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Diversification and systemic risk

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ABSTRACT

Portfolio diversification makes investors individually safer but creates connections between them through common asset holdings. Such connections create "endogenous covariances" between assets and investors, and enhance systemic risk by propagating shocks swiftly through the system. We provide a theoretical model in which shocks spread through constrained selling from N diversified portfolio investors in a network of asset holdings with home bias, and study the desirability of diversification by comparing the multivariate distribution of implied losses for every level of diversification. There may be a region on the parameter set for which the propagation effect dominates the individually safer one. We derive analytically the general element of the covariance between two assets i and j. We find agents may minimize their exposure to endogenous risk by spreading their wealth across more and more distant assets. The resulting network enhances systemic stability.

1. Introduction

When thinking about financial markets and systemic risk, one can find it useful to consider a group of climbers roped together at the top of a cliff. Each climber individually favors being roped as it lowers his chances of falling off, yet one climber slipping now threatens the stability of his neighbors. The effect of being roped on the probability that many or all climbers fall is thus a priori ambiguous.

Prior to the 2008 credit crunch, both market participants and regulatory instances seemed to favor the roped equilibrium, implicitly assuming that individual soundness leads to systemic soundness. Yet the swiftness with which risk spread throughout the market, largely unanticipated, led to suspicions that "connections" may in fact carry systemic risk through the system. Basel III will apply an extra capital ratio requirement of up to 2.5% to well connected establishments. Measures of systemic importance that account for externalities, such as Covar (Adrian and Brunnermeier, 2011), or Shapley values (Tarashev et al., 2010) have recently gained in popularity.

This change in focus has implications on the desirability of portfolio diversification from society's perspective. Indeed while the individually risk reducing effect of diversification has been known since Markowitz (1952), diversification also forms connections between investors through common asset holdings, identified as a major vehicle of contagion in the presence of fire sales (Shleifer and Vishny, 2012). The goal of this paper is to take a first step towards quantifying this contagion externality and comparing it to the individual risk-reducing effect, in order to get a primary assessment of diversification's total impact on systemic risk, as well as the factors on which this impact may depend.

We do so by setting a model in which investors react to stochastic shocks on their wealth by selling/buying assets, which further impact asset prices and wealth, and so on. This occurs in a "home biased" network, in which investors acquire assets which have low informational distance with those they already own. The model generates a normal multivariate distribution[1] of investors wealth. Systemic risk is then studied through the probability that a number η of investors fall below a given bankruptcy threshold K, for different levels of diversification. We then discuss the desirability of each level of diversification by attaching to each probability a cost that grows exponentially with η.

[1] Schematically, this approach allows us to map the individually risk reducing effect and the contagion externality into two distinct components of systemic risk: the former affects in the marginal distribution of each element on the vector of investors wealth, while the latter is embedded within the dependence structure between all N investors.

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We find intermediate numbers of bankruptcies are less likely with a high degree of diversification, but the probability that many or all investors fail simultaneously is larger. In a context of high selling constraint and weak demand, the probability of "extreme failure" outcomes becomes non-trivial, so that no or little diversification may become optimal for society. We then introduce a touch of heuristics in the model by allowing agents on the demand side to grow more risk averse in a high variance environment. We find this strongly enhances the desirability of higher levels of diversification through a more indirect channel: spreading shocks across assets lowers the chances of triggering a panic. In this context, intermediate levels of diversification appear particularly harmful as they provide linkages through which shocks may spread without going far enough in minimizing individual risk and the likelihood that a panic occurs.

Our set-up also allows us to derive an analytical expression for the covariance between assets/investors i and j. In this case covariances depend negatively on the distance between i and j in the financial network and on the number of assets in the economy. We show that an investor may minimize the variance of his portfolio by seeking assets which are far away from his in the financial network. We discuss the systemic implications of the resulting "optimal" network in which all investors are no longer biased, and that of a "wider" network, i.e., one in which there are more assets. Moving to an optimal network is generally desirable for systemic risk, while moving to a wider one is unambiguously so. A mix of more optimality and width is particularly efficient, notably for intermediate levels of diversification which previously were the most dangerous option from a systemic perspective.

Previous work on the link between diversification and systemic has been split between three strands of literature which have rarely crossed.

The first concerns small-scale[2] models of financial contagion. Such models highlight different channels through which common asset holding may lead to fire sales, which may in turn degenerate into systemic events. Schinasi and Smith (2000) for instance show that routine portfolio rebalancing brings contagion. The scope is increased when agents are subject to wealth effects as in Kyle and Xiong (2001). Goldstein and Pauzner (2004) point out that fire sales may also result from strategic risk.[3]

The second strand of literature is based on statistical analysis. One method, taken by Shaffer (1994) or Wagner (2010), is to compare the properties of a fully diversified situation to a fully undiversified one. Both authors show that the risk that all investors fail simultaneously is necessarily higher in the fully diversified situation. Our study confirms this fact but also goes more in depth by considering any level of diversification and any number of failures. A second approach deals with "fat tails", which may mitigate the strength of the variance reducing effect, as showed by Samuelson (1967). In particular, Ibragimov et al. (2011) use an indicator of the tail behavior of returns to define a diversification threshold. They find that on a given parameter range there can exist a wedge between investors interests and society ones.

The link between these first two strands is the correlation structure between asset prices. In any contagion model correlations between asset returns appear endogenously as an output, as even two securities which are "fundamentally" independent become linked through the investors who hold them. In statistical analysis high correlations are an input, as they may cause "fat tailed" portfolios.

The last strand of literature related to this work deals with network analysis of financial stability. In particular, this paper may be related to previous work on the "robust yet fragile" feature of the financial system, as in Nier et al. (2007) or Amini et al. (2012).

The broad method of this paper is to bridge these three approaches, by proceeding in three steps:

(1) *setting up a large scale contagion model.* N constrained "portfolio investors" who hold from 1 to N assets are forced to sell to "convergence traders" in response to negative shocks on their wealth. This lowers prices, further tightening the constraint, and so on. Mathematically this translates into a linear system of N recurrence equations of price returns, in which the amount of recurrence will depend on the weight of the constraint on investors and the discount on the sales.
(2) *within a specified network*. We set two characteristics for investors: they are home biased, and all have the same pattern of asset holdings. The latter leads the network and matrix of asset holdings and to be circulant. This feature is what allows us to solve the system, obtaining analytical expressions for the covariances between assets and investors that depend on distance.[4]
(3) *in order to study systemic risk through statistical analysis and analytical expression of the covariances*. Statistical analysis is run through the multivariate distribution of portfolio losses, which gives us the likelihood that any number of investorsη between 0 and N fail, for a given level of diversification n.

To the best of our knowledge two recent papers have used a similar approach in terms of obtaining endogenous covariances from a theoretical model. Danielsson et al. (2011a,b) define a multivariate model which produces a matrix of covariance of unrestricted dimensions. The correlations obtained have a "fundamental" and an "endogenous risk" component, where endogenous risk is the risk resulting from "the actions of market participants which are hard wired in the system". Cont and Wagalath (2012) specify a similar but more aggregated model, which they calibrate to estimate the realized covariance matrix during well-known fire sales episodes, such as the aftermath of the collapse of Lehman brothers.

Our study places itself within this endogenous risk approach, but differs from these papers in that it puts the network of asset holding at the center of the analysis. In spirit, both papers focus on explaining the pattern of prices correlation during crisis episodes, while our interest lies primarily with the desirability of diversification from a systemic perspective.

Finally, the paper shares some of its conclusions with Caccioli et al. (2012) who find that there might be a window on the diversification spectrum for which systemic risk may become significant. Caccioli et al. study the asymptotic properties of the financial system as a function of the average number of connections of a node in an otherwise random network. Our model is micro founded, and specifies a given network based on economic evidence. This gives the model a greater granularity. In particular we show that different micro foundations lead to different

[2] The models usually feature only 2 assets, and diversification is defined as how evenly an investor spreads his wealth across both. A notable exception is provided by Lagunoff and Schreft (1999) who try moving to a 3 assets case. They find that the scope for contagion is decreased.

[3] Others authors relate diversification to different amplification mechanisms, which deserve to be mentioned although they will not feature as such in this paper. Market distress may lead to an even wider collapse if it turns into liquidity distress: Adrian and Shin (2010) shows that leverage is negatively correlated to the market value of assets. Allen et al. (2010) find that when investors need to roll debt over, being connected brings a negative reputation externality. We also leave out a potential impact of diversification on "banks not doing their homework". For instance, Jiao et al. (2013) show that diversification may reduce the heterogeneity of investors beliefs, Calvo and Mendoza (2000) argue that diversification lowers the incentive for investors to acquire information about securities before selling.

[4] Circulant matrices are a useful tool, and a side goal of the paper is to contribute to widening their use and understanding beyond the fields of pure network analysis and signal theory in which they are more common.