have been issued (Type 2 errors). The fifth column reports the ratio between the fractions of good and false signals (the third column divided by the second column). The sixth column gives the difference between the conditional probability of a crisis (the fraction of signals issued that were followed by a crisis in the subsequent three years) and the unconditional probability of a crisis (i.e. the relative number of crisis years in our sample).

Source: Authors' calculations (data sources described in Appendix 3).

Table A.1.2 Early-warning signals for banking crises

	Fraction of crises called	Fraction of good signals	Fraction of false signals	Noise-to-signal ratio	Difference between conditional and unconditional crises probabilities
Real house prices	0.200	0.200	0.030	0.152	0.368
Real credit	0.200	0.200	0.061	0.303	0.202
Credit-to-GDP ratio	0.200	0.200	0.000	0.000	0.868
Real M3	0.200	0.067	0.051	0.758	0.035
M3-to-GDP ratio	0.400	0.200	0.030	0.152	0.368
Credit-to-M3 ratio	0.200	0.133	0.051	0.379	0.154
Assets-to-GDP ratio	0.200	0.200	0.000	0.000	0.868
Leverage ratio	0.400	0.267	0.081	0.303	0.202
Foreign non-core liab.	0.200	0.200	0.061	0.303	0.202
Total non-core liab.	0.200	0.200	0.081	0.404	0.141
Real GDP	0.200	0.067	0.061	0.909	0.011
Real domestic demand	0.200	0.200	0.040	0.202	0.297
Trade deficit-to-GDP	0.400	0.267	0.020	0.076	0.535
Nominal exchange rate	0.200	0.133	0.081	0.606	0.068
Real exchange rate	0.400	0.333	0.081	0.242	0.253
Terms of trade	0.200	0.067	0.081	1.212	-0.020
Inflation	0.400	0.200	0.091	0.455	0.118
			Averages		
Financial variables	0.240	0.187	0.044	0.275	0.341
Macroeconomic variables	0.286	0.181	0.065	0.529	0.180
All variables	0.259	0.184	0.053	0.380	0.275

The table reports the signalling properties of each variable based on deviations from its Hodrick-Prescott trend that are larger than a threshold value of 1.5 standard deviations over a three-year window in the run-up to each of the five banking crises identified in Table 4. The second column gives the fraction of crisis episodes correctly signalled by each variable. The third column reports the number of correct crisis signals as a fraction of years in which a crisis signal could have been issued (1 – Type 1 errors). The fourth column reports the number of false crisis signals as a fraction of years in which a no-crisis signal could have been issued (Type 2 errors). The fifth column reports the ratio between the fractions of good and false signals (the third column divided by the second column). The sixth column gives the difference between the conditional probability of a crisis (the fraction of signals issued that were followed by a crisis in the subsequent three years) and the unconditional probability of a crisis (i.e. the relative number of crisis years in our sample).

Source: Authors' calculations (data sources described in Appendix 3).

Appendix 2 To be or not to be a financial crisis: how robust are the results to different crisis definitions?

In an economy as volatile as the Icelandic one, where large currency and inflation fluctuations have historically been common, it can be debated whether all the episodes we identify as currency and inflation crises constitute true crisis episodes or whether they are simply a part of the economy's normal, albeit volatile, business cycle. By the same token, it can also be debated whether all the multiple financial crises we identify in Section 4 are truly financial crisis episodes or whether some of them simply reflect the large real economy adjustments to external shocks this very small and open resource-based economy has commonly faced throughout the period.

In this Appendix, we check whether our key results are robust to different definitions of our financial crisis episodes. We start by looking at different threshold levels for identifying currency and inflation crises. In the second half of the Appendix, we test whether our analysis of the multiple financial crises are altered when excluding what may be viewed as the most contentious episodes from our crisis sample. We find that all of our key results are robust to these variations in crisis definitions.

A.2.1 Raising the threshold definition for currency and inflation crises

We start by documenting how our identification of currency and inflation crises changes when the threshold criteria is raised from the 15% per annum depreciation used by Reinhart & Rogoff (2009, 2011). The first panel of Table A.2.1 shows the currency crises identified when the threshold is doubled to a 30% per annum depreciation. In this case, the number of currency crisis declines to eight episodes from the original eleven episodes. Four episodes drop out of the original list: the episodes in 1932, 1939, 1993, and 2001, while the long crisis episode originally identified as starting in 1974 and ending in 1985 is now split into two episodes: one in 1975 and the other from 1978-85. The average duration of the currency crises remains almost identical to that using the original threshold level, however. The second panel of the table shows what happens when we raise the threshold even further. Here, we only include episodes where the currency depreciates by more than 50% per annum, but also retaining episodes that have depreciations over two consecutive years that exceed 50%. In this case the number of currency crises falls to seven, with the episode in the late 1980s dropping out and the long crisis episode starting in 1978 now ending in 1983 rather than 1985 as when the 30% threshold level is used. Other than that, the results are identical to those using the 30% threshold level.

The third panel of Table A.2.1 shows what happens when we similarly double the threshold level for inflation crises to a 40% per annum level of inflation. In this case, the number of episodes falls from five to three, with the two episodes in the early 1940s and 1950s and the episode in the late 1960s dropping out, while the chronic inflation crisis originally identified from 1973 to 1989 is now split into two shorter episodes from 1974-75

Table A.2.1 Currency and inflation crisis dates: robustness analysis

Currency crises threshold raised to 30%			Currency crises threshold raised to 50%			Inflation crises threshold raised to 40%		
Date	Dur-ation	Average depr. per year	Date	Dur-ation	Average depr. per year	Date	Dur-ation	Average inflation per year
1919-20	2	0.263	1919-20	2	0.263	1917	1	0.536
1950	1	0.508	1950	1	0.508			
1960	1	0.535	1960	1	0.535			
1968-69	2	0.248	1968-69	2	0.248			
1975	1	0.348	1975	1	0.348	1974-75	2	0.462
1978-85	8	0.119	1978-83	6	0.153	1978-83	6	0.561
1989	1	0.246						
2008-9	2	0.241	2008-9	2	0.241			
Average	2.3	0.313	Average	2.1	0.328	Average	3.0	0.520

The table reports the dates of currency and inflation crises identified by different thresholds to those used in the main text. The first panel shows the dates for currency crises when the threshold for currency depreciations is doubled to 30% per annum. The second panel shows the dates for currency crises when the threshold for currency deprecations is raised to 50% per annum while also including dates that do not fulfil that criteria but have deprecations over two consecutive years that exceed 50%. The third panel shows the dates for inflation crises when the threshold for annual inflation is doubled to 40% per annum.

Source: Authors' calculations (data sources described in Appendix 3).

and 1978-83. Finally, the first episode, originally identified as starting in 1916 and lasting into 1918, is now concentrated to a single year in 1917.

A.2.2 Excluding some of the multiple financial crises

In the second part of this Appendix, we test whether the results in Section 5 are robust to variations in the identification of the six multiple financial crises. Specifically, we test our results on the early-warning signal properties of our macroeconomic and financial variables in Section 5.1, our comparison of downturns coinciding with these financial crisis episodes and those downturns that do not in Section 5.2, and the extent of global spillovers in Section 5.3, to sequentially leaving out the financial crises in 1948-51, 1968-69, and 1991-93. These three episodes are chosen as they do not coincide with a banking crisis (the 1948-51 and 1968-69 episodes) and could therefore rather be viewed as real economy crises, albeit serious ones, rather than outright financial crises. We also test whether excluding the 1991-93 crisis changes our results as that crisis does not include a systemic banking crisis (although it does include a non-systemic one).

We start by analysing the robustness of the early-warning signals properties shown in Table 8 in the main text. Table A.2.2 shows the average signalling properties of the financial and macroeconomic variables for each case. Compared to the baseline case in Table 8, we find that the signalling performance tends to improve marginally when the 1968-69 and 1991-93 episodes are left out, as all our variables failed to flag these episodes beforehand. The relative comparison of the signalling properties of the macroeconomic and financial variables remains intact, however, with the macroeconomic variables continuing

Table A.2.2 Early-warning signals: robustness analysis

	Excluding the 1948-51 crisis			Excluding the 1968-69 crisis		
	Financial variables	Macro variables	All variables	Financial variables	Macro variables	All variables
Fract. of crises called	0.240	0.314	0.271	0.300	0.457	0.365
Fract. of good signals	0.173	0.162	0.169	0.200	0.276	0.231
Fract. of false signals	0.044	0.058	0.050	0.040	0.036	0.039
Noise-to-signal ratio	0.307	0.332	0.316	0.201	0.159	0.185
	Excluding the 1991-93 crisis			Excluding the 1948-51 and 1968-69 crises		
	Financial variables	Macro variables	All variables	Financial variables	Macro variables	All variables
Fract. of crises called	0.300	0.457	0.365	0.300	0.393	0.338
Fract. of good signals	0.200	0.276	0.231	0.217	0.202	0.211
Fract. of false signals	0.040	0.036	0.039	0.043	0.056	0.048
Noise-to-signal ratio	0.201	0.159	0.185	0.238	0.258	0.246

The table reports the average signalling properties of the financial and macroeconomic variables when the financial crises in 1948-51, 1968-69 and 1991-93 are not defined as a multiple financial crises. See Tables 6 and 8 for details.
Source: Authors' calculations (data sources described in Appendix 3).

to outperform the financial variables on average, although neither group of variables does a sterling job over all the crisis episodes. The only case where the relative performance of these two groups changes somewhat is when the 1948-51 crisis is left out. In this case, the financial variables do a slightly better job on average, although this is mainly due to a larger deterioration in the signalling properties of the macroeconomic variables rather than a marked improvement in the signalling properties of the financial variables.

Next, we move on to testing whether economic downturns coinciding with financial crises tend to be deeper and longer than those that do not coincide with financial crises. Table A.2.3 compares all contractionary years in GDP and per capita domestic demand (to be compared to the lower panel of Table 9), again after leaving out the 1948-51, 1968-69, and 1991-93 crises, and the 1948-51 and 1968-69 episodes combined. The results turn out to be very similar to those reported in the main text: contractions tend to be close to twice as deep when coinciding with financial crises and last almost twice as long.

Finally, the upper panel of Table A.2.4 reports the results from the probit regressions in Table 10 in the main text when leaving out the 1948-51, 1968-69, and 1991-93 crises, and the 1948-51 and 1968-69 episodes combined. As the table shows, the global country share remains statistically significant for each variant of the crisis definitions and the marginal effects are very similar to those reported in Table 10. The lower panel of the table shows what happens when we use the currency and inflation crisis dates in Table A.2.1 as the dependent variable instead of those used in the main text. Again, we find that the global country share has no statistically significant effects on the probability of a currency and inflation crises in Iceland.

Table A.2.3 Economic contractions with and without financial crises: robustness analysis

	Excluding the 1948-51 crisis				Excluding the 1968-69 crisis			
	GDP		Per capita domestic demand		GDP		Per capita domestic demand	
	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis
Aver. contr.	0.041	0.025	0.089	0.046	0.036	0.027	0.096	0.042
Cum. contr.	0.087	0.031	0.159	0.069	0.088	0.031	0.162	0.064
Aver. dur.	2.3	1.3	2.0	1.6	2.4	1.4	1.9	1.6
	Excluding the 1991-93 crisis				Excluding the 1948-51 and 1968-69 crises			
	GDP		Per capita domestic demand		GDP		Per capita domestic demand	
	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis	With fin. crisis	Without fin. crisis
Aver. contr.	0.040	0.024	0.101	0.040	0.040	0.026	0.090	0.047
Cum. contr.	0.091	0.027	0.170	0.061	0.094	0.036	0.159	0.073
Aver. dur.	2.4	1.4	1.9	1.6	2.4	1.4	2.0	1.6

The table compares contractions in GDP and per capita domestic demand for years that coincide with multiple financial crises and years that do not when the financial crises in 1948-51, 1968-69 and 1991-93 are not defined as a multiple financial crises. Reported are the average and cumulative contractions over years of subsequent contractions (in years), and the average duration of periods of subsequent contractions (in years). See Table 9 for further details.

Source: Authors' calculations (data sources described in Appendix 3).

Table A.2.4 International linkages of financial crises: robustness analysis

Multiple financial crises excluded

	1948-51 crisis	1968-69 crisis	1991-93 crisis	1948-51 and 1968-69 crises
Coeff. est.	5.590	9.761	6.791	8.510
P-value	0.022	0.000	0.020	0.000
Marg. eff.	0.053	0.072	0.060	0.054

Currency and inflation crises threshold raised

	Currency crises threshold raised to 30%		Currency crises threshold raised to 50%		Inflation crises threshold raised to 40%	
	Global banking crisis share	Global financial crisis share	Global banking crisis share	Global financial crisis share	Global banking crisis share	Global financial crisis share
Coeff. est.	0.293	1.624	-0.379	1.359	-1.532	1.231
P-value	0.786	0.335	0.771	0.450	0.216	0.433

The table reports the outcomes of probit regressions of different financial crisis indicators for Iceland on the GDP-weighted share of countries in banking crises and general financial crises, respectively, from Reinhart & Rogoff (2011). The regressions also include a one-year lag of the dependent variable (not reported). The estimation period is 1875-2010 (135 observations). The *p*-values reported are based on robust (Hubert-White) standard errors. The upper panel of the table reports the outcomes of probit regressions in Table 10 when the financial crises in 1948-51, 1968-69 and 1991-93 are not defined as a multiple financial crises. The marginal effects reported are based on a one standard deviation increase in the country share, evaluating the regressors at their sample mean. The lower panel of the table reports the outcomes of probit regressions in Table 10 when the dates for currency and inflation crises in Table A.2.1 are used instead of those in Table 3. See Tables 3, 6 and 10 for further details.

Source: Authors' calculations (data sources described in Appendix 3).

Appendix 3 Data sources

Financial variables

Banking system assets (1875-2013)
For savings banks in the period from 1875-1990 we use data on total assets (*Hagskinna: Icelandic Historical Statistics*, Table 13.7). This is only available at five-year intervals and we therefore use linear interpolation to obtain data for the intervening years. For commercial banks we use data on total assets for the period 1964-1990 (*Hagskinna: Icelandic Historical Statistics*, Table 13.6b-c) and for the period 1875-1929 we use data on total assets of Landsbanki (founded in 1885) and Íslandsbanki (founded in 1904) (*Hagskinna: Icelandic Historical Statistics*, Tables 13.2 and 13.3). For the period 1930-1963, we use data on "total" assets of commercial banks, which is only available at five-year intervals until 1950 (annual data from 1953) and we therefore use linear interpolation to obtain data for the intervening years (*Hagskinna: Icelandic Historical Statistics*, Table 13.6a). However, we adjust "total" commercial banks assets in this period from 1930-1963 as data on foreign assets is only provided in net terms. This is done by using data on foreign assets of Landsbanki from Björnsson (1961, tables on p. 126-127) and data on base metal reserves, claims on foreign banks, and assets in foreign currency for Íslandsbanki and its successor, Útvegsbanki, from Björnsson (1981, tables on p. 106, 119, and 129). Data from Björnsson (1961) is only available at three-year intervals until 1954 and two-year intervals until 1960 and we therefore use linear interpolation to obtain data for the intervening years. Data from Björnsson (1981) is available annually for 1938-1946 and then for the years 1930, 1950, 1954, and 1957 and we therefore use linear interpolation to obtain data for the intervening years. Furthermore, we assume that total foreign assets of the banking system in 1957-1960 developed in line with the developments of the foreign assets of Landsbanki (excluding its Central Bank division). For the period 1997-2012, we use data on total assets of commercial banks and savings banks from the Financial Supervisory Authorities. For the remaining years (1991-1996 and 2013), total banking system assets are assumed to develop in line with total assets of deposit money banks (data from Central Bank of Iceland *Annual Reports*).

Banking system equity (1875-2013)
For savings banks in the period from 1875-1990 we use data on reserve funds, retained earnings, and other equity capital (*Hagskinna: Icelandic Historical Statistics*, Table 13.7). This is only available at five-year intervals and we therefore use linear interpolation to obtain data for the intervening years. For commercial banks in the period 1886-1929 we use data on initial capital reserves, retained earnings, and reserve funds of Landsbanki and data on share capital and reserve fund of Íslandsbanki (*Hagskinna: Icelandic Historical Statistics*, Tables 13.2 and 13.3). For the period 1930-1990 we use data on commercial bank share capital and capital contribution, reserve funds and retained earnings, and other equity capital (*Hagskinna: Icelandic Historical Statistics*, Tables 13.6a-c). This data is only avail-

able at five-year intervals until 1950 (annual data from 1953) and we therefore use linear interpolation to obtain data for the intervening years. We correct values for 1963 and 1966-1967 where data on other equity has mistakenly been used as data on total equity in Table 13.6b. For 1963 we use data from Table XVI on p. 186 in *Fjármálatíðindi* September-December 1965 and for 1966-67 we use data from Table 1 in Gudnason (1972). For the period 1997-2012, we use data on total equity from the Financial Supervisory Authorities' website for commercial banks and savings banks. For the remaining years (1991-1996 and 2013), banking system equity is assumed to develop in line with deposit money bank total equity (data from Central Bank of Iceland *Annual Reports*).

Broad money (M3) (1886-2013)
Data for the period 1991-2013 is obtained from the Central Bank of Iceland (data for 1991-1993 from the Bank's *Annual Report* in 2007). For the period 1886-1990 we use data from Statistics Iceland (*Hagskinna: Icelandic Historical Statistics*, Table 13.1).

Credit (1886-2013)
For the period 1970-2007 we use total lending and bond holdings of the credit system, obtained from the Central Bank of Iceland. This series is extended to 2013 using total lending and bond holdings of financial firms from the new financial accounts from the Central Bank of Iceland. For the period 1886-1969 we use data on total credit from Statistics Iceland for deposit institutions (*Hagskinna: Icelandic Historical Statistics*, Table 13.9) and investment credit funds (*Hagskinna: Icelandic Historical Statistics*, Table 13.12). Data on investment credit funds is only available at five-year intervals until 1950 and we therefore use linear interpolation to obtain data for the intervening years (the same applies for missing data in 1951, 1963, and 1971-1972).

Non-core banking system liabilities (1886-2013)

Domestic non-core liabilities
For the period 1991-2013 we use data on domestic bond issuance of deposit money banks obtained from the Central Bank of Iceland. For savings banks in the period from 1875-1990 we use data on credit from other financial institutions (excluding the Central Bank) and sundry liabilities (*Hagskinna: Icelandic Historical Statistics*, Table 13.7), which is only available at five-year intervals. We therefore use linear interpolation to obtain data for the intervening years. For commercial banks in the period 1930-1973 we use data on credit from other domestic financial institutions (excluding the Central Bank) and sundry liabilities (*Hagskinna: Icelandic Historical Statistics*, Tables 13.6a-b and 13.7), for the period 1974-1990 we add data on domestic bond issuance. For commercial banks in the period 1886-1929 we use data on bank bonds, sundry liabilities, credit from the mortgage department (which was a legally separate entity), and funds awaiting disbursements for Landsbanki, and data on bank bonds, sundry liabilities, funds awaiting disbursements and

rediscounted bills of exchange for Íslandsbanki (*Hagskinna: Icelandic Historical Statistics*, Tables 13.2 and 13.3).

Foreign non-core liabilities

For the period 1964-1990 we use data on foreign liabilities of commercial banks (*Hagskinna: Icelandic Historical Statistics*, Tables 13.6b-c). For the period 1991-2013 we use data on total foreign liabilities of deposit money banks obtained from the Central Bank of Iceland. For the period 1886-1929 we use data on credit from foreign banks, the so-called "English long-term loans", and bank bills of exchange for Landsbanki and data on credit from foreign banks for Íslandsbanki (*Hagskinna: Icelandic Historical Statistics*, Tables 13.2 and 13.3). *Hagskinna: Icelandic Historical Statistics* does not provide data on commercial banks' foreign liabilities for the period 1930-1963, only data on net foreign assets. For the period 1930-1960 we therefore use data on foreign liabilities of Landsbanki from Björnsson (1961, tables on p. 126-127) and data on credit from foreign banks and the English loans from 1921 and 1935 for Íslandsbanki and its successor Útvegsbanki from Björnsson (1981, tables on p. 106, 119, and 129). Other commercial banks did not have foreign liabilities during this period. Data from Björnsson (1961) is only available at three-year intervals until 1954 and two-year intervals until 1960 and we therefore use linear interpolation to obtain data for the intervening years. Data from Björnsson (1981) is only available annually for 1938-1946 and then for the years 1930, 1950, 1954, and 1957 and we therefore use linear interpolation to obtain data for the intervening years. Furthermore, we assume that total foreign liabilities of banking system in 1957-1960 developed in line with the development of the foreign liabilities of Landsbanki (excluding its Central Bank division). For Íslandsbanki and its successor Útvegsbanki in the period 1930-1960, we exclude foreign equity (also the part of foreign debt, mainly from the Danish Post Office, which was swapped into equity of Útvegsbanki after the collapse of Íslandsbanki) and categorise bank bonds issued by Íslandsbanki as domestic debt as was done in the bank's accounts although the Supreme Court ruled after the bank's collapse that they should be defined as foreign debt. For the period 1961-1963 we use linear interpolation between our constructed series for the period 1930-1960 and the data from *Hagskinna: Icelandic Historical Statistics*, Tables 13.6c, for 1964 to obtain data for these three years.

Total non-core liabilities

Total non-core banking system liabilities are given by the sum of our two constructed series for foreign and domestic non-core banking system liabilities.

Exchange rates, terms of trade and prices

Domestic price level (1875-2013)

The domestic price level is constructed using annual averages of the consumer price index (excluding housing) from Statistics Iceland for the period 1914-2013. For the period 1875-

1913 we use a "general price level" obtained from Statistics Iceland (*Hagskinna: Icelandic Historical Statistics*, Table 12.25).

House prices (1900-2013)
For the period 1945-2013 we use the annual average of the housing stock implicit price deflator from Statistics Iceland. For the period 1900-1944 we use the building cost index from Statistics Iceland as these series match almost perfectly for the period for which they are both available, up to 1993, when Statistics Iceland changed the way they measured house prices.

Nominal exchange rate (1875-2013)
We use the exchange rate of the króna vis-á-vis the US dollar. The annual average exchange rate for 1961-2013 is obtained from the Central Bank of Iceland. For the period 1914-1960 we use data from Statistics Iceland (*Hagskinna: Icelandic Historical Statistics*, Table 13.16). For the period 1875-1913 we use data on the exchange rate of the Danish króna vis-á-vis the US dollar (as Iceland was in a monetary union with Denmark in that period) from Abildgren (2004).

Real exchange rate (1875-2013)
We use an annual average of a real exchange rate index from the Central Bank of Iceland for the period 1960-2013 (relative consumer prices). For the period 1875-1959 we follow Nordal & Tómasson (1985) in calculating a real exchange rate using a simple average of real exchange rates vis-á-vis the US, UK and Denmark (by far the three most important trading partners in that period). The nominal exchange rates are obtained from Statistics Iceland (for 1914-1959; *Hagskinna: Icelandic Historical Statistics*, Table 13.16) and Abildgren (2004) (for 1875-1913). The domestic price series is explained above, while the price series for the three other countries for the period 1875-1959 are obtained from Abildgren (2004).

Terms of trade (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland (adjusting for the structural break in the data in 1997 due to a methodological change related to the introduction of the ESA-2010 national accounts standards introduced in September 2014). Data for the period 1875-1944 is taken from *Hagskinna: Icelandic Historical Statistics*, Table 10.23.

Real economy

Nominal GDP (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland (adjusting for the structural break in the data in 1997 due to a methodological change related

to the introduction of the ESA-2010 national accounts standards introduced in September 2014). Data for the period 1875-1944 is taken from a statistics publication of the National Economic Institute (Jónsson, 1999, Table V.14.6).

Real GDP (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland (adjusting for the structural break in the data in 1997 due to a methodological change related to the introduction of the ESA-2010 national accounts standards introduced in September 2014). Data for the period 1875-1944 is taken from a statistics publication of the National Economic Institute (Jónsson, 1999, Table V.14.6).

Nominal domestic demand (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland (adjusting for the structural break in the data in 1997 due to a methodological change related to the introduction of the ESA-2010 national accounts standards introduced in September 2014). Data for the period 1875-1944 is constructed by backing out domestic demand using nominal GDP, imports and exports taken from a statistics publication of the National Economic Institute (Jónsson, 1999, Tables V.14.6 and V.15.4).

Real domestic demand (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland (adjusting for the structural break in the data in 1997 due to a methodological change related to the introduction of the ESA-2010 national accounts standards introduced in September 2014). Data for the period 1875-1944 is constructed by deflating nominal domestic demand explained above with the implicit GDP price deflator obtained from the data on nominal and real GDP explained above.

Trade deficit as a % of nominal GDP (1875-2013)
For the period 1945-2013 we use annual averages obtained from Statistics Iceland. Data for the period 1875-1944 is constructed by using nominal GDP, imports and exports taken from a statistics publication of the National Economic Institute (Jónsson, 1999, Tables V.14.6 and V.15.4).

Other data

Data related to banking crises in Table 4
For measuring the market share of distressed financial institutions, we use credit supplied by institutions which are adjudged to fall into distress (either fail or need a major recapitalisation) as a share of total credit of commercial and savings banks and other credit institutions (including the government mortgage lender Íbúðalánasjóður). For the 1920 and 1930 crises, we use data for the years 1919 and 1929, respectively (from *Hagskinna:*

Icelandic Historical Statistics, Tables 13.2 and 13.3). For the 1985 and 1993 crises, we use data for the years 1984 and 1992, respectively (from Central Bank of Iceland *Annual Reports*, Tables 25 and 29 in the 1986 *Report* and Table 21 in the 1994 *Report*). Finally, for the 2008 crisis, we use data from the Financial Supervisory Authority (*Heildarniðurstöður ársreikninga fjármálafyrirtækja og verðbréfa- og fjárfestingarsjóða fyrir árið 2007*, page 4).

For measuring the impact of banking crises in Iceland on the fiscal balance in Table 4, we use data on the central government income and expenditure from *Hagskinna: Icelandic Historical Statistics*, Tables 15.3 and 15.4 for the period 1875-1944, Table 15.9 for the period 1945-1979, and the Statistics Iceland database for the period 1980-2013. For measuring the impact on government debt, we use data on central government debt from *Hagskinna: Icelandic Historical Statistics*, Table 15.16 for the period 1908-1989, and the Statistics Iceland database for the period 1990-2013.

Population (1875-2013)
To obtain per capita domestic demand, we use population data obtained from Statistics Iceland. The data reports population at 1 January each year – which we use as a measure of the population in the previous year.

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