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Network linkages to predict bank distress☆

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ABSTRACT

Building on the literature on systemic risk and financial contagion, the paper introduces estimated network linkages into an early-warning model to predict bank distress among European banks. We use multivariate extreme value theory to estimate equity-based tail-dependence networks, whose links proxy for the markets' view of bank interconnectedness in case of elevated financial stress. The paper finds that early warning models including estimated tail dependencies consistently outperform bank-specific benchmark models without networks. The results are robust to variation in model specification and also hold in relation to simpler benchmarks of contagion. Generally, this paper gives direct support for measures of interconnectedness in early-warning models, and moves toward a unified representation of cyclical and cross-sectional dimensions of systemic risk.

1. Introduction

The global financial crisis has stimulated research on deriving tools for monitoring systemic risk and contagion risk. This is usually approached from two perspectives: the structural and cyclical dimensions of systemic risk. While early-warning models tackle the cyclical dimension and build-up of systemic risk, various network approaches address structural or cross-sectional aspects related to an interconnected financial system. This paper contributes to the field by combining a model of bank distress with bank networks of interconnectedness, in order to account for the propensity of distress to spread in early-warning exercises.

We address systemic risk surveillance by introducing bank networks into an early-warning model to predict bank distress. With a two-step estimation, we rely on the assumption that the vulnerability of one bank is also defined by the vulnerability of its neighbors. This paper provides a general-purpose framework that enables combining any type of networks with any type of distress models. While previous literature on bank-level early-warning models have ignored potential network effects by focusing solely on individual bank distress, the key contribution of the paper is that it explicitly combines potential contagion effects through tail dependencies in a bank failure model. The network perspective is modeled with the multivariate extreme value theory approach of Poon et al. (2004) to estimate tail-dependence networks based on equity prices, which proxy markets' view of bank interconnectedness via direct bilateral or common exposures. Despite being estimated networks, they are not necessarily inferior to real

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exposure data, as the market's view also accounts for more indirect sources of interdependence, such as common and correlated exposures and behavioral aspects. These networks are combined with the early-warning model of Betz et al. (2014) using bank-specific and country-level indicators to provide information on the potential spread of distress through interconnectedness in the banking system. We apply our approach in a European setting with 171 listed banks over 1999Q1–2012Q3.

The paper is related to several strands of literature. First, the sole assumption of an interconnected financial system relates to the theoretical literature on (indirect) contagion (e.g., Freixas et al., 2000; Cifuentes et al., 2005; Brunnermeier, 2008; Brunnermeier and Pedersen, 2009; Tirole, 2011). More concretely, our approach to estimating tail-dependence networks relates mainly to the literature on multivariate extreme value theory (e.g., Poon et al., 2004), as well as more generally to the literature on financial contagion through extreme value theory (e.g., Bae et al., 2003; Hartmann et al., 2004, 2005; Gropp and Moerman, 2004 April; Longin and Solnik, 2001; Gropp et al., 2009). Beyond this, the literature has obviously also proposed a number of other approaches to estimating tail-dependence networks, such as Diebold and Yılmaz (2014), Hautsch et al. (2014), Hautsch et al. (2014), and Betz et al. (2014). On a more general note, the literature has its basis in network structures and contagion as described in a seminal paper by Allen and Gale (2000), as well as in Battiston et al. (2012), Gai et al. (2011) and Battiston et al. (2012), and also surveyed in Nier et al. (2007) and Allen and Babus (2009). Moreover, at the bank level, a directly related study is Hale et al. (2014), in which they show the impact of crises through direct and indirect exposures on bank profitability.

A more related strand of literature has focused on network effects in early-warning models. While being few in number, previous works have accounted for the interconnectedness in assessing and predicting systemic risks. In particular, Mikhail et al. (2013) used indicators of the cross-sectional dimension of systemic risk through connectivity indicators, such as CoVaR, in order to signal banking crises, Minoiu et al. (2013) assess the link between overall cross-country financial connectedness and vulnerability to banking crises, and Peltonen et al. (2014) analyze the impact of both cross-country and domestic interconnectedness in terms of four different financial instruments as vulnerability to banking crises. Yet, in relation to the present paper, these are all at the country level and compute only overall interconnectedness as a vulnerability rather than allowing for distress pass through in networks. In contrast, this paper builds upon and extends the bank failure model by Betz et al. (2014), by complementing it with the estimated tail-dependence network. Beyond country vulnerability indicators, it also includes a country-specific fixed effect to proxy for cross-country heterogeneity like supervisory standards.

The paper finds that models including estimated tail dependencies consistently outperform the benchmark model, which is based solely on bank-specific and country-specific data and does not account for any type of vulnerability transmission. For country-specific data, the variables cover both sector level and macro-financial variables. Our results are robust to a wide range of variation in model specification, such as different network estimations, policymaker's preferences, forecast horizons and selections of explanatory factors. For assessing the out-of-sample performance of different early-warning models we use signal evaluation concepts for classification problems, which are wide-spread in machine learning and statistics. The methodology can be summarized as follows: we start by splitting the data sample into an in-sample period, used to estimate the early-warning model, and an out-of-sample period, used to make predictions and assess the model's performance. The out-of-sample predictions are made iteratively, one quarter at a time, while the in-sample period increases by one quarter after each iteration. After the full iteration, we compute the performance of the model based on the out-of-sample signals, by comparing the predictions delivered by the model to the historically observed bank distress events.

For comparison purposes, we construct contagion variables that are either based on estimated network linkages or location of banks' incorporation (country-level contagion). The results show that for the in-sample estimations, all country and network contagion coefficients are statistically significant and have the expected sign: the probability of banks being vulnerable increases if the bank is exposed to contagion from already vulnerable neighbors. The network contagion coefficients also have the highest magnitude when compared to the country contagion ones. In out-of-sample evaluations, the results of the network-based contagion outperform those of simpler contagion benchmarks, such as geographically neighboring banks. Even though the magnitude of the improvement in out-of-sample performance for the two models with network contagion variables is modest, it is statistically significant. This improvement comes from better performance both in terms of missing less crises (reduced false-negative rate) and giving fewer false signals (reduced false-positive rate). When the contagion variables are built using the location of banks' incorporation, there is almost no change in the results compared to the benchmark case, where no contagion is assumed.

These results give a direct support for including measures of interconnectedness and proxies for contagion when building early-warning models. From a policy perspective, they emphasize the need for macro-prudential perspective to complement micro-prudential analysis of individual bank's risk drivers to monitor systemic risk and analyze contagion risk. It is not only enough to either identify vulnerabilities due to linkages among entities or individual distress probabilities, but clearly useful to combine this information. In particular, this provides early steps toward a unified representation of cyclical and cross-sectional dimensions of systemic risk.

The remainder of the paper is organized as follows: Section 2 describes the modeling framework and Section 3 the data used in the analysis. Section 4 presents the results and also discusses their robustness, while Section 5 concludes. Appendix A includes summary statistics and additional robustness tests.

2. Modeling framework

This section presents a modeling framework for combining early-warning models with bank networks. We estimate individual probabilities of bank vulnerability and complement them with network linkages that account for possible transmission of vulnerabilities between banks. The rationale behind the simultaneous use of early-warning models and networks is that this allows for capturing the vulnerabilities that descend directly from each entity itself as well as indirectly from other interlinked entities. Although this paper uses market data to estimate how the realization of negative shocks for any bank's returns may depend on the realization of negative shocks of other banks' returns, it is worth noting that this is a general-purpose framework that is independent of the techniques used for deriving the probabilities and the network linkages. In addition to tail-dependence networks, this section presents the approaches used for deriving and evaluating early-warning models, as well as their combination with network linkages.

2.1. Tail-dependence networks

Given that data on interbank lending and exposures in Europe is not publicly available, we use market data to estimate how the realization of negative shocks for any bank i's returns may depend on