A Strategic Analysis of Portfolio Compression

Extended Abstract

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ABSTRACT

We analyze portfolio compression, the netting of cycles in a financial network, as a strategic decision made by firms within a debt network. We define a network game in which firms have only local information and ask what criteria the firms should consider in their decision to compress. We propose a variety of heuristic strategies and evaluate them using agent-based simulation and empirical game-theoretic analysis. Our results show that some simple strategies based on local information perform better than the unconditional strategies of always agreeing or disagreeing to a compression and that when the decision is made strategically, the price of anarchy is always high.

KEYWORDS

financial network; portfolio compression; game theory

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1 INTRODUCTION

The idea of *portfolio compression* is to simplify a web of financial obligations by canceling a cycle of debt, leaving each party's net position the same. Consider Figure 1 where financial institution A owes money to institution B, B owes a like amount to institution C, and C owes the same amount to A and all debts have the same interest rates and maturity dates. When such a cycle is identified the institutions on the cycle must make the *compression decision*, deciding to accept or reject the canceling of debts. Intuitively, canceling the three debts leaves all parties in the same net position, while simplifying their balance sheets. If all are solvent and able to pay the debts when due, the operation of compressing portfolios by canceling the debts has no effect and the compression decision is of little interest. With risk of default, however, portfolio compression is not generally neutral and may affect stability in the network.

Prior analyses of compression have determined that preference for compression among individuals in the network is connected to characteristics of the network. In some cases, compression of a cycle can benefit financial institutions because it limits financial contagion by removing paths of default propagation. On the other hand, portfolio compression can also limit the ability for parts of the network to absorb losses from an insolvent institution, allowing contagion to spread that may have been avoided [2, 4].

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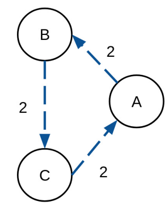

Figure 1: A simple example of a debt cycle.

While these analyses offer us a look at what aspects of the network play an important role in the effects of compression, they are generally conducted with a global view of the network and where details of the external shock are known. In practice, the compression decisions are made by institutions with a limited view of the network and prior to resolution of uncertain financial events. Evaluation of compression decisions, therefore, necessitates a model accounting for uncertainty and incomplete information on the state of the network. Further, prediction of what these firms would decide should also consider strategic effects, recognizing that optimal policies generally depend on how the other firms make their decisions.

To analyze the broader context of compression decisions, we define a one-shot game on a financial network, with nodes representing financial institutions connected by directed edges representing debt obligations. Nodes make a strategic decision to accept or decline a proposed compression using a strategy from a set of heuristic strategies we propose, which may provide useful indications of potential negative effects of compression to the voting node. To evaluate these strategies, we randomly generate networks with debt cycles, and employ agent-based simulation to determine compression decisions and outcomes at different insolvent node recovery rates. Following the methodology of *empirical game-theoretic analysis* (EGTA) [3, 5], we identify Nash equilibria among the heuristic strategies.

Within this environment, we have found evidence that for an individual node, the optimal policy is generally conditional on features of the local network and the individual agent's balance sheet. When the compression decision is made strategically by the nodes, we find that the price of anarchy is high for all recovery rates.

2 COMPRESSION GAME

The game starts with a set of $N = \{1, \ldots, n\}$ nodes each representing a financial institution to which n agents are randomly assigned. Each node is also given a random endowment of external assets, $e_i \sim U[10, 20]$.

We model a *liability* as a directed edge l_{ij} of value v representing v units owed by node N_i to node N_j. The same edge represents an *internal asset* for node N_j. We refer to a node i's *total liabilities*, L_i as the sum of the values on its liability edges. And define the sum of values on node i's internal assets in addition to its external asset holdings as the node's *total assets*, A_i. *Insolvency* can then be formally defined for node i as the case where $A_i - L_i < 0$.

Liability edges are randomly added to the network, creating a set E of network edges, until the network contains at least one cycle $C = (N^c, E^c)$, where $N^c \subseteq N$ and $E^c \subseteq E$, of three or more edges. Note that at this point, all nodes in the network remain solvent.

The game proceeds with a compression vote where agents on a cycle independently cast their vote for the proposed compression using their selected strategy from the strategy set. A compression is performed only if all N^c nodes vote in favor of the compression. We use $\mu = min_{i,j \in N^c, i \neq j} l_{ij}$ to denote the smallest liability on the cycle. Then a *compression* of cycle C is defined by the revised set of liabilities l^c_{ij} for edges on the cycle:

$$\forall l_{ij} \in E^c \quad l^c_{ij} = l_{ij} - \mu.$$

An example of a potential cycle and its subsequent compression can be seen in Figure 2.

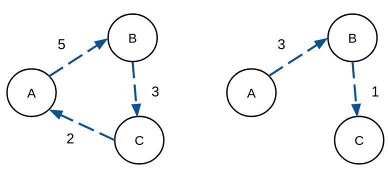

Figure 2: A simple debt cycle before and after compression by two units.

We force insolvency in the network by a shock to external assets, modeled as the failed realization of outside investments. Nodes on a cycle are randomly assigned to invest their remaining external assets in one of two investments with equal probability. All nodes not on a cycle are randomly assigned to either invest their remaining external assets in one of two investment or to not make an investment, with equal probability. One of the investments will be randomly chosen to fail and nodes assigned in it will not recoup any of their investment.

We then make all nodes pay off their debts, using the greatest clearing payment algorithm by Veraart [4] to calculate the payments for each node the resolve the network. At the end of the game, the payoff to the agent assigned to node N_i is the final equity $A_i - L_i$.

2.1 Strategies

Agents may choose from among a set of heuristic strategies to make the compression decision. Each strategy emphasizes a different piece of information available to the node making the decision including assets, liabilities, and cycle's μ-value. We do not claim that our collection of strategies is exhaustive, but rather that they cover a variety of strategically relevant features. The financial institutions we are modeling may always accept a potential compression to comply with regulation or out of a desire to simplify balance sheets, so we include in our analysis the unconditional acceptance strategy YES and its complement the unconditional reject strategy NO.

3 ANALYSIS

We analyze the compression games by extensive simulation of selected strategy profiles through a process known as EGTA. We follow an iterative procedure for selecting profiles to simulate, geared toward identifying symmetric mixed-strategy Nash equilibria, using methods similar to those employed in prior EGTA studies [1, 6]. For some of our games instances, we also apply a method called *deviation-preserving reduction* (DPR), which approximates a many-player game by one with fewer players [7].

Through this approach, we obtain approximate Nash equilibria for six $n = 10$ player games, defined by varying settings of the recovery rate: $\alpha \in \{0, 0.1, 0.3, 0.5, 0.7, 1.0\}$. Games with $\alpha \in \{0.3, 0.7\}$ were reduced from 10-player to 4-player games using DPR.

To analyze the effects of a strategic compression decision on the network, we use the price of anarchy using total equity as the measure of social welfare. Total equity is defined as:

$$E = \sum_i [e_i + \sum_j l_{ji} - L_i].$$

We run the compression game 10,000 times, comparing for each network the outcome with a strategic compression decision made with the Nash equilibria to the outcome under the optimal decision for the network. Then we can define the price of anarchy, P, as:

$$P = \frac{E^s}{max\{E^c, E^{nc}\}}$$

where E^s is the total equity in the network where the compression decision comes from a strategic vote, E^c is the total equity in the network where the cycle is compressed, and E^{nc} is the total equity in the network without compression.

4 PRELIMINARY RESULTS

We find that strategies employing simple, local network information are preferred to the unconditional strategies by nodes making the compression decision. The only exception is when $\alpha = 0$ and the pure Nash equilibrium is YES. The results of the price of anarchy experiment shows that the average price of anarchy is high and close to 1 for all α values. Thus, while self-interested decision makers will not choose the social optimum, the cost to the network of a strategic compression decision is not high.

5 CONCLUSION

Our study provides a first look at the strategic decision facing nodes in a financial network presented with compression opportunities. We focus on the implications for financial contagion, anticipating how a compression may insulate or expose an institution to the effects of an asset shock. Taking a perspective ex ante to the potential shock, we ask what types of strategies nodes with imperfect information should use to make such a decision.

From our results, we can confirm that adopting a heuristic strategy based on privately held information will often be the better response for an individual node in the network. When we compare the choice made by strategic choice to the optimal decision, we see that the price of anarchy remains high. Therefore, allowing compression to be a decision made strategically by nodes in the network will not necessarily always negatively affect systemic risk.

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