The Internationalisation of Financial Crises: banking and currency crises 1883-2008

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Abstract

Financial crises are high cost events which can transmit across international borders. Using data from 1883 to 2008 this paper develops a means of mapping changes in the degree of international synchronisation of banking and currency crises through a formal concordance index. This index specifically accounts for the typically low incidence and potential serial correlation of crisis data. The results show that banking crises were highly internationalised at the beginning of the 20th century, and became far less so in the strong regulatory environment prevailing after the Depression until the 1980s. A strong increase in the synchronicity of international banking crises is revealed during the late 20th and early 21st century. Currency crises began the century as more idioysncratic, but have tended to become more synchronised over the 115 year sample.

Keywords: financial crises, currency crisis, banking crisis, synchronisation, concordance indices

JEL Classification: F31, F47, N20

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1 Introduction

As is glaringly apparent from the crisis events of 2007-2008, financial crises can have a huge impact on economies. Fortunately they do not occur very often. Partly motivated by policy interest in mitigating their economic costs there is a relatively large literature focussed on whether crises are becoming more linked across geographic borders. Some of the channels proposed include trade links, Glick and Rose (1999), banking linkages, Van Rijckeghem and Weder (2001), more recently via credit derivatives, Brunnermeier (2009) and lacking common fundamental and institutional features, via contagion effects, Rose and Spiegel (2009). Important debates concern how to limit the spread of crises, particularly through various agenda on reforming global financial architecture, see for example Eichengreen (2002) following the East Asian crisis and Brunnermeier, Crockett, Goodhart, Persuad and Shin (2009) on the recent credit crunch and even Bagehot (1873).

Evidence suggests that the prevalence of financial crises has been increasing, particularly since World War II; Eichengreen and Bordo (2003), Kaminsky and Reinhart (1999) Glick and Hutchison (2001), and Reinhart and Rogoff (2009). However, measures of changes in the extent of internationalisation of crises are more scarce. It is of particular interest to understand whether more prevalent crises are internationally linked or are idiosyncratic and simply occur coincidentally.

The contribution of this paper is in developing a means of mapping changes in the degree of international synchronisation of financial crises from the late 19th century through to 2008 through a formal concordance index.

To examine the history of crises we use a sample of 21 countries' annual banking and currency crisis data for 1883 to 1998 drawn from Bordo et al. (2001), updated with the recent dataset of Laeven and Valencia (2008) to 2007 to which we add observations for 2008. In common with most crisis data, the sample consists of bivariate indices taking the value 1 in the presence of a crisis. Our concordance index uses this data to construct a measure ranging from 0 to 1 to characterise the extent of international interdependence in financial crises. A value of 1 indicates that all crises are simultaneous. The advantage of the concordance indices compared to the traditional correlation measure is the ability to investigate synchronisation among more than two crises and to formally test for independence. These tests take into account the binary nature of the data, the relatively low incidence of crises, and potential serial correlation. When applied to the sample data they reveal that the occurrence of 5 (4) or more contemporaneous currency (banking) crises in the data is not likely to be coincidental.

The evolution of the concordance indices indicates that currency crises have not only become more prevalent but also more internationally synchronised over the twentieth century. Banking crises were highly internationalised at the beginning of the 20th century, but became far less so during the strong regulatory environment prevailing after the Depression until the 1980s. However, the incidence of banking crises has grown in the past 30 years, and the global financial crisis of 2007-2008 sees a jump in the synchronisation of these crises. Greater frequency of currency crises and lower frequency of banking crises are associated with capital controls by Glick and Hutchison (2001) and Kaminsky and Reinhart (1999). Coupling their results with the concordance

indices reveals that more liberalized financial conditions are associated with a greater prevalence of banking crises at the end of the sample and increasing internationalisation of currency crises. Although there are limited incidences of joint banking and currency crises (twin crises) in the data set, some analysis of their transmission is warranted in the light of their much higher cost for economies involved, see for example Stiglitz (1999).

The paper proceeds as follows. Section 2 briefly describes the historical background of banking and currency crises in the 20th century. Section 3 is methodological, presenting definitions of synchronisation, and bivariate and multivariate concordance indices and means of testing for independence between crises with these indices. Section 4 provides the results of applying these techniques to the sample data and extracts a number of testable propositions from the literature. Section 5 concludes.

2 Banking and Currency Crises in the 20th Century

There is a substantial literature on various episodes of crisis from the late 19th century to the close of the 20th century. See for example Kindleberger (1996), Bordo and Schwartz (1996), Bordo et al. (2001), Bordo (2003), Eichengreen (2003), Isard (2005, Chapter 2), or Reinhart and Rogoff (2009). The exact chronology of the period is not uniformly agreed, as rules for dating crises are notoriously imprecise. However, there is broad agreement about a number of periods.

Chronologically the first period runs from the late 1800s to the beginning of World War I associated with the period of the gold standard. Two major crises from this period were the Barings scandal resulting from over investment in Latin America, and the banking panic in the US and other countries in 1907 and 1908. This period is covered in some detail in the Appendix to Bordo and Eichengreen (1999).

The interwar period can be divided into two. The first covers the decade from 1919 to 1929, characterised by the attempts to return the international financial system to the gold standard and the consequent strains placed on economies in aligning their internal and external positions, as discussed by Isard (2005). The period from 1929 to the advent of World War II includes the Depression and the greatest concentration of both banking and currency crises in developed nations as the gold standard was broken, resulting in what Isard (2005) calls an 'uncoordinated hybrid system'. The period of the second World War was one of tight controls and produces no crisis data.

Post World War II, the next 25 years are characterised by the exchange rate arrangements of Bretton-Woods. During the Bretton-Woods era currency crises were prevalent, and as Bordo and Schwartz (1996) discuss, often traumatic due to the need to align the internal economy with previously agreed rates and political difficulties in making changes to the exchange rates. Following the breakdown of Bretton-Woods in 1971 an increasing number of countries adopt a floating exchange rate. The 1990s in particular seems to have been characterised by plentiful financial crises, including the East Asian crisis, comprising both currency and banking crises across a variety of countries. The high incidence of crises in these years is noted by both Crockett

(2004) and Haldane and Kruger (2004).

Finally, 2007-2008 represents the period of greatest financial turmoil since the crises associated with the Great Depression. The source of the crisis is widely regarded to be the collapse of the securitised market for sub-prime mortgages in the US, which in itself was riding the back of a housing price bubble likely exacerbated by relatively loose monetary policy. Financial innovation and a tendency to self-regulation in new financial products contributed to the creation of a set interlinkages based on credit derivatives and regulatory arbitrage which seriously threatened the most developed markets and their economies. Descriptions of this crisis can be found in Rose and Spiegel (2009), Brunnermeier et al. (2009).

To investigate the measurement of synchronisation of crises we use the long run annual data set of Bordo et al. (2001) for currency and banking crises for 21 countries over the period 1883 to 1998, and update this to 2007 with the crisis data provided in Laeven and Valencia (2008). Finally, we augment this with data for 2008, based on the details of the programs implemented in each of the 21 countries in response to the 2007-2008 crisis as laid out by the IMF (2009a). In Bordo et al. currency crises occur in association with either a forced change in parity, a realignment or as indicated by an exchange market pressure index exceeding a threshold value.[1] In Laeven and Valencia (2008) currency crises are indicated by a currency depreciation of at least 30%, where this is at least 10% greater than the rate of depreciation in the previous year. This did not occur for any of the currencies in

[1]The exchange market pressure index is constructed as a weighted sum of exchange rates, interest rate differentials and changes in reserves as per Eichengreen, Rose and Wyplosz (1995,1996).

the sample in 2008. Banking crises in Bordo et al. are dated as periods of continuous financial distress leading to substantial erosion of banking capital, as per Caprio and Klingebiel (1996). Laeven and Valencia (2008) use a combination of qualitative and quantitative indicators, including the presence of bank runs, bank guarantees or substantial injections of liquidity or capital. The selection of a country as having experienced a banking crisis in 2008 was based upon the criteria of whether the IMF (2009a) (i) reported a loan guarantee program (ii) nationalisation of financial institutions (iii) significant injections of capital into banks. This was augmented by material from individual central banks and country sources.[2]

The data set takes the form of annual binary indices, taking a 1 in years when a crisis occurs, and a 0 otherwise. The countries included are Argentina, Australia, Belgium, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK and the US. Table 1 shows the occurrences of the crises in the dataset.[3] The Table clearly shows the greater prevalence of currency than banking crises; only in the US, Italy and Belgium have there been more banking crises than currency crises for a particular country. The Table also indicates the incidence of joint occurrence of contemporaneous banking and currency crises in a single country, labelled twin crises. Compared with the occurrence of single crisis types, twin crises are uncommon, a feature also apparent in the data sets of Glick and Hutchison (2001) and Kaminsky and

[2]The countries denoted as experiencing a banking crisis are: Belgium, France, Germany, Greece, Italy, Netherlands, Portugal, Switzerland, the UK and the US.

[3]Obviously, alternative crisis dating rules would result in somewhat different crises chronologies; see Jacobs and Lestano (2007) for a discussion of sensitivity of currency crises dating methods.

Reinhart (1999).

Figures 1 and 2 give the time distribution of each of the currency and banking crises. What is immediately apparent is the relative infrequency of these events; there are many more non-crisis years than crisis years. Particular years stand out. In 1907 a banking crisis occurred in seven of the 21 countries in the sample—see Goodhart and Delargy (1998). Both banking and currency crises were widespread in 1931 associated with the Great Depression, with eight countries experiencing both banking and currency crises (twin crises), a further five countries experienced a banking crisis alone, and a further six countries a currency crisis alone.

The next major period of disruption in the sample is the currency crises associated with the breakdown of Bretton Woods in 1971 when 12 countries observed currency crises (but not banking crises). The third major set of currency crises in the dataset occurs in the 1992 ERM crisis, when the UK and Italy exited the system, and seven of the European countries report a crisis observation (Denmark, France, Italy, the Netherlands, Spain, Sweden and the UK). Banking crises in this data set do not meet with pre-World War II levels again. The 1997-1998 period of the East Asian currency crisis does not stand out in this dataset as this crisis did not heavily impact the countries included in the dataset.

Finally in 2008 there is a cluster of banking crises across 10 of the countries in the sample. This is the second highest occurrence of simultaneous crises in the sample after the year 1931 where there were 13 countries in banking crisis. It surpasses the 1907 crisis at the beginning of the sample.

Increasing incidence of currency crises has been associated with periods

of war by Bordo and Schwartz (1996) and Bordo and Eichengreen (1999). Considering the Wars that occur in the 20th century as the Boer War (1899-1902), World War I (1914-1918), World War II (1939-1945), the Korean War (1950-1953), the Vietnam War (1962-1973) and the Gulf Wars (1991, 2003-2008) we see that the two wars where the hypothesis of increasing currency crisis sychronisation is evidently upheld here are the Korean and Vietnam Wars. In the 1930s there was an increase in currency crisis synchronisation, and to the (large) extent that the poor inter-war economic conditions contributed to World War II, this also supports the association between war and currency crises.

The dataset provides prima facie evidence that clusters of crises occur together. In order to establish a measure of the degree of synchronisation between banking crises and currency crises the following section develops a concordance index. The index accounts for the particular characteristics of the data—binary, low incidence, potentially serially correlated data with a largely unobserved underlying data generating process. We use it to both formally test the extent to which observed contemporaneous crises may be independent and to analyse the history of financial crises in Section 4.

3 Methodology

3.1 Synchronisation

We consider P countries and Q markets. Let a financial crisis be represented by the binary variable $S_{i,t}$, where $i = 1, \ldots, PQ$, $t = 1, \ldots, n$. $S_{i,t}$ takes

the value one if a crisis occurs in the corresponding country and market in period t and zero otherwise. The mean of the series $S_{i,t},\ t = 1, \ldots, n$ is denoted μ_{S_i}. If two series are identical, that is $S_{x,t} = S_{y,t}$ for all t, the series are perfectly synchronised and have equal means and perfect positive correlation. When series exhibit strong synchronisation, the means of the two series and the correlation between them describe how synchronised the series are, omitting the uninteresting cases where the series are either continually in crisis, or continually not ($S_{x,t} = 1$ or $S_{y,t} = 0$ for all t). For the remainder of this paper the means of the financial crises series and the number of observations are assumed known.[4] Binary financial crises series typically have low incidence, are ordered in time, stochastically dependent and possibly serially correlated. A standard way of defining synchronisation is by means of correlation coefficients. However, there is no one-to-one relation between correlation coefficients and synchronisation. It is quite possible to observe series with equal means but different correlation coefficients, or sets of series with equal correlation coefficients but different means. In this case the synchronisation between the series will differ.

An alternative way to define synchronisation is from contingency tables which 'count' the number of times the variables $S_{x,t}$ and $S_{y,t}$ are in various combinations of states.[5] Consider the following (2×2) contingency table.

[4]The binary financial crisis dummy series are constructed from an underlying data generating process by clipping or hard limiting (Benjamin Kedem 1980) although there need not exist a clear link to the data generating process. We deviate from Pagan (2005) in this respect.

[5]For an introduction to contingency tables see Agresti (2002, Chapter 2).

Bivariate crises: (2×2) contingency table

	Crisis S_y	No crisis S_y	Row sums
Crisis S_x	n_{11}	n_{12}	$n_{1.}$
No crisis S_x	n_{21}	n_{22}	$n_{2.}$
Column sums	$n_{.1}$	$n_{.2}$	n

In the contingency table n_{11} denotes the number of simultaneous crises that is when $S_{x,t} = S_{y,t} = 1$, n_{12} the number of periods with a crisis of a type x only, n_{21} the number of periods with a single crisis of type y, and n_{22} is the number of tranquil periods. The row and column sums are fixed, as well as the number of observations n. Therefore only one of the n_{ij} can vary independently. Without loss of generality we take this to be n_{11}. As we will show next, the contingency table approach provides a useful means of developing bivariate, and later multivariate, indices of the contemporary concordance between financial crises.

3.2 Bivariate concordance indices

Concordance indices can be simply constructed from a 2×2 contingency table like that shown in Section 3 by 'counting' the number of times the variables $S_{x,t}$ and $S_{y,t}$ are in various combinations of states. In a bivariate setting the total observations in the sample (n) consist of the number of simultaneous crises periods (n_{11}), the number of periods with a single crisis $(n_{12} + n_{21})$ and the number of tranquil periods (n_{22}), or $n \equiv n_{11} + n_{12} + n_{21} + n_{22}$.

Harding and Pagan (2006) advocate measuring the degree of synchronisation in business cycles in terms of the fraction of time the cycles are in the same phase. Their *concordance index* has the form

$$\hat{I}^{hp} = \frac{n_{11} + n_{22}}{n}. \tag{1}$$

A typical feature of financial crises is their low incidence, or a large number of tranquil periods in the sample. It seems natural then to confine attention to the concordance of crises in turbulent periods and introduce the *turbulent-periods concordance index*

$$\hat{I} = \frac{n_{11}}{n - n_{22}}, \tag{2}$$

where we assume that there is at least one crisis in the sample, *i.e.,* $n_{22} \neq n$. Equation (2) gives the number of times in which the two markets are both in crisis as a proportion of the number of times there are any crises in the sample. The construction of the denominator removes the influence of the dominant proportion of non-crisis periods (all zeros) which would prevail if the Harding and Pagan indicator of Equation (1) was applied.[6] Hence, the influence of the dominant non-crisis periods is removed.

Equation (2) can be expressed in terms of means and correlation coefficients as

$$\hat{I} = \frac{\hat{\rho}_s(\hat{\mu}_{S_x}(1-\hat{\mu}_{S_x}))^{1/2}(\hat{\mu}_{S_y}(1-\hat{\mu}_{S_y}))^{1/2} + \hat{\mu}_{S_x}\hat{\mu}_{S_y}}{-\left(\hat{\rho}_s(\hat{\mu}_{S_x}(1-\hat{\mu}_{S_x}))^{1/2}(\hat{\mu}_{S_y}(1-\hat{\mu}_{S_y}))^{1/2} + \hat{\mu}_{S_x}\hat{\mu}_{S_y}\right) + \hat{\mu}_{S_x} + \hat{\mu}_{S_y}}, \tag{3}$$

where $\hat{\rho}_s$ represents the sample correlation coefficient between the two crisis

[6]The bivariate signal extraction measure used in Glick and Hutchison (2001) also makes the modification of removing non-crisis periods from the denominator.

indices $S_{x,t}$ and $S_{y,t}$. This function is plotted in Figure 3 for the example of equivalent means in the two series. Figure 3 shows that high concordance is achieved when correlation is high, $\hat{\rho}_s = 1$ or means are high $\hat{\mu}_x = \hat{\mu}_y = 1$, or a combination of these two characteristics. As either of $\hat{\rho}_s$ or $\hat{\mu}_x = \hat{\mu}_y$ approach one, the value of the concordance index increases. This makes sense because as the number of crisis observations in the sample increases the possibility of overlap also increases, even in the extreme case of independence of crises (a topic to which we return below).

3.3 Multivariate concordance indices

Consider the more interesting case of concordance in the context of multiple financial crises across countries for any particular market. Clearly synchronisation cannot be expressed in correlation coefficients any more, unless we consider all bivariate combinations appropriate. However the contingency table framework can be extended from (2×2) to $(r \times c)$.

Any instances of concordance across the indices for a particular market may be of interest, focussing attention on the joint occurrence of two or more crises. Denoting Z as the minimum number of crises to occur concurrently we can work out the frequency of observing Z crises in n periods as $f_Z = n$ multichoose $Z = \frac{n!}{(n-Z)!Z!}$. So the frequency of observing Z or more crises in n periods must be the sum of f_z for all $z \geq Z$.

The total number of periods n is divided into periods involving multiple crises, denoted n_z, which can be further separated into $n_{z \geq Z}$ where there are Z or more crises contemporaneously and $n_{1 \leq z < Z}$, where there are less than

Z crises but at least one, and the number of periods involving no crises in any country, denoted $n_{z=0}$, so that $n \equiv n_{z\geq Z} + n_{1\leq z<Z} + n_{z=0}$. Then the multivariate version of our concordance index is expressed as

$$\hat{I}^M = \frac{n_{z\geq Z}}{n - n_{z=0}}. \tag{4}$$

Movements in this index are easily interpreted. An increase in the value of the index simply indicates that further episodes of concurrent financial crises have occurred (both the numerator and denominator have increased, recalling that we have omitted the uninteresting case of perfect synchronisation to ensure that the index is not equal to one). In the case of no change in the index, there have been no periods of turmoil and neither numerator or denominator of the index change. Declines in the index indicate the occurrence of isolated crises so that the denominator increases without an accompanying change in the numerator. This trade-off is illustrated in Figure 4 which shows the multivariate version of the index for $Z = 2$, with equal means for all series.

Before turning to the applications of the concordance indices we consider tests for independence between series based on the concordance indices.

3.4 Testing synchronisation

To test whether synchronisation is not coincidental involves testing for independence. In the case of bivariate combinations of crises this could be done by a correlation coefficient test, tests in the contingency table framework of Section 3.1 or by simulation. And each of these has analogues for the multivariate case. One complication is the potential serial correlation of the binary

crises data. In other applications with constructed binary indices from observed data generating processes, a test for correlation takes the possibility of serial correlation and heteroskedasticity into account as in Harding and Pagan (2006). Here we apply tests based on the contingency table framework and simulation methods. We explicitly make use of the low incidence of financial crises and the resulting discrete distributions which enable the design of exact tests. We pretest each binary crisis series for serial correlation with a Fisher exact test using the null of independence against a higher-order Markov chain.[7] A rejection of the null indicates serial correlation, although does not uniquely establish its Markov chain order.

At least one of the countries exhibits serial correlation in each of the banking and currency crisis series. For this reason we test bivariate and multivariate synchronisation using simulation techniques. We simulate the series $\tilde{S}_x$ to have the same properties as S_x. Under the null hypothesis that the observed number of crises are randomly drawn from a uniform (0,1) distribution, the number of observed crises in the data set gives the exact number of draws to simulate, that is in each case the $\mu_x = \tilde{\mu}_x$ where the latter term is the mean of the simulated series. In cases where S_x rejects the null of independence, i.e. is serially correlated, the simulated data uses the observed runs of contiguous crises in the original data in simulating to retain the serial correlation properties in the simulated data. We use 10,000 replications to generate the critical values. Converting these critical values for the totals into critical values for the bivariate and multivariate concordance indices is

[7]For a description of Fisher's exact test for 2×2 tables see Agresti (2002), Section 3.5. For statistical inference with Markov chains see e.g. Anderson and Goodman (1957).

straightforward from Equations (2) and (4).

4 Empirical Application

Table 2 shows the results of pretesting independence against a first order Markov process on the transition matrices as described in the previous section for currency and banking crises in each of the 21 countries. As is quickly observed, almost all series display independence. The exceptions are Denmark and the UK for currency crises, and France, Norway and the US for banking crises.

4.1 Bivariate concordance

Table 3 shows bivariate turbulent-period concordance indices for currency crises with corresponding 95% critical values in the upper and lower triangles of the table respectively. The critical values are obtained by simulation as described in the previous section. The country pairs for which currency crises reject the null of independence predominantly involve crises where two European countries are involved. For example, the results for Finland show that nine of the rejections of independence involve other European countries (Belgium, Greece, Netherlands, Norway, Poland, Spain, Sweden and the UK) and three non-European pairs with Argentina, Australia and Canada. The Netherlands, Norway and Poland show similar patterns. Argentina is also frequently one of the pair considered in bivariate tests which reject independence, including with all other Latin American countries. These results lend further credence to the concern over regional interdependence in financial

crises; for example Kaminsky and Reinhart (2003), Glick and Rose (1999), Dungey and Martin (2007), and Reinhart and Rogoff (2009, 257-259).

Table 4 lists bivariate turbulent period concordance indices and corresponding 95% critical values derived from simulation for banking crises. Serial correlation has been taken into account for France, Norway and the US. There are a substantial number of incidences of rejections of independence between the bivariate banking crises. The greatest number of rejections as part of a pair occur for the US, likely reflecting its status as a world financial centre during much of the sample period. Italy, Belgium and Poland have the next greatest number of rejections, rejecting independence in bivariate crisis observations with most European countries as well as the US. Interestingly, the UK only rejects independence in bivariate pairs of crisis with the US, while Japan and Canada find no incidences in which independence is rejected.

Given the relationships revealed by the bivariate indices we now consider the testing of multivariate concordance.

4.2 Multivariate concordance

Table 5 reports the multivariate concordance indices for the group of crises which across countries over the entire sample. Each row reports the concordance index for the stated number of common crises occurring across these categories shown in the first column. So the first row reports the concordance index for at least two concurrent currency crises across the 21 economies sampled. A total of 39 time periods are identified which fulfill that criteria, giving

a turbulent periods index of 0.57.

The final column of Table 5 reports the 95% critical value for the concordance indices in each case expressed as the maximum number of times that one would observe that many crises and be able to reject the null of independence. That is for the row of at least two simultaneous currency crises, one can observe up to 18 occurrences of two simultaneous crises without having to reject independence. In the sample there are 39 occurrences of at least two simultaneous currency crises, clearly rejecting independence. In the case of banking crises, the row labelled at least two crises contains 26 observations with a turbulent periods index value of 0.59 for the sample. One can observe up to seven cases of two simultaneous crises whilst being consistent with independence, which is clearly rejected by the 26 cases observed in the dataset. The results in Table 5 show that the sample rejects independence between simultaneous crises in all instances. The Table shows that a single occurrence of five simultaneous currency crises (four simultaneous banking crises) is sufficient to reject independence in the data. This implies there is some underlying mechanism connecting the observed occurrence of simultaneous crises.

Policy makers are correct to be concerned about the occurrence of a crisis. However, knowing which crises are going to spread is as yet unresolved. Isolating the characteristics of what makes a particular crisis spread, or alternatively what makes other markets vulnerable to spread from other crises remains an important issue, and is the focus of work on indicators of financial fragility such as associated with Goldstein, Kaminsky and Reinhart (2000). Unfortunately this literature has not been particularly successful to date,

with the relatively poor performance of these indicators documented in Berg and Patillo (1999). Further, the cross-section analysis of Rose and Spiegel (2009) suggests little commonality in macroeconomic and institutional settings across countries affected by the 2007-2008 global financial crisis. The problem lies with the heterogeneity of the crises; it seems no two crises are ever the same. However, it is important we do know that crisis situations will tend to exacerbate other weaknesses in the economy and financial system, increasing the possibility of crises in other markets and countries, which is the aspect we see reflected in the concordance indices and their critical values.

4.3 Twin crises

Before proceeding to the analysis of the internationalisation of banking and currency crises over time we first examine the evidence on twin crises; that is where a banking and currency crisis occur simultaneously. Twin crises are well known to be more costly than individual crises. Bordo et al. (2001) calculate the output loss of twin crises as twice as costly as currency crises and four times more costly than banking crises, see also Stiglitz (1999), and Kaminksy and Reinhart (1999). The lack of occurrences of twin crises in the dataset prohibits the construction of an informative concordance index.[8]

[8]Both Kaminsky and Reinhart (1999) and Glick and Hutchison (2001) avoid the problem of low incidence of contemporaneous crises by defining a window in which crises may occur and still be considered twin. We have constructed a similar index of twin crises to Glick and Hutchison, which increases the number of incidences in our sample from 21 (of which 3 are post World War II) to almost 50 (with 13 post World War II), however the method induces serial correlation into the index data which further complicates statistical analysis. Neither Kaminsky and Reinhart (1999) nor Glick and Hutchison (2001) deal with this complication.

Table 6 illustrates the joint occurrence of contemporaneous currency and banking crises. The columns give the number of occurrences of either no, one or multiple contemporaneous banking crises, while the rows give the same information for currency crises. As already seen the most populous combination is a non-crisis period (the top left cell), with 46 of the 126 sample observations. The presence of both multiple banking and currency crises only numbers 13, of which twin crises (restricted to occur in the same country) are a subsample. It is worth noting that the number of periods with no currency crises but one or more banking crises is very small at seven (of a total of 39 banking crises in the sample) while the number of periods with no banking crises but one or more currency crises is 36, or 52 percent of the 69 periods containing currency crises. It seems that the occurrence of banking crises in isolation from currency crises somewhere in the world is much less likely than the occurrence of currency crises in isolation from banking crises somewhere in the world. In this respect the events of 2007-2008 have been unusual in being dominated by banking crises.

4.4 Historical analysis

Figure 5 shows recursive calculations of the multivariate concordance indices for banking and currency crises using the initial 20 observations of the dataset as the starting point and increasing the sample size by one observation at the time. Increases in the concordance index indicate an increase in international financial turmoil. A stable concordance index is associated with a period of tranquility. A decrease in the concordance index is equally informative, as it

signals an increase in isolated financial turmoil, that is turmoil confined to single (or small groups of countries if $Z > 2$). Figure 5 shows the recursive concordance index for the case of two or more simultaneous crises, so that a decline in this index is associated with the occurrence of isolated single crises. Similar indices can be constructed for higher numbers of simultaneous crises, but the results are consistent with the analysis presented here.

We observe a constant value of the currency concordance index from 1908 to 1920, indicating periods of tranquility during the gold standard for currencies. As discussed in the historical overview of Section 2, the 1920s is characterised by periods of currency crises. There are instances of both increased international turmoil (increases in the index) and of isolated turmoil (decreases in the index). The most pronounced feature of the figure is the large increase in the currency crisis concordance index in the early 1930s, associated with several years of contemporaneous crises, 14 in 1931 and 6 in 1932 as shown in Figure 1. This is followed by a few isolated crises in the mid 1930s and then the stability associated with controls during World War II. The Bretton-Woods era divides clearly into two components, the general movement in the index to the mid 1960s is downwards, reflecting isolated currency crises. From 1963 onwards the index begins to increase, indicating increasing internationalisation of crises, reflecting the building pressure towards the end of Bretton-Woods in 1971. The index climbs in the 1970s before a brief hiatus after the second oil price shock. From 1992 and the ERM crisis, however, the general impression is again of increasing internationalisation of currency crises.

The banking concordance index begins at a higher level than the cur-

rency crisis index, referring to the greater degree of disruption in the late 19th century in banking than in currency markets. For the period up to World War II the pattern is not dissimilar to that of the currency crises. The index falls in the 1920s reflecting isolated turmoil, and then rises in 1931 and 1932 reflecting the Depression period. A very long stable period in the banking crisis concordance index prevails during the post World War II period until 1963, when there is a banking crisis in Brazil. Stability again ensues until 1976. The scattering of isolated banking crises shown in Figure 2 then results in further falls in the index. The index then decreases up to 1986, followed by a period of increase to 1991 associated with increased international turmoil. Thereafter the index is relatively stable until the recent period where it has recently kicked up again to levels last seen in the 1991. Beck, Demirgüç-Kunt and Levine (2006) hypothesise that increased concentration in the banking sector is associated with fewer crises on data for 1980-1997. This may be borne out in the most recent crisis where some of the most concentrated banking sectors in the world, such as Australia, have been relatively unaffected.

The tests of multivariate synchronisation provided in the previous section mean that it is possible to identify particular points in time which contribute statistically significant information to the analysis. These are when there are 5 (4) or more contemporaneous currency (banking) crises. In terms of currency crises this occurs in 1921, 1931, 1932, 1949, 1971, 1976, and 1992. Each of these periods are well known stress points in historical analysis. In banking crises 4 or more crises are observed in 1907, 1921, 1923, 1931, 1932 and then a very long hiatus in internationally synchronised banking crises

until 2008.

An interesting aspect of Figure 5 is that the historical pattern differs across the two indices.[9] In general there have been more periods of international financial turmoil in currency crises, leading to an increase in the index over the 20th century, while banking crises have tended to be more internationally linked at the beginning of the century than the end. Banking crises have tended to have relatively more independent occurrences following the Great Depression until the last decade of the 20th century. There is a disturbing uptick in the internationalisation of banking crises in the late 20th and early 21st centuries.

5 Conclusion

This paper developed a multivariate turmoil-periods concordance index for financial crises in order to provide a measure of the degree of internationalisation of banking and currency crises. The index is readily interpretable over time and accounts for the typical properties of crisis data: that is binary, low incidence, potentially serially correlated crisis events. The index can be used to assess the independence of observed events, using simply constructed critical values. Moves in the multivariate turmoil-periods concordance index indicate the changing pattern of financial turmoil in world financial markets for the period 1883-2008. The index is stable during periods without financial crises, declines in the presence of independent crises and increases when internationally linked financial crises occur.

[9]The values of the indices are coincidentally similar at the end of the period, but little can be read into this given the different numbers of crises experienced.

The degree of international financial turmoil in currency crises was shown to have broadly risen over the 20th century, associated with a rise in the currency crisis turbulent-periods concordance index. Banking crises were highly internationalised at the beginning of the sample, and following the crises of 1931 experienced a relatively crisis free period, associated with the strict regulatory structures of the post Depression era (through War controls, the Bretton Woods system). The degree of international financial turmoil in banking crises fell until late in the 20th century, shown as a fall in the banking crisis turbulent-periods concordance index. However, in the late 20th century and first decade of the 21st century, the banking crisis concordance index has risen again. This reflects the internationalisation of recent banking crisis episodes, particularly the global financial crisis of 2007-2008. The analysis suggests support for the view put forward in Brunnermeier et al. (2009) that while crisis management may be a matter for individual country authorities, crisis prevention requires international coordination.

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Table 1:
Occurrences of financial crises: 1883-2008

	Currency Crises	Banking Crises	Twin Crises
Argentina	20	9	4
Australia	7	2	0
Belgium	5	6	0
Brazil	14	9	3
Canada	10	1	0
Chile	10	5	1
Denmark	8	6	2
Finland	7	5	3
France	9	7	0
Germany	5	4	1
Greece	7	2	1
Italy	8	9	1
Japan	7	4	0
Netherlands	6	4	1
Norway	4	5	1
Portugal	6	6	2
Spain	8	5	1
Sweden	5	5	2
Switzerland	4	3	0
UK	11	3	0
UK	7	11	2
All countries	168	111	25

Table 2:
Univariate tests of independence versus first order Markov process: p-values

	Currency Crises	Banking Crises
Argentina	0.2611	0.3793
Australia	0.2893	0.9681
Belgium	0.8126	0.1751
Brazil	0.1406	0.1098
Canada	0.4203	0.9920
Chile	0.4203	0.8126
Denmark	**0.0080**	0.2336
Finland	0.6612	0.8126
France	0.3739	**0.0254**
Germany	0.8126	0.9292
Greece	0.2893	0.9920
Italy	0.3373	0.3373
Japan	0.2893	0.8766
Netherlands	0.7398	0.9292
Norway	0.8766	**0.0120**
Portugal	0.7398	0.1751
Spain	0.5798	0.1751
Sweden	0.1751	0.1751
Switzerland	0.8766	0.9681
UK	**0.0490**	0.9681
UK	0.2893	**0.0033**

Table 3: Currency crisis turbulent-period concordance indices with critical values

	AR	AU	BE	BR	CA	CH	DE	FI	FR	GE	GR	IT	JA	NE	NO	PO	SP	SW	SZ	UK	US
AR		0.04∗	0.00	0.17∗	0.20∗	0.20∗	0.08∗	0.08∗	0.00	0.04∗	0.17∗	0.08∗	0.13∗	0.00	0.04∗	0.04∗	0.17∗	0.09∗	0.00	0.11∗	0.04∗
AU	0.04		0.20∗	0.00	0.00	0.00	0.25∗	0.17∗	0.00	0.09∗	0.40∗	0.07∗	0.08∗	0.18∗	0.22∗	0.30∗	0.15∗	0.33∗	0.10∗	0.13∗	0.27∗
BE	0.04	0.09		0.00	0.00	0.00	0.08∗	0.20∗	0.00	0.11∗	0.09∗	0.08∗	0.00	0.38∗	0.29∗	0.10∗	0.08∗	0.25∗	0.13∗	0.07∗	0.09∗
BR	0.03	0.05	0.06		0.09∗	0.14∗	0.05∗	0.05∗	0.05∗	0.12∗	0.05∗	0.00	0.05∗	0.00	0.06∗	0.05∗	0.05∗	0.06∗	0.00	0.09∗	0.00
CA	0.03	0.06	0.07	0.04		0.11∗	0.13∗	0.21∗	0.00	0.15∗	0.13∗	0.06∗	0.21∗	0.07∗	0.17∗	0.14∗	0.06∗	0.07∗	0.00	0.05∗	0.13∗
CH	0.03	0.06	0.07	0.04	0.05		0.06∗	0.06∗	0.06∗	0.07∗	0.06∗	0.00	0.06∗	0.00	0.08∗	0.07∗	0.13∗	0.07∗	0.08∗	0.11∗	0.00
DE	0.04	0.07	0.08	0.05	0.06	0.06		0.36∗	0.06∗	0.08∗	0.25∗	0.14∗	0.25∗	0.27∗	0.20∗	0.27∗	0.33∗	0.44∗	0.09∗	0.19∗	0.07∗
FI	0.04	0.08	0.09	0.05	0.06	0.06	0.07		0.00	0.20∗	0.17∗	0.00	0.17∗	0.30∗	0.57∗	0.18∗	0.15∗	0.33∗	0.10∗	0.13∗	0.08∗
FR	0.04	0.07	0.08	0.05	0.06	0.06	0.06	0.07		0.00	0.00	0.13∗	0.00	0.15∗	0.00	0.00	0.06∗	0.08∗	0.08∗	0.05∗	0.00
GE	0.04	0.09	0.11	0.06	0.07	0.07	0.08	0.09	0.08		0.09∗	0.00	0.09∗	0.10∗	0.29∗	0.10∗	0.08∗	0.25∗	0.00	0.14∗	0.09∗
GR	0.04	0.08	0.09	0.05	0.06	0.06	0.07	0.08	0.07	0.09		0.00	0.17∗	0.08∗	0.22∗	0.30∗	0.15∗	0.33∗	0.10∗	0.06∗	0.17∗
IT	0.04	0.07	0.08	0.05	0.06	0.06	0.07	0.07	0.06	0.08	0.07		0.07	0.17∗	0.00	0.08∗	0.23∗	0.08∗	0.09∗	0.19∗	0.00
JA	0.04	0.08	0.09	0.05	0.06	0.06	0.07	0.08	0.07	0.09	0.08	0.07		0.08∗	0.10∗	0.08∗	0.07∗	0.20∗	0.00	0.06∗	0.00
NE	0.04	0.08	0.10	0.05	0.07	0.07	0.08	0.08	0.07	0.10	0.08	0.08	0.08		0.25∗	0.09∗	0.17∗	0.38∗	0.11∗	0.13∗	0.08∗
NO	0.04	0.10	0.13	0.06	0.08	0.08	0.09	0.10	0.08	0.13	0.10	0.09	0.10	0.11		0.25∗	0.20∗	0.50∗	0.14∗	0.15∗	0.10∗
PO	0.04	0.08	0.10	0.05	0.07	0.07	0.08	0.08	0.07	0.10	0.08	0.08	0.08	0.09	0.11		0.27∗	0.22∗	0.11∗	0.13∗	0.18∗
SP	0.04	0.07	0.08	0.05	0.06	0.06	0.07	0.07	0.06	0.08	0.07	0.07	0.07	0.08	0.09	0.08		0.30∗	0.09∗	0.36∗	0.07∗
SW	0.04	0.09	0.11	0.06	0.07	0.07	0.08	0.09	0.08	0.11	0.09	0.08	0.09	0.10	0.13	0.10	0.08		0.13∗	0.23∗	0.09∗
SZ	0.04	0.10	0.13	0.06	0.08	0.08	0.09	0.10	0.08	0.13	0.10	0.09	0.10	0.11	0.14	0.11	0.09	0.13		0.00	0.10∗
UK	0.03	0.06	0.07	0.04	0.05	0.05	0.06	0.06	0.05	0.07	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.07	0.07		0.00
US	0.04	0.08	0.09	0.05	0.06	0.06	0.07	0.08	0.07	0.09	0.08	0.07	0.08	0.08	0.10	0.08	0.07	0.09	0.10	0.06	

Note: Upper triangle gives the bivariate concordance indices for each combination of countries, lower triangle gives the critical values of the concordance index for which the null hypothesis of independence is rejected at the 5 percent level; * indicates a significant rejection of independence at the 5 percent level. All independence test outcomes are obtained by simulation.

Table 4: Banking crisis turbulent-period concordance indices with critical values

	AR	AU	BE	BR	CA	CH	DE	FI	FR	GE	GR	IT	JA	NE	NO	PO	SP	SW	SZ	UK	US
AR		0.10∗	0.15∗	0.06∗	0.00	0.00	0.07∗	0.08∗	0.07	0.08∗	0.10∗	0.13∗	0.00	0.00	0.08∗	0.15∗	0.08∗	0.08∗	0.09∗	0.09∗	0.11∗
AU	0.10		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10∗	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08∗
BE	0.07	0.14		0.00	0.00	0.10∗	0.09∗	0.22∗	0.18∗	0.25∗	0.33∗	0.15∗	0.00	0.25∗	0.10∗	0.20∗	0.22∗	0.10∗	0.29∗	0.13∗	0.21∗
BR	0.06	0.10	0.07		0.11∗	0.00	0.00	0.08∗	0.14∗	0.08∗	0.00	0.06∗	0.08∗	0.08∗	0.08∗	0.07∗	0.00	0.08∗	0.00	0.09∗	0.00
CA	0.11	0.50	0.17	0.11		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20∗	0.17∗	0.00	0.00	0.00	0.00	0.00
CH	0.08	0.17	0.10	0.08	0.20		0.10∗	0.00	0.09∗	0.00	0.00	0.08∗	0.13∗	0.00	0.00	0.00	0.11∗	0.11∗	0.00	0.00	0.07
DE	0.07	0.14	0.09	0.07	0.17	0.10		0.22∗	0.18∗	0.11∗	0.14∗	0.25∗	0.11∗	0.11∗	0.38∗	0.09∗	0.10∗	0.22∗	0.13∗	0.00	0.13∗
FI	0.08	0.17	0.10	0.08	0.20	0.11	0.10		0.09	0.13∗	0.17∗	0.17∗	0.00	0.29∗	0.25∗	0.10∗	0.11∗	0.25∗	0.14∗	0.00	0.07
FR	0.07	0.14	0.09	0.07	0.17	0.10	0.09	0.10		0.22∗	0.29∗	0.33∗	0.10	0.10	0.09	0.30∗	0.09	0.33∗	0.25∗	0.11	0.38∗
GE	0.08	0.20	0.11	0.08	0.25	0.13	0.11	0.13	0.11		0.50∗	0.18∗	0.14∗	0.14∗	0.13∗	0.25∗	0.29∗	0.13∗	0.40∗	0.17∗	0.15∗
GR	0.10	0.33	0.14	0.10	0.50	0.17	0.14	0.17	0.14	0.20		0.22∗	0.00	0.20∗	0.17∗	0.33∗	0.17∗	0.17∗	0.67∗	0.25∗	0.18∗
IT	0.06	0.10	0.07	0.06	0.11	0.08	0.07	0.08	0.07	0.08	0.10		0.08∗	0.18∗	0.17	0.25∗	0.08∗	0.17∗	0.20∗	0.09∗	0.33∗
JA	0.08	0.20	0.11	0.08	0.25	0.13	0.11	0.13	0.11	0.14	0.20	0.08		0.00	0.00	0.00	0.00	0.13∗	0.00	0.00	0.07
NE	0.08	0.20	0.11	0.08	0.25	0.13	0.11	0.13	0.11	0.14	0.20	0.08	0.14		0.13∗	0.11∗	0.00	0.13∗	0.17∗	0.17∗	0.07
NO	0.08	0.17	0.10	0.08	0.20	0.11	0.10	0.11	0.10	0.13	0.17	0.08	0.13	0.13		0.22∗	0.11∗	0.11∗	0.14∗	0.00	0.07
PO	0.07	0.14	0.09	0.07	0.17	0.10	0.09	0.10	0.09	0.11	0.14	0.07	0.11	0.11	0.10		0.22∗	0.22∗	0.29∗	0.13∗	0.21∗
SP	0.08	0.17	0.10	0.08	0.20	0.11	0.10	0.11	0.10	0.13	0.17	0.08	0.13	0.13	0.11	0.10		0.11∗	0.14∗	0.00	0.07
SW	0.08	0.17	0.10	0.08	0.20	0.11	0.10	0.11	0.10	0.13	0.17	0.08	0.13	0.13	0.11	0.10	0.11		0.14∗	0.00	0.23∗
SZ	0.09	0.25	0.13	0.09	0.33	0.14	0.13	0.14	0.13	0.17	0.25	0.09	0.17	0.17	0.14	0.13	0.14	0.14		0.20∗	0.27∗
UK	0.09	0.25	0.13	0.09	0.33	0.14	0.13	0.14	0.13	0.17	0.25	0.09	0.17	0.17	0.14	0.13	0.14	0.14	0.20		0.17∗
US	0.06	0.00	0.07	0.06	0.11	0.08	0.07	0.08	0.07	0.08	0.10	0.06	0.08	0.08	0.08	0.07	0.08	0.08	0.09	0.09	

Note: Upper triangle gives the bivariate concordance indices for each combination of countries, lower triangle gives the critical values of the concordance index for which the null hypothesis of independence is rejected at the 5 percent level; * indicates a significant rejection of independence at the 5 percent level. All independence test outcomes are obtained by simulation.

Table 5:
Multivariate Concordance Indices

	Index value	Observations	Critical Values
Currency crises across countries			
At least 2 crises	0.57	39	18
At least 3 crises	0.29	20	7
At least 4 crises	0.14	10	3
At least 5 crises	0.10	7	1
At least 6 crises	0.09	6	1
At least 7 crises	0.06	4	1
At least 8 crises	0.04	3	1
At least 10 crises	0.03	2	1
At least 12 crises	0.03	2	1
At least 14 crises	0.01	1	1
Crises observations $(n - n_{z=0})$		69	
Banking crises across countries			
At least 2 crises	0.59	26	7
At least 3 crises	0.34	5	2
At least 4 crises	0.14	6	1
At least 5 crises	0.09	7	1
At least 6 crises	0.07	3	1
At least 7 crises	0.07	3	1
At least 8 crises	0.05	2	1
At least 10 crises	0.05	2	1
At least 12 crises	0.02	1	1
At least 13 crises	0.02	1	1
Crises observations $(n - n_{z=0})$		44	

Note: the critical value gives the maximum number of observations for the case at hand that rejects the null hypothesis of multivariate independence at the 5 per cent level.

Table 6:
Simultaneity of currency and banking crises

		Number of periods with z simultaneous banking crises			Total
		$z = 0$	$z = 1$	$z \geq 2$	
Number of periods	$z = 0$	46	4	7	57
with z simultaneous	$z = 1$	19	5	6	30
currency crises	$z \geq 2$	17	9	13	39
Total		82	18	26	126

Figure 1: Distribution of Currency Crises over 1883–2008

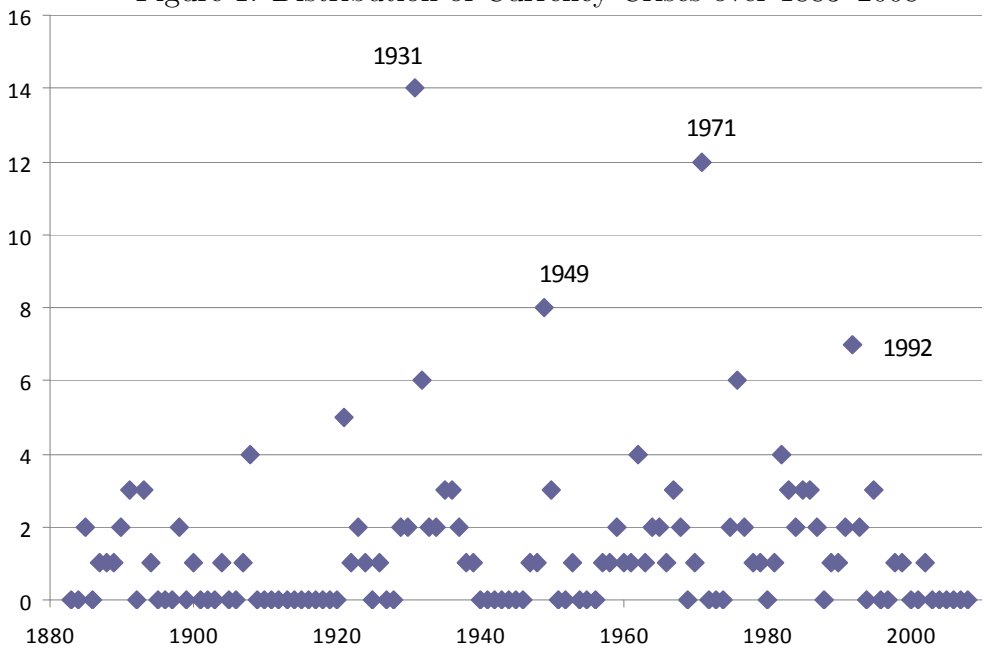

Figure 2: Distribution of Banking Crises over 1883–2008

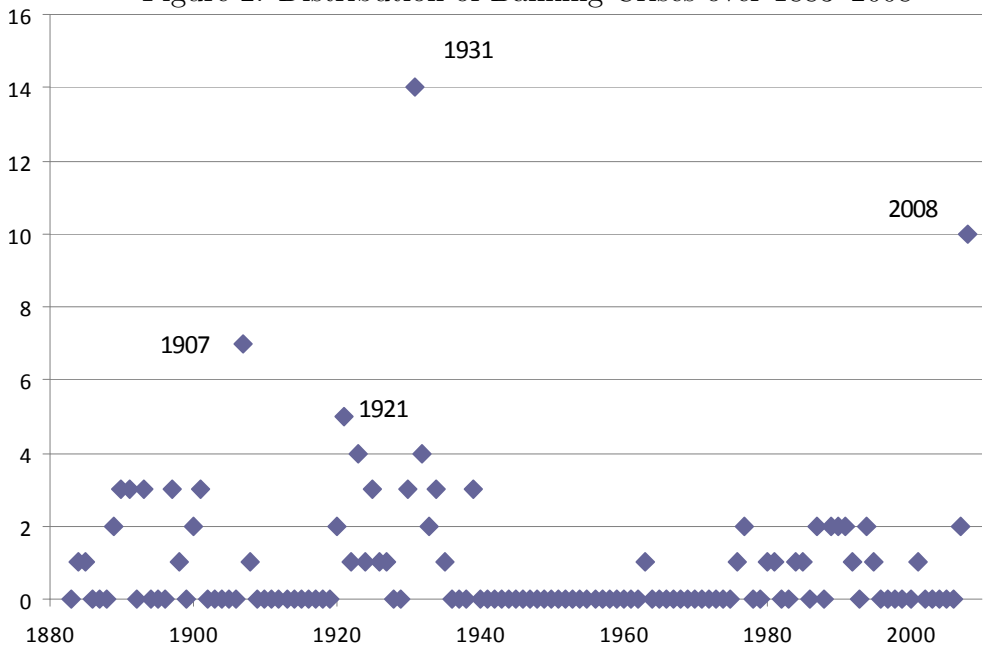

Figure 3: Turbulent-periods concordance index for two series with equal means and all feasible correlations

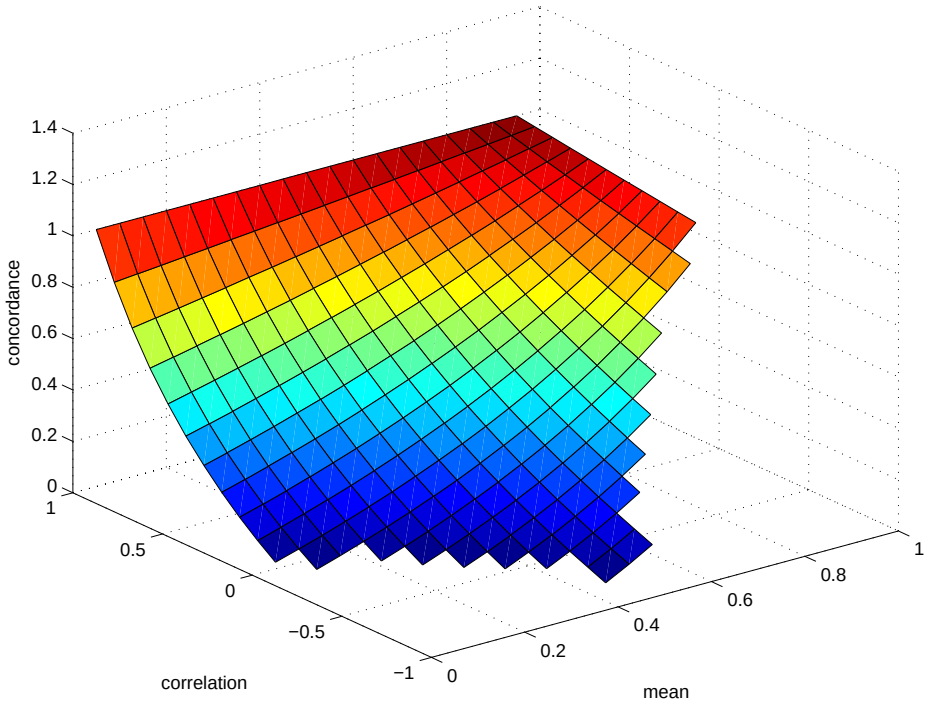

Figure 4: Multivariate turbulent periods concordance index for two or more simultaneous crises as a function of the number of single crisis periods $n_{z=1}$ and the number of tranquil periods $n_{z=0}$

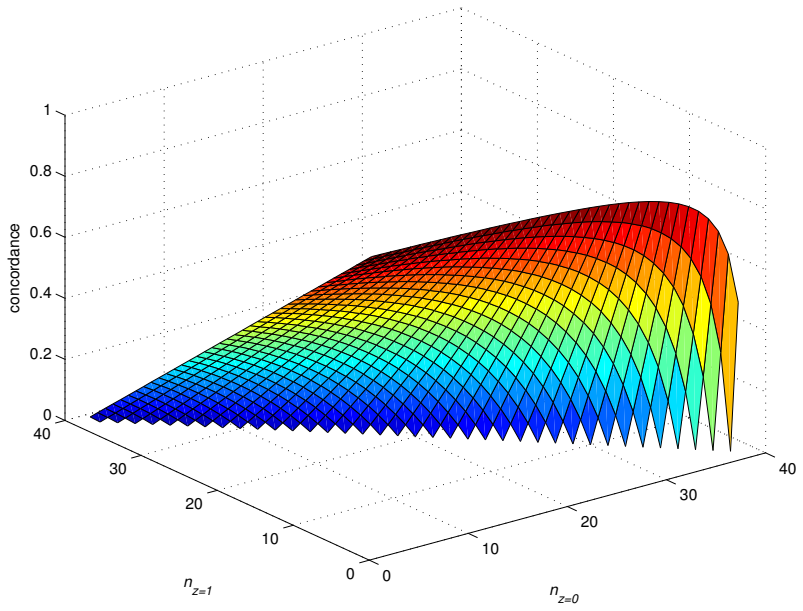

Figure 5: Recursive multivariate concordance indices, 1902–1998