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A network approach to portfolio selection

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ABSTRACT

In this study, a financial market is conceived as a network where the securities are nodes and the links account for returns' correlations. We theoretically prove the negative relationship between the centrality of assets in this financial market network and their optimal weights under the Markowitz framework. Therefore, optimal portfolios overweight low-central securities to avoid the large variances that result when highly influential stocks are included in the investor's opportunity set. Next, we empirically investigate the major financial and market determinants of stock's centralities. The evidence indicates that highly central nodes tend to coincide with older, larger-cap, cheaper and financially riskier securities. Finally, we explore by means of in-sample and out-of-sample analysis the extent to which the structure of the stock market network can be employed to improve the portfolio selection process. We propose a network-based investment strategy that outperforms well-known benchmarks while presenting positive and significant Carhart alphas. The major contribution of the paper is to employ the financial market network as a useful device to improve the portfolio selection process by targeting a group of assets according to their centrality.

1. Introduction

In his seminal paper, Markowitz (1952) laid the foundation of modern portfolio theory. In this static framework, investors optimally allocate their wealth across a set of assets considering only the first and second moment of the returns' distribution. Despite the profound changes derived from this publication, the out-of-sample performance of Markowitz's prescriptions is not as promising as expected. The poor performance of Markowitz's rule stems from the large estimation errors on the vector of expected returns (Merton, 1980) and on the covariance matrices (Jobson and Korkie, 1980) leading to the well-documented error-maximizing property discussed by Michaud and Michaud (2008). The magnitude of this problem is evident when we acknowledge the modest improvements achieved by those models specifically designed to tackle the estimation risk (DeMiguel et al., 2009). Moreover, the evidence indicates that the simple yet effective equally-weighted portfolio rule has not been consistently out-performed by more sophisticated alternatives (Bloomfield et al., 1977; DeMiguel et al., 2009; Jorion, 1991).

Recently, researchers from different fields have characterized financial markets as networks in which securities correspond to the nodes and the links relate to the correlation of returns (Barigozzi and Brownlees, 2014; Billio et al., 2012; Bonanno et al., 2004; Diebold and Yilmaz, 2014; Hautsch et al., 2015; Mantegna, 1999; Onnela et al., 2003; Peralta, 2015; Tse et al., 2010; Vandewalle et al., 2001; Zareei, 2015). In spite of the novel and interesting insights obtained from these network-related papers, most of their results are fundamentally descriptive and lack concrete applications in portfolio selection process. We contribute to

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this line of research by investigating the extent to which the underlying structure of this financial market network can be used as an effective tool in enhancing the portfolio selection process.

Our theoretical results establish a bridge between Markowitz's framework and the network theory. On the one hand, we show a negative relationship between optimal portfolio weights and the *centrality* of assets in the financial market network. The intuition is straightforward: those securities that are strongly embedded in a correlation-based network greatly affect the market and their inclusion in a portfolio undermines the benefit of diversification resulting in larger variances. We refer to the centrality of stocks as their systemic dimension. On the other hand, each security is also characterized by an individual dimension such as Sharpe ratio or volatility depending on the specific portfolio formation objective. Next, we theoretically show a positive relationship between the assets' individual performances and their optimal portfolio weights. In a nutshell, optimal weights from the Markowitz framework can be interpreted as an optimal trade-off between the securities' systemic and individual dimensions in which the former is intimately related to the notion of network centrality.

From a descriptive perspective and relying on US data, we present evidence indicating that financial stocks are the most central nodes in the financial market network in accordance with Peralta (2015) and Tse et al. (2010). Additionally, we document a positive association between the centrality of a security and its corresponding beta from CAPM pointing out the large, although not perfect, correlation between this network indicator and the standard measure of systematic risk. In order to identify the salient financial and market features affecting securities' centrality, we estimate several specifications of a quarterly-based panel regression model upon a set of 200 highly capitalized stocks in the S&P500 index from Oct-2002 to Dec-2012. Our results present some empirical evidence indicating that highly central stocks correspond to old firms with low prices, great market capitalizations and low cash holdings.

Finally, by means of in-sample and out-of-sample analysis, we investigate the extent to which the structure of the financial market network can be used to enhance the portfolio selection process. In order to check the robustness of our results and to avoid data mining bias, four datasets are considered, accounting for different time periods and markets. We propose a network-based investment rule, termed as ρ-dependent strategy, and report its performance against well-known benchmarks. The evidence shows that our network-based strategy provides significant larger out-of-sample Sharpe ratios compared to the ones obtained by implementing the $1/N$ rule or Markowitz-based models. Moreover, these enhanced out-of-sample performances are not explained by large exposures to the standard risk factors given the reported positive and statistically significant Carhart alphas. Finally, it is worth mentioning that our results are robust to different portfolio settings and transaction cost. We argue that our network-based investment policy captures the *logic* behind Markowitz's rule while making more efficient use of fundamental information, resulting in a substantial reduction of wealth misallocation.

The contribution of the paper is twofold. On the one hand, this paper sheds light on the connection between the modern theory of portfolios and the emerging literature on financial networks. On the other hand, our network-based investment strategy attempts to simplify the portfolio selection process by targeting a group of stocks within a certain range of network centrality. As far as we are aware, Pozzi et al. (2013) is the only paper that attempts to take advantage of the topology of the financial market network for investment purposes. They argue in favor of an unconditional allocation of wealth towards the outskirts of the structure. We depart from their results by proposing the ρ-dependent strategy which is contingent on the correlation between the systemic and individual dimensions of the assets comprising the financial market network. Moreover, and in contrast to their synthetic centrality index, we show that our measure of centrality is strongly rooted in the principles of portfolio theory.

The remainder of the paper is organized as follows. Section 2 presents the notion of assets' centrality in the financial network and its connection to Markowitz framework. Section 3 describes the datasets used in the empirical applications. Section 4 provides a detailed statistical description of stocks in accordance to their centrality. Section 5 addresses the interaction between assets' centrality and optimal portfolio weights by relying on an in-sample analysis. Section 6 presents the ρ-dependent strategy and compares its out-of-sample performance to various conventional portfolio strategies. Finally, Section 7 concludes and outlines future research lines.

2. A bridge between optimal portfolio weights and network centrality

The notion of centrality, intimately related to the social network analysis, aims to quantify the influence/importance of certain nodes in a given network. As discussed in Freeman (1978), there are several measurements in the literature each corresponding to the specific definition of centrality. The so-called *eigenvector centrality*, firstly proposed by Bonacich (1972), has become standard in network analysis. This section formally defines this measure and determines its relationship with optimal portfolio weights.

2.1. Defining network centrality

We denote by $G=\{N,\omega\}$, a network composed by a set of nodes $N=\{1,2,\dots,n\}$ and a set of links, ω, connecting pairs of nodes. If there is a link between nodes i and j, we indicate it as $(i,j)\in\omega$. A convenient rearrangement of the network information is provided by the $n\times n$ adjacency matrix $\Omega=[\Omega_{ij}]$ whose element $\Omega_{ij}\neq 0$ whenever $(i,j)\in\omega$. The network G is said to be undirected if no-causal relationships are attached to the links implying that $\Omega=\Omega^T$ since $(i,j)\in\omega\Longleftrightarrow(j,i)\in\omega$. When Ω_{ij} entails a causal association from node j to node i, the network G is said to be directed. In this case, it is likely that $\Omega\neq\Omega^T$ since $(i,j)\in\omega$ does not necessarily imply $(j,i)\in\omega$. For unweighted networks, $\Omega_{ij}\in\{0,1\}$ and therefore only on/off relationships exist. On the contrary, when