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Technical Perspective
Complex Financial Products: *Caveat Emptor*

By David C. Parkes

THE FLOW OF capital in the financial industry relies on the packaging of assets into products that can be reliably valued and then sold to global investors. For example, many home mortgages were packaged into products known as *Collateralized Debt Obligations* (CDOs) in the run-up to the sub-prime mortgage crisis of 2007. An investor in a CDO buys the rights to a share of the principal and interest payments collected from homeowners. By pooling assets and promising to pass along payments before making payments to other investors, new financial products offering lower risk than the underlying assets can be constructed. CDOs are examples of *financial derivatives,* with a value that depends on the underlying assets—mortgages in this case—with which they are linked.

These kinds of complex financial products are the cause célèbre of the financial crisis, and many have called for their regulation or even elimination. In the following paper, Arora, Barak, Brunnermeier, and Ge provide new insight into the problem: a complexity-theoretic explanation for how sellers can hide bad assets in these derivatives. Even when buyers are fully informed, with correct beliefs about the probability with which underlying mortgages are likely to default, sellers can package a disproportionate number of bad assets into some products, and do so without detection. The reason is the intractability of checking whether or not this manipulation has occurred. By focusing on this missing angle of computational complexity, this paper starts to bridge the gap between the common view that derivatives can be rigged and a viewpoint from economics that this is impossible when buyers are fully informed. Computationally bounded buyers may end up significantly overpaying, and a trustworthy seller cannot even prove that financial products have not been rigged.

To understand the reason to sell derivatives in the first place, we can consider Akerlof's famous "lemons problem." Suppose that 80% of second-hand cars are good, and worth $1,000 to buyers, while the rest are lemons and worth $0. Without the ability for a seller to credibly signal the quality of a car, buyers will only pay $800 and trades of good cars by sellers with values in the range [$800, $1,000] are forfeited. If all sellers of good cars want close to $1,000 then the effect of information asymmetry between buyers and sellers is much worse—only lemons remain in the market and there is complete market collapse! Still, a seller with 100 cars, each correctly known by a buyer to be a lemon with probability 0.2, can make a new deal: the right to use up to 80 of the cars. Because it is highly likely that at least this many cars will be good, this deal can be priced at about $80,000, around the price at which it would trade without information asymmetry. The same thing happens in a simple model of CDOs, in which a seller packages assets into a *single* derivative that can be accurately priced and sold.

Now consider a seller with 1,000,000 cars, with the cars partitioned into classes, and the association with a class known to buyers. Each class is a "lemons class" with some probability, in which case it contains only lemons, and otherwise is a "good class" and contains a mixture of good cars and lemons. The probability of a lemons class, and the fraction of lemons in a good class, is known to buyers. The seller again constructs deals, each deal this time consisting of 100 cars drawn from one or more classes. But whereas a buyer knows only the distributional properties of the classes, the seller knows which are lemons and which are good classes. The new problem is this information asymmetry allows a seller to assign a disproportionate number of cars from lemons classes to some deals, and to do so without detection by a computationally bounded buyer! The same story applies for CDOs, where a big bank can choose how to package together assets into derivatives.

The authors establish the intractability of detecting rigged financial products for the kinds of CDOs that arise in the financial industry. The penalty for the realism of their model is that the hardness assumption that they require is not as standard as **P** vs **NP**; rather the results assume the intractability of finding *planted dense subgraphs* in random graphs. The seller is doing the "planting" in this case, by placing a disproportionate number of assets from one class into some subset of products. Under this assumption, CDOs cannot alleviate the lemons problem: either buyers are fooled and sellers make excess profits, or buyers know not to trust sellers. Many believe the planted dense subgraph problem is hard, and this has been considered a plausible conjecture before this paper was published. Still, it is possible this hardness assumption is false, and this should be studied by computer scientists.

This provocative paper should be required reading for commentators and financial regulators alike. Among the questions it raises: Are sellers using this information asymmetry to their advantage in packaging "booby-trapped" CDOs and other financial derivatives? Given that buyers and ratings agencies may not be aware of their own computational limitations, is there a role for regulation in protecting buyers by banning complex financial products that are provably untrustworthy? Do there exist derivatives that cannot be manipulated by strategic sellers, thus avoiding this new lemons cost due to computational complexity?

Buyers might like to reflect on the implications of their bounded rationality. *Caveat emptor!*

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