Can Markets Solve Coordination Problems? A Theoretical and Experimental Investigation

April 15, 2019

# Introduction

Coordination problems and the sources of their resolution are central to Austrian economics and market process theory. In his reinterpretation of F.A. Hayek’s early work, Gerald O’Driscoll (1977) defines “economics as a coordination problem.”. Unlike a Walrasian model of the world where everyone chooses their best action, given the objective facts of the work, for a real economy “It is not sufficient for an individual to have complete knowledge of all objective conditions (technology, resources, and so on).” Instead “the attainment of equilibrium is a coordination problem” (O’Driscoll 1977, 23–24).[[1]](#footnote-1) For Hayek, the interesting question is how such coordination comes about, not simply the definition of equilibrium as when coordination occurs.

Vernon Smith’s experiments provide one answer to Hayek’s question about how equilibrium comes about, even though his 1982 paper is framed as experiment about the market’s ability to economize on information, as (**???**). Instead of assuming everyone was a price-taker, Smith allowed players to post prices. Smith could show an explicit path from disequilibrium to equilibrium. Through what the other famous Smith, Adam Smith, called the “higgling and bargaining of the market”, individual actions led to competitive equilibrium and resolve a coordination problem in markets.

But “coordination problem” has come to mean something different outside of Austrian economics, especially within game theory. To differentiate the broader notion of coordination used by writers like Hayek and the game theory form of coordination, let me use the terms “market coordination” and “game coordination.”[[2]](#footnote-2) Unlike the market coordination in any equilibria, game coordination occurs in any situation where each player’s best-response is to somehow match the other players’ actions. Coordination games have multiple pure-strategy equilibria. If equilibria can be Pareto-ranked, we will call any equilibrium that is not Pareto-optimal a coordination failure.[[3]](#footnote-3) The coordination failure remains as a Nash equilibrium because people cannot contract for a “joint-deviation”; markets are incomplete. Coordination failures of this type would seem to be ubiquitous, at least if we look at the amount of game theory research devoted to them.

Yet, when we look at actual markets, many investments are made in the face of incomplete markets, seemingly without much fear of those dreaded coordination failures. Entrepreneurs develop hardware before the matching software is available. College students invest in skills before looking for jobs. In both examples. the actors must trust that proper market forces will work things out. The amazing thing about markets is their ability to coordinate people’s actions. This project asks, can markets, theoretically and experimentally, solve game coordination problems like they solve market coordination?

To test this question, I will consider a model where people first must sink an investment before entering a market. Since people cannot directly write contracts about their investments, markets are incomplete, and coordination failures can occur. The chance for “better” coordination means there can be gains from trade left on the table. However, gains from trade left on the table also leave open the possibility for entrepreneurs to *discover* those gains. (Kirzner 1973, 14) If we are in a world with a coordination failure, the failure is not immediately obvious to everyone.[[4]](#footnote-4) Each actor does not see the price they would get if they invest more. It is up to the entrepreneurial actor to discover that opportunity. Just as Kirzner argues entrepreneurs will discover arbitrage opportunities (buy low and sell high), I will argue that entrepreneurs will discover coordination opportunities.

# Literature Review

To formally study the connection between market coordination and game coordination, I build on a series of papers that model players as playing a game before entering a market.[[5]](#footnote-5) Makowski and Ostroy (1995) first reformulated a First Welfare Theorem without price-making and incomplete markets. They showed that two conditions were sufficient for markets to generate efficient outcomes:

* full appropriation: each individual’s private benefit from any investment coincides with his/her social contribution;
* non-complementarity: different player’s investments cannot be complementary.

As Makowski and Ostroy show, perfect competition gives full appropriation. However, when there are complementarities, game coordination problems can still arise. Perfect competition alone is not sufficient for efficiency.[[6]](#footnote-6) Further follow up papers, such as Makowski (2004) and most recently Nöldeke and Samuelson (2015) have further generalized results and clarified the connection between competition and efficiency. But the take-away is always the same: coordination failures will plague competitive markets. However, none of these papers examine whether these coordination failure equilibria are robust.

There is an entirely separate literature on adverse selection in Walrasian markets. As Gale (1992) points out, in these models there are many equilibria. However, some of those equilibria are sustained by unreasonable off-equilibrium beliefs. To discipline off-equilibrium beliefs, Gale uses a form of a trembling-hand refinement (Selten 1975). Whether the refinement leads to more or less efficient equilibria depends on the exact context. In Gale (1992) , the refined equilibria are inefficient, while in Gale (1996) they are efficient. More recent studies have been done by Dubey and Geanakoplos (2002), Dubey, Geanakoplos, and Shubik (2005), and Zame (2007).

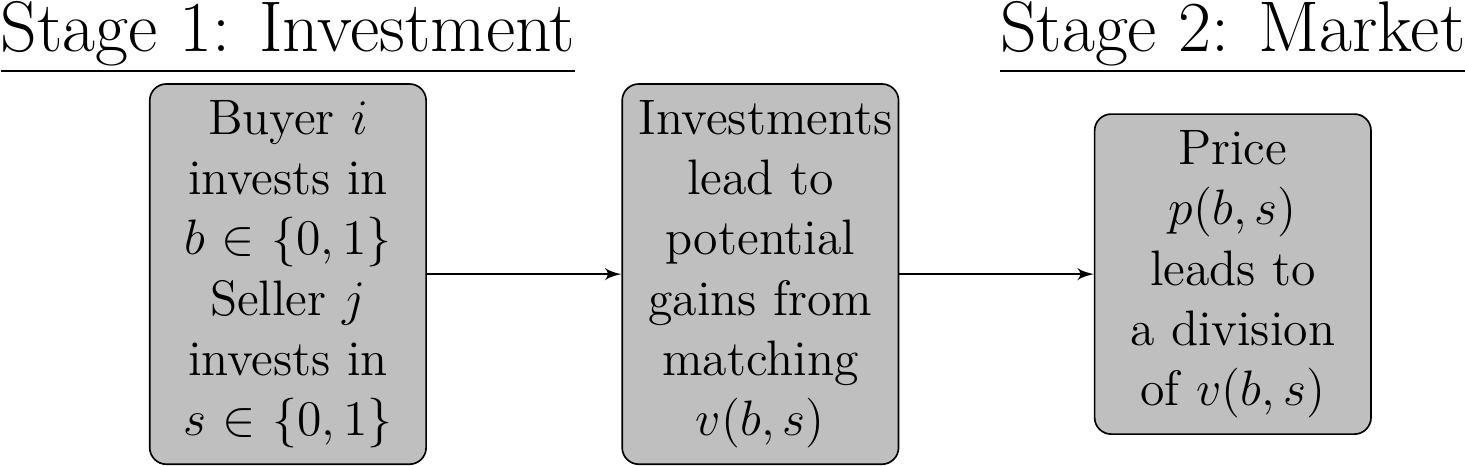
Using the refinement from the adverse selection models, I will argue that coordination failure equilibria are not robust and require people to be hyper-rational. My job market paper formally proves that coordination failures do not survive a trembling-hand refinement, where equilibrium is seen as the limit of a sequence of mistakes that become small. In a sense, Adam Smith’s “higgling and bargaining of the market” can fix coordination failures. This proposal explains the model in my job market paper and how I hope to test the model in the lab.

# Model and Example

Consider a simple example of a two-sided matching market. For consistent language, I talk about buyers and sellers. Buyers (he) are indexed by and sellers (she) are indexed by . I will be interested in small vs. large markets. For the formal model, a small market is a finite player game, , and a large market means there is a continuum on both sides of the market, .

There are two stages to the game. First, before matching, buyers and sellers must invest in an attribute, and . The cost to buyer is and the cost to seller is . These investments generate a surplus for any match: . Second, after buyers and sellers sink their investment, each side posts a price. A buyer posts a price, , which means he has attribute , wants to match with a seller with attribute , and will pay that price. The seller posts a similar price, .[[7]](#footnote-7) A matching occurs between any buyer and seller who post the same . If there are more buyers than sellers for any price, the buyers are matched to a seller or left unmatched randomly.

The payoff function for a buyer is . The payoff function for a seller is . The game is summarized in the figure below.



Because utility is quasi-linear (transferable), a profile of investments and matchings is efficient if and only if it maximizes the . For this example, the efficient allocation is to maximize investment: .

# Equilibrium and Hypotheses

A profile of investments and matchings is an “ex post contracting equilibrium”" if markets clear and everyone optimizes given prices and their rational conjectures about prices. The first two conditions are the usual Walrasian conditions, where markets clear and people optimize given prices. Note that the equilibrium notion does not involve the standard Nash equilibrium epsitemic justification. Actions need not be common knowledge. Instead, equilibrium only knowledge about prices, or as Hayek (1933, 129) put it: “the co-ordination of individual efforts in society is not the product of deliberate planning, but has been brought about, and in many cases could only have been brought about, by means which nobody wanted or understood…” Beyond a Walrasian equilibrium, when players are deciding how much to invest, the must form conjectures about what prices will be in the future. The equilibrium disciplines those conjectures.[[8]](#footnote-8) I will further discipline conjectures below. As Hayek (1937) p. 41 points out, “the concept of equilibrium merely means that the foresight of the different members of the society is in a special sense correct.”

We can think of a matching, , as a market for a good sold by a seller of type to buyer of type . A market is open if that pair is part of an equilibrium. A market is closed if it is not open. While in the formulation here, players act like price-takers, players know they can affect the set of markets when they deviate. They are therefore “market-makers.”

First, assume the level of investments, or equivalently the set of open markets, as fixed. Then the players are deciding whether to form a match given prices. The definition immediately gives the following observation about what those equilibria look like.

###### Observation #1: All ex post contracting equilibria are Walrasian equilibria and efficient *given the investments*.

However, the equilibrium price is not unique. Consider the above bargaining game, but only after buyers and seller have both chosen the maximum investment. There is a pie to divide by . The division which occurs is indeterminate, even though the optimal “quantity traded” is when all buyers and sellers match. This is exactly the setup and outcome in Figure 4 of Smith (1982) p. 171. As Smith finds, even though the number of trades is the efficient amount, the price moves between each round of play. In the model, this leads to the following observation:

###### Observation #2: Walrasian prices with complementarities are not unique.

However, even though all equilibria are Walrasian, they are not all efficient in the ex ante sense. In particular, investment coordination failures can arise. In the example, and can be part of an ex post contracting equilibrium. Suppose buyers conjecture that for all other levels of investment they could choose. They would not want to deviate, because any other investment is too costly. Similarly, if sellers conjecture that the price is zero, they will not make a return on their positive investment. Since only the price for is observed in equilibrium, both sides’ conjectures are rational; there is no feedback that tells the buyers and sellers they should revise their conjectures. Even though there is competition, players are stuck in a coordination failure. This leads to the following observation:

###### Observation #3: There can exist inefficient ex post contracting equilibria.

Notice that the inefficient equilibria is sustained by strange, off-equilibrium conjectures about those closed markets. In game theory, to rule equilibria out that are sustained by strange, off-equilibrium conjectures, we consider trembling-hand perfect equilibrium (Selten 1975).[[9]](#footnote-9) However, in general games, such a refinement does not rule out inefficient equilibria. See Selten’s original example. That is also turn in the game considered about with finite players. I will skip the argument of the result and just present it.

###### Proposition #1: With finite players, there can exist inefficient perfect ex post contracting equilibria.

However, the problem is that with finite players, markets are not competitive enough. Markets can still be very thing. However, if there are many buyers and sellers, a trembling-hand refinement does eliminate coordination failures. With many players, conjectures about prices are even more disciplined. This leads to the following theorem, which job market paper formally proves for a general class of matching games.

###### Theorem #1: With a continuum of players, all perfect ex post contracting equilibra are efficient.

The next section lays out how I hope to test the corresponding hypotheses generated by the formal model.

# Hypotheses and Quantitative Strategy

Coordination problems are notoriously hard to empirically study. By definition, a coordination problem is only possible if there are two observed outcomes that reflect the same underlying primitives/game. Conducting such a test requires, not a *ceteris paribus* clause but a *omnibus paribus* clause.

Therefore, a controlled experiment provides an excellent way to test the predictions of the model. SinceI can control the setup as the experimenter, I can make sure the game is identical and test whether outcomes are efficient or not. However, I am not actually an experimental economist but an economic theorist. Therefore, the exact implementation is quite vague at this point. I look forward to feedback on how to implement this broad idea.

Let us start in the second stage of the game. The second stage experiment will resemble Smith (1982). Buyers and sellers will post prices or accept other people’s prices. The complication over the standard double-sided auction is that people are buying and selling differentiated goods; there are different markets based on their investments. However, even with that complication, the results from the Smith paper, Observation #1, and Observation #2 lead me to hypothesize that these markets will still look like Walrasian markets. The two hypotheses are:

###### Hypothesis #1: With fixed investments, gains from trade will be maximized.

###### Hypothesis #2: Prices will not be unique across rounds of play.

In agreement with Smith’s classic experiments, a hypothesize that an Walrasian outcome occurs despite the fact that:

“each agent is not in a price taking environment. The environment is one of multilateral negotiation in which each agent is as much a price maker (who actively announces bids or environment. The environment is one of multilateral negotiation in which each agent is as much a price maker (who actively announces bids or offers) as a price taker (who accepts bids or offers)” (Smith 1982, 169).

Smith gives us reason to expect people to be efficient price-makers. Will they also be efficient market-makers? To test this, let us move to the first stage which is trickier to implement. Before trading, players will be allowed to invest. The sellers invest in the “quality” of their product before trying to sell their product. However, it is not clear exactly what information to provide the players with before they make and investment and how expectations will be formed. To better understand expectations, first I will consider a case where, players will be prompted with an expected value of the product from the experimenter, such as “Market research says ‘upgraded’ widgets are expected to sell for $X.”

###### Hypothesis #3: With prompted expectations, coordination failures will not occur.

In an essence, the prompted expectations are analogous to an auctioneer calling out prices. The players can passively react to those prices. However, I’m ultimately interested in whether people will be entrepreneurial and discover their own markets without prompting. To test this, suppose players only know . The model suggests a difference between games with a small or large numbers of players when people only know . The two corresponding hypotheses are:

###### Hypothesis #4: With small numbers of players, such as one buyer and one seller, coordination failures can occur and the efficient set of markets will not open.

###### Hypothesis #5: With large numbers of players, coordination failures will be eliminated.

A central issue to investigate is exactly what counts as “large numbers of players”. Obviously, contrary to the model, we will never have a continuum of players. However, the important step is not that there are actually a continuum of players, but that players mistakes or Smith’s “higgling and bargaining” are able to open up markets that remain closed in the inefficient equilibria. If markets open up at some point, then people can see the price in that market. If there are only two types of qualities for sellers or two types of qualities for buyers, there are only four types of goods to trade and people’s random actions will be more likely to open up the relevant markets.

Any suggestions on how to exactly test these hypotheses in a feasible way and any suggests for related hypotheses are greatly appreciated.

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1. Prices, an objective fact, do all the work of coordinating supply and demand in a Walrasian model. Mainstream critics, like Makowski and Ostroy (2012), see this as the main problem of the Walrasian model and why market socialists like Lange (1936) and Lerner (1937) could use the Walrasian model to justify socialism. Instead, for Makowski and Ostroy, prices are really about incentives, not information and coordination. [↑](#footnote-ref-1)
2. Klein and Orsborn (2009) make a similar distinction between “concatenate coordination” and “mutual coordination.” Another paper of mine (Albrecht 2016) provides a model that ties together the two different forms of coordination through the effort of entrepreneurs. [↑](#footnote-ref-2)
3. A game like Battle of the Sexes does not have an equilibrium which is a coordination failure. [↑](#footnote-ref-3)
4. Coordination failures are especially problematic, compared to other “market failures” such as monopoly. It also makes them of a different from a normative perspective. As Israel Kirzner points out, > “Welfare economics requires a criterion for economic “goodness” in regard to a society. Unlike conventional criteria, “coordination” (among independent decisionmakers) does not violate methodological individualism. The coordination criterion can be objectively deployed to judge events or policies, referring only to the given preference rankings of relevant individuals, given their initial positions." (Kirzner 1998, 289) I agree with Kirzner, although by coordination he seems to mean something like equilibrium. For Kirzner, we can objectively say an equilibrium is better than a disequilibrium. I would add we can sometimes further Pareto-rank equilibria. [↑](#footnote-ref-4)
5. Brandenburger and Stuart (2007) called such games, with a non-cooperative game before a cooperative games, “biform games.” Such games are understudied. [↑](#footnote-ref-5)
6. Following up on Makowski and Ostroy (1995), two important papers Cole, Mailath, and Postlewaite (2001a); Cole, Mailath, and Postlewaite (2001b) find three different types of coordination problems can arise: (1) under-investment equilibria, (2) over-investment equilibria, and (3) mismatch equilibria, as first pointed out by Felli and Roberts (2016). [↑](#footnote-ref-6)
7. While a buyer could post a different price for all seller attributes, it is without loss, in terms of payoffs, to consider prices for only a single attribute. [↑](#footnote-ref-7)
8. “Rational conjectures” are similar to rational expectations, but not identical. See Makowski (1983),Makowski2004 for precise definitions. [↑](#footnote-ref-8)
9. Trembling-hand perfection is also the justification for focusing on subgame perfect equilibria, compared to Nash equilibria. [↑](#footnote-ref-9)