

**FINANCIAL CRISIS PROBABILITY MEASUREMENT MODEL**

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**Methods.** The research used the method of analysis and synthesis – to clarify the nature of modern financial crises, the method of grouping – to determine the types of financial crises, general and specific – to differentiate between different types of financial crises, econometric methods – to quantify the level of systemic risk in the financial sector that leads to the financial crisis.

**Results.** Excessive credit growth, the main cause of financial crises, is reflected in the insufficient capitalization of the financial sector. The paper briefly reviews the theoretical and empirical studies on the developments in these markets around the financial crisis. Market-based measures of systemic risk, such as SRISK, which stands for systemic risk, allow monitoring of how such vulnerabilities emerge and progress in real time.

**Novelty.** This paper presents a quantitative assessment of the level of systemic risk in the financial sector that leads to a financial crisis. The model builds on the theory that deleveraging will have a price impact and the greater the magnitude of the deleveraging, the more dangerous the adjustment. In its most extreme case, the real economy has restricted access to credit as the financial sector experiences a fire sale, thus endogenously generating a financial crisis.

**Practical value.** In an econometric framework, the relationship between SRISK and severity of financial crisis for different developed countries is given. The paper focuses on financial crises characterized by disruptions in credit supply, the lower tail of which may be related to various factors. A report on the probability of a financial crisis is provided in real-time from an indication of excessive credit growth. The study shows the important role of the cross-border external effect of financial non-capitalization.

**Keywords:** financial crisis, measure, method SRISK, macroeconomic, Tobit model, currency.

**Statement of problem.** The process by which undercapitalization leads to a financial crisis has been widely studied in the theoretical macro finance literature and to some extent in the empirical literature. We build on existing empirical measures and come up with quantitative estimates of how much systemic risk it takes to generate a financial crisis.

Financial crises have common elements, but they come in many forms. A financial crisis is often associated with one or more of the following phenomena: substantial changes in credit volume and asset prices; severe disruptions in financial intermediation and the supply of external financing to various actors in the economy; large-scale balance sheet problems; and large-scale government support. Financial crises are typically multidimensional

events and can be hard to characterize using a single indicator.

A financial crisis can take many shapes and forms, but two broad types can be distinguished. Reinhart and Rogoff describe two types of crises: those that are classified using strictly quantitative definitions and those that rely heavily on qualitative and judgmental analysis [1, p. 466–472]. The first group mainly includes currency and sudden stop crises, while the second group includes debt and banking crises. Nevertheless, definitions are heavily influenced by theories that attempt to explain crises.

The literature has been able to achieve specific definitions of many types of crises. For example, a currency crisis involves a speculative attack on a currency that leads to a devaluation

or forces the government to defend the currency by spending large amounts of international reserves, or by sharply increasing interest rates, or by imposing capital controls. A sudden stop can be defined as a large decline in international capital inflows or a sharp reversal of total capital flows into a country, which is likely to occur along with a sharp increase in its credit spreads. Because these are measurable variables, they refrain from using quantitative methodologies.

Systemic risk market indicators allow monitoring of how such weakness manifests and progresses in real time. This paper shows one indicator – SRISK, which stands for systemic risk and measures the dollar amount of capital that a financial firm must raise to operate normally if we have another financial crisis based on stock market data.

Based on the Romer-Romer crisis severity measures, this model estimates the level of undercapitalization that precipitates a financial crisis. Reported crisis probabilities as a function of total capital shortages and other variables for various advanced economies over time. From this estimate, it is possible to calculate a SRISK power that will keep this probability below 50% as long as SRISK remains below this level [2, p.40-43].

**Aim of the paper.** The article is aimed at summarizing theoretical and empirical approaches to the analysis of the development of credit markets and asset markets in the conditions of the probability of financial crises.

**Materials and methods.** *Distribution and Frequency of Crises.* Financial crises often come in bunches. Sovereign defaults tend to come in waves and take place in specific regions. According to Jordà et al, report that there were five major periods when a substantial number of now-advanced countries experienced crises: 1890, 1907, 1921, 1930–1931, and 2007–2008 [3, p. 340-378]. Earlier crises bunched around events such as the Napoleonic Wars (Examples of bunches since the 1980s include the Latin America debt crises in the 1980s; in 1992, the European Exchange Rate Mechanism currency crises; in the late 1990s, the East Asian, Russian, and Brazilian financial crisis; the multiple episodes observed in 2007–2008; and the crises in Europe still ongoing in 2013. Periods of widespread sovereign defaults often coincide

with a sharp rise in the number of countries going through banking crises.

These coincidences point toward common factors driving these episodes as well as spillovers of financial crises across borders. According to the Laven and Valencia report, 147 of the total number of crises are banking crises 217 are currency crises, and 67 are sovereign debt crises during the period 1980–2020 [4, p. 653–700]. However, the various types of crises overlap to some extent. In addition, sudden stop crises, not surprisingly, can overlap with currency and balance of payments crises, and sometimes sovereign crises (Figure 1).

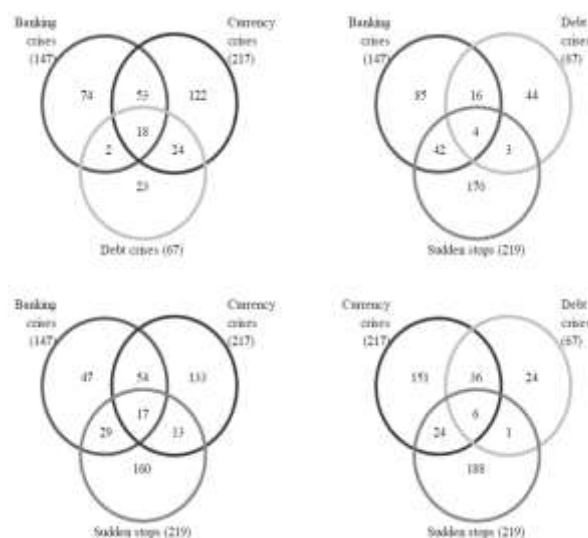


Figure 1. Coincidence of Financial Crises: 1980-2020

Sources: The dates of banking, currency, and debt crises are from Laeven and Valencia and the dates of sudden stops are from Forbes and Warnock (2020).

Note: A financial crisis starting at time T coincides with another financial crisis if the latter starts at any time between T-3 and T+3. A financial crisis starting at time T coincides with two other financial crises if the latter two start at any time between T-3 and T+3. The sample consists of 181 countries.

Of the 431 banking (147), currency (217), and sovereign (67) crises Laeven and Valencia examine they consider 68 to be twin crises, and 8 can be classified as triple crises.

*Real and financial consequences of crises.* The macroeconomic and financial consequences of crises are usually severe and similar in different types of crises. Despite the obvious differences between crises, variables follow similar patterns.

Large output losses are common, and other macroeconomic variables typically show significant declines. Financial variables such as

asset prices and credit tend to follow qualitatively similar patterns during crises, albeit with variations in duration and severity. Will consider a summary of the literature on the macroeconomic and financial consequences of crises.

Financial crises have large economic costs. According to Claessens et al, many recessions are associated with financial crises (Figure 2) [5, p. 653–700].

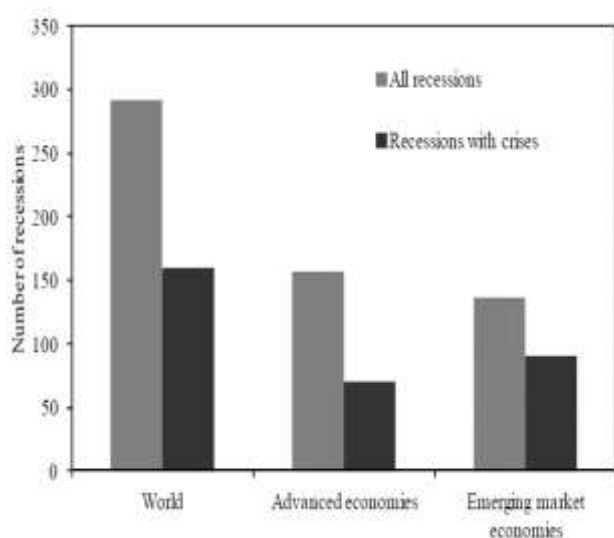


Figure 2. Coincidence of Recessions and Crises

And financial crises often tend to make these recessions worse than a «normal» business cycle recession. The average duration of a recession associated with a financial crisis is some six quarters, two more than a normal recession. And the cumulative loss of a recession associated with a crisis is also much larger than that of a recession without a crisis.

The real impact of a crisis on output can be computed using various approaches. For a large cross-section of countries and a long period, Claessens et al, use the traditional business cycle methodology to identify recessions. They show that recessions associated with credit crunches and housing busts tend to be more costly than those associated with equity price busts.

On this basis, Laeven and Valencia estimate that the cumulative cost of banking crises is, on average, about 23% of GDP during the first four years.<sup>5</sup> Regardless of the methodology, losses do vary across countries. The median output loss for advanced countries is now about 33%, which exceeds that of emerging markets at 26%. Crises are generally associated

with significant declines in a wide range of macroeconomic aggregates. Recessions following crises exhibit much larger declines in consumption, investment, industrial production, employment, and exports and imports compared with those recessions without crises.

For banking crises, Laeven and Valencia estimate that fiscal costs, net of recoveries, associated with crises are on average about 6.8% of GDP. Debt crises can be costly for the real economy. According to Furceri and Zdzienicka debt crises are more costly than banking and currency crises and are typically associated with output declines of 3–5% after one year and 6–12% after eight years [6, p.726–742].

According to Reinhart and Rogoff crisis episodes are often associated with substantial declines in tax revenues and significant increases in government spending. Using a larger sample, Laeven and Valencia report the median increase in public debt to be about 12% for their sample of 147 systemic banking crises. Although empirical work has not been able to pinpoint the exact reasons, sudden stops are especially costly. Using a panel data set for 1980–2000 and covering 24 emerging markets, Hutchison and Noy finds that while a currency crisis typically reduces output by 2–3%, a sudden stop reduces output by an additional 6–8% in the year of the crisis [7, p. 225–248]. The cumulative output loss of a sudden stop is even larger, about 13–15% over a three-year period (of course, this and other analyses can suffer from reverse causality. That is, private agents see events that lead them to predict future drops in a country's output and, as a result, these agents pull their capital from the country. In this view, anticipated output drops drive sudden stops, rather than the reverse).

The risk of a financial crisis in a country depends on the total capital shortfall of the financial sector in this country. The risk of any one country depends on the aggregate SRISK of the rest of the world. Hence, a country that relaxes its regulation or fails to adequately capitalize its institutions will increase the risk of a financial crisis in other countries. This global externality clearly calls for a coordinated approach for regulation to maintain financial stability.

The widespread impact of the 2007–2009 global financial crisis underlines the importance of having a solid understanding of crises.

*Excessive Credit Growth.* It is widely believed that financial crises result from excessive credit growth. Normal operation of a financial firm requires that its market capital ratio be above the prudential capital ratio.

Under some mild assumptions, the formula for SRISK for a financial was adapted by the Englea and Ruanb:

$$SRISK_t = kDebt_r - (1-k)Equity_t \exp(\varrho_t \log(1-\theta)).$$

Where  $\varrho_t$  is the beta coefficient from the dynamic conditional beta (DCB) model [8, p. 643–667] which augments a standard market model with asynchronous trading, time-varying correlation, and asymmetric volatility.  $k$  is set at 8% which corresponds to the typical leverage ratio of well-managed financial firms in tranquil periods. [9, p. 607].

If the crisis were 6 months in the future, the market stress level  $\theta$  would be 40%, because the MSCI ACWI index declined by ~40% in 6 months during the global financial crisis. For insurance companies, 40% of individual accounts are allowed to calculate SRISK. Aggregate SRISK for each country is the sum of all financial firms with positive values.

*Data and Econometric Specifications.* Country-level SRISK data, as well as the total market capitalization and total banking assets, are obtained from New York University (NYU) Stern’s Volatility Laboratory (V-Laboratory). SRISK has been available since 2000. GDP data are from the World Bank (New York University (NYU) Stern’s Volatility Laboratory (V-Laboratory) Systemic Risk Analysis, Systemic Risk Analysis (Global Dynamic MES) of World Financials).

A Rommer-Rommer text-based measure of the severity of the financial crisis is used. It is a semi-annual measure of crisis severity derived from the OECD Economic Outlook available for 24 advanced economies. According to its classification criteria, the main characteristic of the financial crisis is the disruption of credit supply.

Based on the specification tests SRISK/(TA\*k) is the most important variable. A financial crisis represents a left tail event for the economy. Any measure of financial crisis severity does not distinguish between strong and borderline economic conditions as long as a

crisis has not started yet. The Tobit model which recognizes that the dependent variable is truncated at 0 is the preferred estimator. Thus a natural measure of the size of SRISK which is dangerous is SRISK/(TA\*k), where TA stands for the total assets in the financial sector. Consistent with our partial inclusion of separate accounts for calculating SRISK, only 40% of separate accounts are included in total assets.

Consider a domestic model that uses only country-level SRISK variables to explain crisis severity and a global model that expands the set of explanatory variables with world SRISK variables. For each country, the world SRISK variables are calculated using the sum of the respective country-level variables across all other countries. This modification also facilitates the SRISK capacity measure developed later.

The estimation results are reported in Table 1. The SRISK/(TA\*k) variable is highly significant in either the domestic model or the global model. Columns 1 and 2 in Table 1 are the specifications with the best Schwarz criterion among many specifications including many not reported here for the domestic and global models, respectively.

Based on the Tobit model, it is possible to quantify the distance from the financial crisis. According to Englea and Ruanb, 2 measures are proposed for this quantitative assessment.

**Table 1. Crisis severity and systemic risk measures (Tobit)**

	Romer–Romer crisis severity	
	1)	2)
<b>SRISK/(TA*k)</b>	18.325*** (1.213)	13.165*** (1.366)
<b>D.SRISK/(TA*k)</b>	6.592*** (1.931)	
<b>World SRISK/(TA*k)</b>		14.249*** (2.387)
<b>D.World SRISK/(TA*k)</b>		7.987*** (2.759)
<b>Var(e.CRISIS)</b>	11.102*** (1.263)	9.852*** (1.110)
<b>Country fixed effects</b>	Yes	Yes
<b>Pseudo R<sup>2</sup></b>	0.261	0.291
<b>Observations</b>	561	561

The first one is a probability of a crisis. The second measure gauges whether there is a level of SRISK that makes the probability of a crisis just 50%. In the domestic model, since both  $SRISK/(TA \cdot k)$  and its lag are included in the domestic model is the sum of their coefficients or 24.917. In the global model is the coefficient of country  $SRISK/(TA \cdot k)$  or 13.165. These two measures are calculated on a monthly basis.

*Results and Discussion.* Crisis probabilities and SRISK power are reported from both domestic and global models. The global model captures the important global externality whereby the risk of a crisis in one country is strongly influenced by the rest of the world. The undercapitalization of the financial sector in one country will increase the probability of a crisis in another.

Market-based measures of systemic risk are useful for this analysis because of their forward-looking nature. According to Adrian et al, the conditional value-at-risk (CoVaR) measure is an alternative market-based measure that is closely related to SRISK. The main difference is that SRISK depends also on the firm's volatility whereas CoVaR does not due to differences in conditioning. In addition, SRISK depends on both size and leverage [10, p.19–50].

Besides the Romer–Romer chronology, several other crisis chronologies exist. Almost all of them use a 0 to 1 classification: Either a country experienced a crisis or it did not. The Romer–Romer methodology that compiles a continuous measure of disruptions of credit supply from real-time narrative accounts is suitable for this purpose.

**Conclusion.** Many theories have been developed about the underlying causes of crises. The paper briefly summarizes the theoretical and empirical literature analyzing developments in credit and asset markets around financial crises. Financial variables like asset prices and credit usually follow qualitatively similar patterns across crises, albeit with variations in duration and severity. The paper summarizes the literature on the macroeconomic and financial implications of crises.

The paper evaluates a model of systemic risk which is designed to show both the probability of a crisis and the distance between current measures of systemic risk and the level which makes the probability of crisis equal to one-half.

This paper quantifies this process with a simple model that incorporates systemic externalities both within countries and between countries.

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## МОДЕЛЬ ВИМІРЮВАННЯ ЙМОВІРНОСТІ НАСТАННЯ ФІНАНСОВОЇ КРИЗИ

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**Методологія дослідження.** При проведенні дослідження було використано метод аналізу й синтезу – при з'ясуванні природи сучасних фінансових криз, метод групування – при визначенні видів фінансових криз, загального й особливого – для проведення диференціації між різними видами фінансових криз, економетричні методи – для кількісної оцінки рівня системного ризику у фінансовому секторі, який призводить до фінансової кризи.

**Результати.** Надмірне зростання кредитування, що є головною причиною фінансових криз, відображається у недостатній капіталізації фінансового сектора. У статті подано короткий огляд теоретичних та емпіричних досліджень розвитку подій на ринках, що виникають внаслідок фінансових криз. Продемонстровано, що ринкові показники системного ризику, такі як SRISK, дозволяють відстежувати, як виникають і розвиваються системні ризики в режимі реального часу.

**Новизна.** У цій роботі представлено кількісну оцінку рівня системного ризику в фінансовому секторі, який призводить до фінансової кризи. Модель ґрунтується на теорії, згідно з якою зменшення боргу матиме вплив на ціну, і чим більшою буде величина зменшення боргу, тим небезпечнішим коригування. У крайньому випадку реальна економіка обмежує доступ до кредитів, оскільки у фінансовому секторі відбувається зниження ціни на фінансові активи, і у такий спосіб ендогенно породжує фінансову кризу.

**Практична значущість.** В економетричній системі існує зв'язок між SRISK і серйозністю настання фінансової кризи для групи розвинених країн. Стаття зосереджена на фінансових кризах, що характеризуються нестабільністю пропозиції кредитів, нижня межа яких може бути пов'язаний з різними факторами. Звіт про ймовірність фінансової кризи надається в режимі реального часу за ознакою надмірного зростання кредитування. Дослідження показує важливу роль транскордонного зовнішнього ефекту фінансової некапіталізації.

**Ключові слова:** фінансова криза, оцінка, методика SRISK, макроекономіка, модель Тобіна, готівкові гроші.

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