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An Analytic Network Process model for financial-crisis forecasting

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Abstract

We discuss and develop an imbalance-crisis turning point model to forecast the likelihood of a financial crisis based on an Analytic Network Process framework. The Analytic Network Process (ANP) is a general theory of relative measurement used to derive composite-priority-ratio scales from individual-ratio scales that represent relative influence of factors that interact with respect to control criteria. Through its supermatrix, which is composed of matrices of column priorities, the ANP framework captures the outcome of dependence and feedback within and between clusters of explanatory factors. We argue that our framework is more flexible and is more comprehensive than traditional methods and previous models. We illustrate how the ANP model would be implemented for forecasting the probability of crises.

Keywords: Financial crises; Modeling; Analytic Network Process (ANP); 1991 U.S. banking crisis

1. Introduction

William Stanley Jevons (1835–1882) was a highly respected and influential economist and statistician of his time. Jevons argued in his book, *Investigations in Currency and Finance*, the economy underwent a series of "commercial crises," which he traced back to the 18th century. Jevons' view of the trade or business cycle as a *sequence of crises* was embraced broadly throughout the economics profession until the 1920s. Then as more economic and financial data were compiled and newer statistical techniques were crafted to analyze them, Wesley Mitchell's "statistical cycles" replaced the event-driven concept of the business cycle. *Statistical time-series cycles* continue to underlie modern business cycle research. Today, cyclical composite index models, probit models, hidden Markov models (HMM), and threshold autoregressive (TAR) models are some typical methodologies used to forecast turning points in statistical cycles.

However, over the last 10 years, the literature on financial crises rediscovered the traditional Jevons view of the cycle, where a turning point is triggered by some economic and/or political event. Financial crises are *sudden events* that may and often do occur after a growth cycle slowdown begins or classical business cycle recession ensues. Crises are predicated on some development, such as a collapse of a financial or nonfinancial institution or the recognition of a major imbalance in the financial sector, such as heavy debt holdings or too much dependence on foreign capital.

In modern crisis theory of the business cycle, three types of financial crises are identified: *fiscal,*

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banking, and *currency* (Sachs, 1998). A *fiscal crisis* occurs when a government cannot roll over foreign debt and/or attract new loans. A *currency crisis* occurs when investors shift demand to foreign-denominated assets and away from domestic assets. A *banking crisis* occurs when a bank cannot attract enough new deposits to meet sudden withdrawal of reserves. Each of these crises can exist independently or in conjunction with one or more other crisis.

Statistical data needed to track and to forecast a potential financial-crisis point can be somewhat illusive from country to country. Data limitations exist especially in some emerging market economies that have undergone major structural change. In those countries, historical data are no longer consistent with the present institutions and, as such, are insufficient to signal a financial crisis before it occurs. Even when data exist, judgmental variables play a role in statistical models, as witnessed by the "freedom from corruption" qualitative variable in the probit model by Radelet and Sachs (1998).

For these reasons, we propose a flexible and comprehensive framework to simultaneously model and forecast the three types of financial crisis using an Analytic Hierarchy Process (AHP) with feedback, which is known as the Analytic Network Process (ANP) as developed and implemented by Saaty (1996). The Analytic Network Process also provides a structure that potentially can reduce judgmental forecast error through improved "reliability of information processing."[1]

The modeling application in this paper extends the ANP recession forecasting model by Blair, Nachtmann, Saaty, and Whitaker (2002) to capture key economic concepts specified in the financial-crisis econometric model by Kaminsky and Reinhart (1999), the contagion econometric model by Lowell, Neu, and Tong (1998), as well as the studies by Aziz, Caramazza, and Salgado (2000), Burns (1969), Glick and Moreno (1999), International Monetary Fund (1998), Kindleberger (1996), and Wolfson (1994). Our ANP financial crisis model's determinants are directly specified using quantitative and qualitative variables and empirically tested using an "expert system" approach instead of a true "expert opinion" approach—as the Blair study did—to allow for an historical back-test.

2. The ANP financial crisis model structure

The Analytic Network Process provides the mathematical framework for our model to forecast a financial-crisis probability using heuristics. Conceptually, the financial-crisis model can be described as a system of N components (which may be part of a cluster of components) that forms a network where every component (C_{n}) can interact or have an influence on itself or some or all of the other components of the system. The network, N, equals $\{C_a, C_b, C_c, \ldots, C_n\}$ where $L=\{\{C_a, C_a\},\{C_a, C_b\},\{C_a, C_c\},\ldots,\{C_n, C_n\}\}$ and represents the set of pairwise linkage within or between components of the network. The ANP-based crisis-forecasting model provides a formal

[1] Judgmental forecasting accuracy is difficult to establish ex ante since it is impossible to go back in time and evaluate how a person or group would have forecasted a situation. However, one insight from Stewart and Lusk (1994) is worth considering. The authors proposed a seven-part decomposition of Murphy's skill score for measuring judgmental forecast accuracy, which is defined as:

$$\mathrm{ss} = (r_{fa})^2 - \left[r_{fa} - \left(\frac{s_f}{s_a}\right)\right]^2 - \left[\frac{[\bar{F} - \bar{A}]}{s_a}\right]^2$$

where r_{fa} is the correlation between the forecast (f) and the observed or actual event (a); s_f and s_a are the standard deviations of the forecast and the actual values, and the notation F and A with the bars over the letters designate the means of the forecast and the actual values. The first term—the square of the correlation coefficient—represents the "potential" skill of the forecaster or judgmental forecast. The second term is "conditional bias" and will be equal to zero when the regression slope between the forecast and actual values is one. The third term is "unconditional bias"; as the difference between the forecast and actual means increases, the intercept of the regression line between the forecast and actual departs from zero. The Stewart and Lusk version of the Murphy skill score divides the first term into five additional segments, which represent: (1) environmental predictability, (2) fidelity of the information, (3) match between the environment and the forecaster, (4) reliability of information acquisition, and (5) reliability of the information processing. The last two components of the skill score are retained by Stewart and Lusk. The authors observed that their decomposition of the skill score into seven subcriteria for evaluation was to emphasize the conceptual and theoretical issues, but the skill score, while useful for empirical analysis of forecast performance, faced a major limitation that "the data necessary to estimate all the parameters of the full decomposition will rarely be available." So what is the point? The authors argued that decomposition provides a sense of where judgmental forecasts can go wrong. Hence, one of their proposed methods to improve judgmental forecasts was to decompose the forecast task. In essence, this provides another reason to use the Analytic Network Process for judgmental forecasting since it structures the forecast decision-making process based on key determinants or criteria.