Coordination in the Presence of Asset Markets[1]

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Abstract

We explore both theoretically and experimentally how final prices and security holdings in an asset market influence and forecast behavior and outcomes in an affiliated coordination game. We vary the incentives from the market relative to payoffs from the game, the number of players in a group, and whether traders' payoffs are influenced by outcomes in their own or another group. Markets lead to significantly less efficient group outcomes across all treatments, even when the market produces little or no distortion of incentives in the game. At the same time, we find that asset markets are informative about group outcomes and thereby reduce "wasted input." Our experiment may therefore shed light on how financial markets themselves may contribute to economic crises.

Keywords: Equilibrium Selection; Asset Prices; Coordination Games; Experimental Economics.

Coordination in the Presence of Asset Markets

1 Introduction

Markets aggregate widely dispersed information and direct resources to where they produce the greatest value (Hayek 1945, Smith 1776). It is these dual roles of allocative and informational efficiency that help explain why asset markets are often used to guide economic activity such as production and investment.

Many economic contexts involving production and investment are characterized by multiple equilibria (Bryant 1983, Hirshleifer 1983, Cooper 1999, Camerer and Knez 1997, Brandts and Cooper 2006). When asset markets are linked to such contexts, it is important to understand what role they play in aiding coordination and selecting equilibria. If asset markets properly function to obtain allocative and informational efficiency, then they should guide behavior to an efficient equilibrium and should coordinate the beliefs of economic agents. Indeed, some evidence suggests that one-sided asset markets may serve these two functions well in an environment with multiple equilibria (Van Huyck, Battalio and Beil 1993, Crawford and Broseta 1998). However, the broader question of whether all types of asset markets lead to efficient outcomes and to equilibrium behavior remains an open question. There are well-known contexts, such as adverse selection and moral hazard, in which markets may fail to achieve the goals of allocative and informational efficiency. It is worthwhile, then, to investigate the effects of different kinds of institutions on equilibrium selection and coordination.

In this paper, we explore the influence of two-sided futures asset markets – which are prevalent in economic, financial, and organizational settings – on behavior and outcomes in an economic activity characterized by multiplicity of equilibria. We focus on situations where the outcome of the economic activity is sensitive to the behavior of small numbers of agents. We use a laboratory experiment, in which we control important features of both the market and the underlying activity.

The economic activity in our setting consists of a coordination game with Pareto-ranked equilibria, in which the payoff to each player is a function of her own choice, or input, and the minimum choice of all players, or group output (see Van Huyck, Battalio and Beil (1990), Crawford (1995)). In these games, multiple players choose among several ordered input actions, with pure-strategy equilibria consisting of outcomes in which all players select the same input. Players all do better if they coordinate on the highest (most efficient) equilibrium, but they also prefer to select lower input if they believe others will do so. Such games have been applied widely to model economic activity, from the relationship between beliefs and output in macroeconomic models (Cooper 1999), to public good provision (Hirshleifer 1983), to firm production (Camerer and Knez 1997, Brandts and Cooper 2006).

Financial markets are often linked to the above kinds of economic activity. Therefore, we study the relationship between economic performance, measured by outcomes in the game, and a corresponding asset market in which the traded assets' values are contingent on the game outcome. More precisely, in each period of our experiment participants play the coordination game and receive payoffs from the outcome in the game. Prior to playing the game, participants trade in a market with Arrow-Debreu securities, each corresponding to one of the possible outcomes (minima or output) in the game.

Our primary purpose is to explore the extent to which markets influence outcomes in the underlying economic activity, both in the sense of equilibrium selection (Do markets guide behavior to the Pareto-optimal equilibrium?) and of information aggregation (Do markets coordinate players' beliefs?). Our experiment is thus informative about the allocative and informational roles asset markets serve in economic environments characterized by multiple equilibria.

There are many ways in which asset markets may influence equilibrium selection and coordination in the subsequent game. Previous experiments using similar games demonstrate that pre-play communication among players helps reassure them of their mutual intent to pursue the efficient equilibrium and is thus effective for obtaining the efficient outcome (Blume and Ortmann 2007, Cooper, DeJong, Forsythe and Ross 1992). The pre-play asset market might be one mechanism through which players engage in such mutual reassurance and coordinate on the efficient equilibrium (see also Van Huyck et al. (1993)).

However, asset markets of the kind we use here are much more complex and potentially noisy than the more simple kinds of communication used in the experiments above. There exist separate markets for each equilibrium output level, and players' communication through the asset market may be very rich and diffuse. For example, a player indicating a desire to buy assets corresponding to an inefficient equilibrium even at a low price may be indicating some doubt that the efficient equilibrium will result. Therefore, pre-play asset markets may in fact result in communication that leads players' beliefs to converge on the inefficient equilibrium (see Morris and Shin (2002)).

Moreover, the market also potentially creates incentives for players to decrease the group's output in the coordination game. Since group output is determined by the lowest input by any group member, any single player can lower the output unilaterally (assuming it is not already at the lowest possible value). Therefore, a market with sufficiently high payoffs creates a possible incentive to engage in such opportunism, thereby harming output in the underlying economic activity.

Finally, the strategic uncertainty in coordination games means that players often mismatch their choices, at least when playing initially (Van Huyck et al. (1990)). These out-of-equilibrium outcomes represent wasted input by players. Therefore, another important possible benefit of pairing market trading with the economic activity is that the presence of a market might eliminate such wasted input. That is, even if the market has no positive effect on aggregate outcomes (higher output), it may improve efficiency by coordinating players' actions on a particular equilibrium (resulting in fewer input choices above the group minimum).

We explore the above potential influences of asset markets on behavior in coordination games by varying the incentives of the market relative to the game. When market incentives are high, the possible influence of opportunism is considerable and markets are likely to influence economic behavior because of modified individual incentives. However, when market incentives are low such a direct influence is less likely, and any influence of markets on economic behavior is the likely result of influences on beliefs, communicated through prices.

In addition to varying the incentives from the market relative to the game, we also study other treatments in our experiment. We vary the number of players in the coordination game since this is perhaps the most important factor in determining outcomes (Van Huyck et al. 1990, Weber 2006). We also vary whether the coordination game is played absent any market (*Control* condition), is directly linked to the market (*Insiders* treatment), or is indirectly linked to the market by having players in the game trading in a market whose values are determined by another group's game (*Outsiders* treatment).

We demonstrate theoretically how the market may influence outcomes in the game. Our laboratory experiment reveals that the presence of markets significantly lowers the group's output, which is true across *all* our treatments, even when the market incentives are very weak (*Market L* treatment) or when the outcome of the game is unrelated to market payoffs (*Outsiders* treatment). The market, however, forecasts such behavior and, perhaps as a result of such information aggregation, there is generally less "wasted input" or choices above the group minimum. In general, these results are consistent with the market influencing behavior and outcomes through prices and beliefs.

2 Model and Hypotheses

Players participate in a two-stage game consisting of an asset market followed by a coordination game. The values of the securities traded in the asset market depend upon the realization of the output in the coordination game.

We first examine the second stage coordination game. Players participate in an n player weak-link coordination game. This game was first analyzed theoretically by Bryant (1983) and Hirshleifer (1983). All players simultaneously select input levels $e_i \in \{1, \ldots, M\}$. Each player's payoff depends upon his or her own input level and the group's output, which is determined by the minimum input level in the group:

$$\pi_i(e_i, \underline{e}_i) = a + b \min(e_i, \underline{e}_i) - ce_i \tag{1}$$

where $\underline{e}_i = \min(e_1, \ldots, e_{i-1}, e_{i+1}, \ldots, e_n)$, is the minimum input chosen by the other $n-1$ players and $0 < c < b$. Any selection of identical inputs such for all players is a pure-strategy Nash equilibrium. The Nash equilibrium with $e_i = M$ for all i is the *high output* equilibrium and Pareto dominates any lower output equilibrium where $e_i = m$ with $m < M$ for all i.

While Pareto efficiency suggests that the high output equilibrium is the natural choice in this setting, the low output equilibrium ($e_i = 1$ for all i) has some intuitive appeal in terms of risk. The payoff from low input is 'secure'; someone who has chosen $e_i = 1$ receives a certain payoff whereas selecting $e_i > 1$ may involve lower payoffs if other players select $e_j < e_i$. If a player assigns enough probability to the event that other players play lower input choices, then she will prefer to play lower input herself. This concept is formalized by saying that the low output Nash equilibrium is *risk dominant* (Harsanyi and Selten 1988).

Van Huyck et al. (1990) conducted the first experimental study of the game and found two regularities replicated by subsequent studies (Knez and Camerer 1994, Weber, Camerer, Rottenstreich and Knez 2001). First, groups often fail to coordinate on the Pareto dominant equilibrium. Second, group size exerts a strong influence on equilibrium selection. Small groups of two to three players converge to much higher output levels than larger groups of six or more players. To explore how such group size effects interact with the presence of assets markets, our experiments examine two different group sizes: *Small* groups with three subjects each and *Large* groups with six subjects each.

Prior to the coordination game all players participate in an asset market. In the market, the value of a traded security is based upon the output (minimum input) in the subsequent game. More precisely, there are M state-contingent securities traded with the following payoffs:

$$X_m = \begin{cases} \beta & \text{if } \min(e_1, \ldots, e_n) = m \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where $\beta > 0$.

There is a considerable literature demonstrating that properly designed markets can provide high-quality information regarding uncertain outcomes. Using experimental markets, Plott and Sunder (1988) show that markets with Arrow-Debreu securities like those above can aggregate dispersed information. Field studies of asset markets designed to predict uncertain events also show that these types of markets provide accurate signals regarding future outcomes. Forsythe, Nelson, Neumann and Wright (1992) study the Iowa Political Stock Market, which allows participants to trade securities linked to presidential election outcomes. Forsythe et al. show that the market better predicted ex-post outcomes than professional opinion polls. Further support for the performance of this market structure is provided by Berg and Rietz (2003).[2]

Our main purpose is to explore how the asset market influences outcomes in the game. We first present three hypotheses regarding the market's influence on group minima, and how such influence may differ depending on the relative payoffs from the market and the game. We then present additional hypotheses regarding the relationship between the market and the game.

2.1 Communication and Equilibrium Selection

One factor that may significantly improve coordination on Pareto-efficient outcomes is communication. Previous experiments demonstrate that pre-play costless communication gener-

[2] The interested reader is referred to Sunder (1992), Spann and Skiera (2003), and Wolfers and Zitzewitz (2004), which provide further details on the study of information aggregation using markets. More broadly, this evidence is related to the Efficient Market Hypothesis (Fama 1970).

ally improves the frequency of efficient play (Cooper et al. 1992, Blume and Ortmann 2007). Asset markets may serve as an effective pre-play communication device. For example, Van Huyck et al. (1993) found that an auction market in which participants purchased the right to play in a subsequent median-input coordination game always resulted in coordination on the Pareto dominant equilibrium. In their experiment, the winning bidders, and thus participants in the game, are those who are willing to pay the highest value for the right to play. Therefore, subjects appear to signal via the market an expectation of high output which is in turn self-reinforcing (see also Crawford and Broseta (1998)). The asset markets we study here offer a similar opportunity for participants; by buying or offering to buy assets that only pay off in the highest output level, subjects can declare their intention to select high input. Thus, Arrow-Debreu futures markets may result in similar coordination improvements to those observed via pre-play communication and 'right to play' auction markets.

Hypothesis 1 (Pure Communication Effect) *For both market treatments, communication through an asset market will produce higher output.*

On the other hand, the effect of pre-play communication can depend critically on the structure of the communication. Several differences between the kind of communication available to players in our two-sided asset markets and the kinds of communication in the above experiments might make efficient coordination less likely in our setting. First, while communication is effective when all players in the coordination game can indicate their intended action, it has a much weaker effect when only a subset of players send messages (Cooper et al. 1992, Weber et al. 2001). In our experiment, some participants may not trade in the market, thereby reducing the effectiveness of communication. Second, in the above communication experiments players communicate by indicating only which action they intend to play, and in the auction markets used by Van Huyck et al. (1993) players' bids implicitly indicate a minimum level of output that they expect to be realized. In our experiment, however, communication is potentially richer and may involve players indicating more diffuse beliefs by bidding to buy or sell different assets, each corresponding to an output level, at varying prices. Therefore, players assigning even small probability to low output levels, and who communicate this belief via the market, may create self-reinforcing doubt among other players that results in lower output. Finally, unlike in Van Huyck, et al.'s, experiment, the asset markets in our experiment potentially influence players' incentives in the subsequent coordination game. For the above reasons, the effect of an asset market in our experiment might be less positive than in the above "cheap-talk" experiments and in the auction markets of Van Huyck et al. (1993). To see precisely why, we consider the relationship between our asset markets and incentives and beliefs in the coordination game.

2.2 Portfolio Incentives and Equilibrium Selection

We begin by examining the direct effect asset markets may have on players' choices in the coordination game. In the right-to-play asset market of Van Huyck et al. (1993), the results of the asset market leave the payoffs from the coordination game unchanged. In contrast, in our experiment player actions in the asset market can directly affect the payoffs to playing various input levels in the game.

At the conclusion of trading in the asset markets, all players possess a particular *portfolio* of securities. Let x_{mi} be player i's units of asset X_m and $x_i = (x_{1i}, x_{2i}, \ldots, x_{Mi})$ be player i's *portfolio* at the end of trading. Since these assets pay off based upon the outcome of the game, the original game payoffs from (1) are modified to be:

$$\overline{\pi}_i(e_i, \underline{e}_i; x_i) = a + b\min(e_i, \underline{e}_i) - ce_i + \beta \sum_{m=1}^{M} \delta_m x_{mi} \quad (3)$$

where $\delta_m = 1$ if $\min(e_i, \underline{e}_i) = m$ and 0 otherwise. We call this game the *market-modified coordination game.*

We assume that the aggregate endowment for each asset is the same, or $\sum_{i=1}^{n} x_{mi} = k$ for all m. Under this assumption, the efficiency properties of higher matched inputs is the same as it is in the original game since the market is a constant-sum game. However, different ex post portfolios can affect individual players' incentives to select particular input levels. It is straightforward that all pure-strategy Nash equilibria of this game also involve identical input choices since the payoffs from the assets are only affected by the output. With this is mind, the following proposition characterizes the set of pure-strategy Nash equilibria of the market-modified coordination game.

Proposition 1 *The selection of input level $e_i = m$ for all i is a pure-strategy Nash equilibrium if and only if asset portfolios are such that for all i and for all $\ell < m$,*

$$x_{\ell i} - x_{mi} \leq \left[\frac{b-c}{\beta}\right](m-\ell). \tag{4}$$

Proofs are provided in the Appendix.

This proposition tells us that the asset market can directly alter the incentives and expected outcomes of the game. When a particular player has enough of an asset that pays off under lower output (relative to higher output assets), he or she has a weakly dominant strategy to play the corresponding lower input, thus making the higher output equilibrium impossible to support. The following observations arise directly out of the proposition:

1. For all asset positions, the lowest input choice, $e_i = 1$, by all players is a Nash equilibrium.

2. In order for higher input choices to be Nash equilibria, it must be that asset positions of the players are not too *diverse*, where (4) provides the limit on differences between particular security holdings in players' portfolios.

3. The asset portfolios that induce certain Nash equilibria depend upon the relative payoff of the asset market (β) to the coordination game ($b - c$).

The final point states that while we should expect the asset positions of the players at the end of trading to affect the subsequent choices in the game, the strength of such an effect should depend upon the payoffs in the market and coordination game. If β is large relative to $(b-c)$ then even small differences across a single player's state-contingent holdings may eliminate high input choices as equilibria. On the other hand, if β is small relative to $(b-c)$, large (potentially infeasible) cross-asset holdings differences will be necessary to change the set of the equilibria from those of the original game.[3]

In order to examine this potential effect in our experiment, we systematically varied the payoffs from the market relative to those from the game. In the *Market H* variant we set $(b-c)/\beta = 2$ and in the *Market L* variant, we set $(b-c)/\beta = 40$. Thus, the *Market L* treatment significantly lowered the relative payoff of the market. In order to see the potential strength of this treatment, consider the differences in asset holdings that would be necessary to induce an individual to be unwilling to play the input level $e_i = 4$. In the *Market H* treatment, the individual would have to hold greater than 2, 4, or 6, more units of the X_3, X_2, or X_1 assets respectively (than units of the X_4 asset). Whereas, in the *Market L* treatment, the required minimum differences are 40, 80, and 120. Since the set of pure-strategy Nash equilibria in the market-modified coordination game is always a subset of the set of pure-strategy Nash equilibria of the original game, we have our next hypothesis.

Hypothesis 2 (Portfolio Incentive Effect) *The presence of an asset market will lower output in the* Market H *treatment and will have little or no effect in the* Market L *treatment.*

While this hypothesis suggests that coordination will be more difficult to obtain in the presence of an asset market, the asset market as conducted does not preclude efficient outcomes. The aggregate endowment of each state-contingent asset is the same so a uniform portfolio of the same unit holdings for each asset is always feasible for every agent.[4]

[3]Even if the set of equilibria have not been changed by asset market holdings the payoffs in the coordination game have changed and become potentially asymmetric. Goeree and Holt (2005), Brandts and Cooper (2006) and Hamman, Rick and Weber (2007) study the effect of changes in payoffs on equilibrium selection in coordination games. However, our results will show that asset markets influence outcomes and behavior even when incentives are completely unchanged (Outsiders treatment).

[4]The asset market might offer an opportunity to offset some of the risk associated with other players playing lower input. However, in this setting hedging or insurance opportunities are limited for two reasons. First, as agents attempt to smooth allocations across output levels, the asset allocations become inconsistent

The above analysis demonstrates how the asset market can modify incentives in the coordination game affecting final output. Another way in which the market can affect behavior and output in the game is through communication and potential influence on beliefs via trading and prices in the market.

2.3 Markets and Communication

To address the relationship between market communication and beliefs in our experiment, we posit a model that is consistent with the stylized details of strategic uncertainty in the coordination game. Suppose that each player has some beliefs about the minimum input, $\underline{e}_i$, that will be chosen by the $n-1$ other players, where μ_{mi} indicates player i's belief that $\underline{e}_i = m$. The usual interpretation of coordination failure arising due to strategic uncertainty in this game is that each player recognizes that high output is the Pareto-dominant equilibrium, but their beliefs about the choices of others players may make it rational for players to select $e_i < M$. Specifically, a player's expected payoff from his or her input choice given this strategic uncertainty is:

$$\Pi_i(e_i) = \sum_{m=1}^{M} \mu_{mi}\overline{\pi}_i(e_i, m; x_i). \tag{5}$$

If players maximize their expected utility with respect to these preferences, then they may decide to play input levels other than the Pareto-dominant equilibrium. Let $\mu = (\mu_1, \ldots, \mu_n)$ be the set of beliefs for all agents. Then we say that $e^* = (e_1^*, \ldots, e_n^*)$ is an *equilibrium given beliefs* μ if e_i^* maximizes (5) for all i.

Players maximizing with respect to these beliefs provide an explanation for the two forms of inefficiency in coordination games. First, if a player's beliefs place sufficient likelihood on low input choices by other players, the player will prefer low input. Second, players' initial input choices may fail to be *ex post* best responses to the *ex post* choices of the other players, resulting in wasted input. Of course, via repeated interaction players will refine their beliefs to be consistent with the observed history of play and we expect that players will converge

with Proposition 1. Second, the cost of acquiring these assets in the market further limits hedging.

to a particular Nash equilibrium.[5]

The market, like any communication device, may provide an opportunity for players to refine their beliefs prior to playing the game. Let p_m be the market price for the asset X_m that pays β in the event that the output is m. Ideally, we would like to identify a perfect Bayesian equilibrium that accounts for both the market and coordination game stages as well as the dynamic signaling opportunities available through the markets. However, such an analysis is not readily tractable so we define a market equilibrium notion that captures the essential elements of rational expectations and strategic uncertainty that are important features of both the market and the subsequent game. Our market equilibrium has two features. First, agents' asset buying/selling choices must be consistent with their expected input choices and their beliefs about other agents. Second, the actual input choices must be the result of maximizing behavior in the second-stage market-modified coordination game. We say that (x^*, p^*, e^*) is a *rational expectations equilibrium* if there exist beliefs μ such that: (1) x_i^* maximizes $\sum_{m=1}^{M} [\mu_{mi}\overline{\pi}_i(e_i^*, m; x_i) - p_m^* x_{mi}]$ for all i, and (2) e^* is an equilibrium given beliefs μ.[6]

If there are no restrictions on the set of allowable beliefs, there are likely many potential rational expectations equilibria. As is typical in rational expectations type equilibria, we focus on prices that reveal information to the agents. A rational expectations equilibrium is *revealing* if the beliefs that support the equilibrium are given by $\mu_{mi} = p_m / \sum_{\ell=1}^{M} p_\ell$ for all i, or beliefs are simply given by the observed normalized prices. Further, the equilibrium is said to be *fully revealing* if there exists an output level m such that $p_m = \beta$ so $\mu_{mi} = 1$ and for all $\ell \neq m$, $p_\ell = 0$ so $\mu_{\ell i} = 0$ for all i. In the event of a fully revealing equilibrium, all strategic uncertainty is resolved and the resulting input choices must constitute a Nash

[5] Crawford (1995) proposes a model that formally interacts learning dynamics with strategic uncertainty in these kinds of games. Crawford and Broseta (1998) apply this kind of model to the experiment of Van Huyck et al. (1993).

[6] One feature of this equilibrium is that players consider their asset allocation (via the market) and input (via the coordination game) choices assuming the other choice is fixed at the time of decision making. We selected this approach since it provides high-output market equilibria the best chance of existence whereas any equilibrium that allowed co-determination of input in the market phase would result only in low-output equilibria as in the upcoming Proposition 3.

equilibrium of the game. If markets are an effective communication tool they should admit fully revealing rational expectations equilibria that result in high output for the players. In fact, we find that any Nash equilibrium can be supported as a fully revealing rational expectations equilibrium.

Proposition 2 *Given an input level m, there exists a fully revealing rational expectations equilibrium with $p^*_m = \beta$ and $p^*_\ell = 0$ for all $\ell \neq m$ and $e^*_i = m$ for all i.*

The intuition behind this result is obvious. Let $e^*_i = m$ for all i and notice that, given these prices, for all players $\mu_{mi} = 1$. However, this means that each player has identical preferences and the marginal benefit of another unit of $x_{i\ell}$ is β if $\ell = m$ and 0 otherwise. Thus, setting p_ℓ equal to β for $\ell = m$ and 0 otherwise ensures that each agent is indifferent between more units of each of the assets and the equivalent amount of cash. Given this indifference between cash and assets, portfolios can be assigned in order to ensure that $e^*_i = m$ remains a Nash equilibrium (the conditions of Proposition 1 are satisfied); the allocation $x_{mi} = x_{\ell i}$ for all ℓ and i will trivially satisfy this condition given any output level.

We see in Proposition 2 that information revelation that results in efficient outcomes is possible, which could be taken as further support for Hypothesis 1. However, any pure-strategy Nash equilibrium is also possible under this proposition. Therefore, we need to investigate whether any of these potential equilibria are more likely to be observed. The attainment of a particular rational expectations equilibrium is fundamentally a dynamic process where agents begin with differing beliefs and somehow converge to a consensus opinion regarding the output that will be observed. If small perturbations in equilibrium beliefs result in dramatically different equilibria then we would expect that these equilibria would be unlikely to be observed.

If even one agent assigns some small amount of strategic uncertainty to the choices of other players, and this uncertainty influences either market or game behavior to move the group away from the particular equilibrium outcome of the game, then this equilibrium is fragile. We say that a fully revealing rational expectations equilibrium (x^*, p^*, e^*) is *stable* if for all $\epsilon > 0$ and for all i, there exists an x' such that (x', p^*, e^*) is a rational expectations equilibrium given beliefs for players $j \neq i$ of $\mu_{mj} = 1$ if $p^*_m = \beta$ and 0 otherwise and for player i beliefs of $\mu_{mi} = 1 - \epsilon$ if $p^*_m = \beta$ and $\epsilon/M - 1$ otherwise. The following proposition shows that only one of the fully revealing rational expectations equilibria identified earlier is stable.

Proposition 3 *The unique stable fully revealing rational expectations equilibrium is given by $p^*_1 = \beta$ and $p^*_m = 0$ for all $m \neq 1$ and $e^*_i = 1$ for all i.*

First, in order to see why the lowest output outcome is stable, consider a player who places some small probability on others choosing a higher minimum. While the difference between beliefs and prices might create opportunities for trade, given the player's input plan $e^*_i = 1$, the marginal value of any asset that pays off in the event of higher input is still 0 and so the agent's trading preferences are unchanged and allocations can be adjusted slightly to insure that $e^*_i = 1$ remains maximal. Next, to see why higher output levels are unstable consider a player who originally planned to play $e^*_i = M$ but now assigns some small probability to other players selecting a lower input. The marginal expected value of an increase in holdings of these lower output assets is now positive and the player's demand for these assets is unbounded given the price of 0. Thus, the player will buy all feasible units of the assets $X_1, X_2, \ldots, X_{M-1}$ which, assuming feasibility is not overly binding, will induce the player to take a different expected utility maximizing input choice, meaning the equilibrium is unstable.

The previous result demonstrates how the strategic uncertainty inherent in the coordination game may influence the market equilibrium. Players who plan on playing high input but have some uncertainty about the play of others are easily encouraged by market prices to take lower input actions whereas players who plan on playing low input and are similarly uncertain remain unwilling to invest in higher output assets. This hypothesis stands in direct contrast to the earlier Hypothesis 1 which predicts coordination on higher and more efficient output due to communication. Unlike the asset market of Van Huyck et al. (1993) where players' buying decisions helped to resolve strategic uncertainty by demonstrating that the set of game participants were those that expected high output, our asset market makes it easier for players to communicate the intention of playing the low output equilibrium, and for other players to be influenced to follow any such pessimistic signals.

Hypothesis 3 (Market Communication Effect) *For both market treatments, the process of communication through an asset market will produce lower output.*

The first three hypotheses predict differing output patterns between the *Control* treatment and Insinders in our two *Market* treatments. If Hypothesis 1 is valid, then we would expect that output would increase under both the *Market H* and *Market L* conditions. On the other hand, under Hypothesis 2 the *Market H* condition should result in lower output whereas output in the *Market L* condition should not be substantially different than that of the *Control*. Finally, Hypothesis 3 predicts that both *Market* conditions should result in lower output than the *Control* treatment. We now direct our attention to several other hypotheses that do not directly relate to output by Insiders.

If markets can serve to communicate the eventual output, we would expect that market prices will accurately predict such outcomes. Proposition 2 identifies fully revealing rational expectations equilibria that precisely predict the game outcome. Since the literature on information aggregation suggests that markets can be very effective at revealing such information, we hypothesize that the market will provide a reasonably good predictor of actual outcomes in the game. However, there are at least two reasons to expect the accuracy of prices in the *Market H* condition to be greater than in *Market L*. First, it is often argued that markets must be financially relevant in order to encourage active trading. We expect prices in the *Market L* not to be as accurate at predicting subsequent behavior as in *Market H*. Second, given that asset holdings significantly reduce the set of viable equilibria in the

Market H condition, it may be easier to anticipate the output that will be played in *Market H* compared with *Market L*.

Hypothesis 4 (Market Price Accuracy Effect) *Market prices will more accurately forecast group output in the* Market H *treatment than in the* Market L *treatment.*

In coordination games with Pareto-ranked equilibria, such as the weak-link coordination game, there are typically two forms of inefficiency that arise: (1) players fail to coordinate on the high output Nash equilibrium and (2) players fail to play a best response to the input choices of the other players. We term the second type of inefficiency "wasted input" since it involves players selecting a higher input level than the realized output and only serves to increase the cost to that player. One potential benefit of communication through the market, independently of any effect on the group output, is that it might result in more coordinated input choices (more players selecting the minimum) so that the inefficiency generated by wasted input might be mitigated.[7]

Hypothesis 5 (Wasted Input Effect) *The presence of an asset market will diminish wasted input.*

2.4 Outsiders and Equilibrium Selection

We kept the number of market traders constant across the Small and Large group treatments in order to control for the possibility that market size might affect the performance of the market. This required that some traders in both *Market* treatments were *Outsiders*, meaning that the liquidation value of their assets depended only upon another group's output. In order to observe the pure effect of market participation on input choices, independently of any portfolio incentives, we allowed Outsiders to participate in a separate second-stage coordination game as well. Thus, Insiders traded in a market corresponding to outcomes

[7] Heinemann, Nagel and Ockenfels (2004) show in a related setting that public information about a payoff-relevant parameter decreases heterogeneity in behavior, thus improving coordination.

in their game, while Outsiders traded in a market corresponding to outcomes in another group's game. Since Proposition 1 only applies to *Insiders*, where their input choices affect the liquidation value of their asset holdings, the set of Nash equilibria for the Outsiders is unaffected by the presence of an asset market.

Hypothesis 6 (Outsiders Behavior Effect) *The presence of a market will not affect output for Outsiders.*

One might expect, however, that Outsiders could still be affected by the potential communication effects of the market; they observe market prices and assume that those prices also provide information about the intended play in their group (or perhaps believe that others in their group assume so). Given that other Outsiders are also participating in the same market, it is possible that some communication may occur through the market.

3 Experiment Design

We examined three distinct primary treatment conditions in order to analyze the interaction between markets and coordination in games with multiple equilibria. The three variants were: a *Control* condition in which all subjects participated only in the coordination game, and *Market H* and *Market L* conditions in which all subjects participated in the coordination game preceded by an asset market. The relative payoff of the asset market differed between the two *Market* conditions.

Subjects sat at computer terminals and received a set of written instructions, which were then read aloud by the experimenter. Throughout the session, no communication between subjects was permitted and all choices and information were transmitted via the computer terminal, utilizing the z-tree program (Fischbacher 2007).

At the beginning of the session, each subject was assigned to a group. This assignment did not change throughout the experiment. Each session consisted of both Small groups (with three subjects each) and Large groups (with six subjects each). A typical session divided

18 subjects into four groups as follows: groups A and C were Small three-person groups, and group B and D were Large six-person groups. Each session consisted of eight periods, all identical in structure. In each period, every subject submitted a number, corresponding to her input choice. The input choice took one of four values: $e_i = \{1, 2, 3, 4\}$. The payoff function was the same as in (1). The parameters used were $a = \$1.20$, $b = \$.40$, and $c = \$.20$. Thus, the payoff for the Pareto-dominant equilibrium in the coordination game was always \$2.00.

In the *Market* conditions, subjects first traded in an asset market in which securities' liquidating values depended upon the output in the coordination game.[8] In the *Market H* treatment, $\beta = \$.10$ whereas in the *Market L* treatment $\beta = \$.005$.[9] Prior to trading, subjects were assigned to markets such that the number of traders per market was fixed at nine. This was achieved by conducting two parallel and separate sets of markets, each populated by one Small group and one Large group. Therefore, in one market set the value of the securities traded was determined by the output of a Small group, and in the second market set the value of the securities was determined by the output of a Large group. For example, in most sessions Market 1 included members from groups A and B trading securities linked to the output of group A, and Market 2 included members from groups C and D trading securities linked to the output of group D.

Each market contained two types of traders. Insiders were subjects who traded on outcomes that they could directly influence, meaning that their own game determined asset values. Outsiders traded on an exogenous outcome, meaning that asset values were determined by the outcome of the other group's game. In a typical session, Groups A and D were Insiders and groups B and C were Outsiders.[10]

[8] In two of the market treatment sessions, only six market periods were conducted due to time considerations. In both cases, subjects still participated in eight game periods with their initial endowment taken as their payoff from the market.

[9] The parameter amounts were expressed to subjects in 'experimental dollars' and the appropriate exchange rate was selected so that, in both treatments, the liquidation values of the assets were exactly 1 experimental dollar. This allowed prices to potentially directly reveal probabilistic information in both *Market* treatments.

[10] Some sessions included only 9 participants. In these cases, there was one Small group and one Large

Trading took place over an electronic double-auction market. The trading stage lasted approximately six minutes. During that time subjects were free to submit limit orders, which were posted to the limit-order book, or to accept limit orders submitted by others.

At the beginning of each trading stage, subjects were endowed with units of the different assets and with an interest-free loan of cash. The endowments varied across subjects and across periods but the aggregate endowment at the beginning of each trading period was equal across securities at 54 units. In each period two subjects in each market had an endowment of 24 units of a particular asset and none of the other assets; one subject in each market had an endowment of six units of each asset. The choice of asymmetric endowments (across subjects) is standard in these types of asset markets and is designed to stimulate trading by providing rebalancing motives to participants. Also, the aggregate endowment did not constrain further trading; subjects could sell each asset short.[11] At the end of the trading stage, subjects participated in the coordination game. Then, subjects' positions in the securities were liquidated according to the appropriate group's output.

After choosing their own input level, subjects observed the anonymous distribution of input choices in their group. In addition to receiving information about their own group's input choices, each group also observed the input choices of one other group such that a Small group was linked to a Large group. The feedback from the game provided to subjects in all variants of the experiment was the same. In the *Market* variants, subjects were informed of the choices of their group as well as those of the other group (of the other size) participating in their market. In the Control variant, subjects were informed of the choices in their group as well as those in a group of the other size.

The experiment consisted of 17 sessions conducted at the Laboratory for Economic Management and Auctions (LEMA) at the The Pennsylvania State University, between October 2006 and October 2007. We obtained data for 16 groups in the *Control*, 24 in *Market H*,

group, both participated in the same market, and one group's (Insiders) outcome determined the value of the assets while the other (Outsiders) did not.

[11] A margin requirement was used to ensure that no subject's short sales exceeded the amount of their cash loan.

and 16 in *Market L*. In every condition, half (8, 12, 8) of the groups were Large and the other half were Small. In the two *Market* conditions, half of the groups were Insiders and the other half were Outsiders. Thus, in the *Market H* (*Market L*) treatment we have data for 6 (4) groups in each of the four conditions (Large/Small-Insider/Outsider). No subject appeared in more than one session. Subjects were recruited from a distribution list comprised of primarily economics and business undergraduate students. Participants received a show-up fee of $6 and an additional performance-based payment averaging $13.52 (ranging from $7.00 to $28.40) for a session lasting around 2 hours.

4 Results

4.1 Group Output

We begin by assessing the market treatment effect on output.[12] Figure 1 depicts the average output across treatments over the eight periods of the experiment while separating the data into Small groups (Panel A) and Large groups (Panel B). First, we find that the results under the *Control* treatment are in line with those reported by previous studies (e.g., Van Huyck et al. (1990)); Small groups generally coordinate on higher output levels, close to 4, and there is little decline over time. In contrast, Large groups find it difficult to maintain high output and experience a steady decline over periods, ending up with average output of 2.

Compared with the *Control* treatment, output in both *Market* treatments (pooling the Market H and Market L treatments) is substantially lower for both Large and Small groups. For Small groups, the average output level falls from 3.66 in the *Control* treatment to 1.84 in the *Market* treatments. For Large groups, average output falls from 2.44 to 1.10. Average output in the presence of asset markets is not only lower overall but also on a period-by-period basis.

[12]Throughout this section, unless noted otherwise, we analyze data obtained from Insider groups only.

We test for the statistical significance of these patterns in Table 1, which reports ordered probit regression results of groups' output regressed on group size and *Market* treatments. Each observation consists of group output in a period. These regressions take into account the ordinal nature of output. First, we find that output is lower for Large groups (across both treatments) by at least 0.9 units (see columns 2, 3, and 5). Second, the *Market* treatments produce output that is lower by at least 1.6 units (across both group sizes) compared with the *Control* treatment (see columns 1 and 3). Interacting the *Market* treatment with group size (column 3) reveals that Large and Small groups are affected almost identically by the presence of the market, as the interaction term is small and not statistically different from zero. Third, we find that group output in the *Market L* treatment is higher than in the *Market H* treatment (see columns 4 and 5), but still significantly below output in the *Control* treatment. When we repeat the same analysis for observations collected in the first period only, we get qualitatively similar results.

To account for possible between-group heterogeneity, we explore to where output converges in later periods separately for each group. To obtain a relevant statistic, we use the median of each groups' output level over the last five periods of the experiment (Hamman et al. (2007) use a similar measure). This measure represents an estimate of the central tendency in a group's output in the latter part of the experiment.[13]

Table 2 reports the distribution of median output levels, across groups, during the latter part of the session (periods 4 through 8). In the *Control* treatment, the most frequent median outcome for Large groups is 1, but several groups also are at higher output. However, the distribution of outcomes shifts dramatically in the *Market* treatments; virtually all Large groups are at the lowest output level. Small groups' median output level in the *Control* treatment is high, with all groups at an output of 3 or 4. In both *Market* treatments, however, the distribution of outcomes once again shifts toward lower output levels.

[13] For example, consider the following two hypothetical groups: the first group has an output of $\{4, 3, 2, 1, 1\}$ and the second group has an output of $\{4, 4, 4, 4, 1\}$, in the last five periods. While both groups start and end at the same output levels, it is clear that their behavior is quite different. Capturing this difference, the measure described above assigns a value 2 to the first group and the value 4 to the second.

Overall, the presence of an asset market in conjunction with a coordination game results in a substantially less efficient output level. For all group sizes and periods, output is lower in the *Market* treatments compared with the *Control* treatment. The effect is not only statistically but also economically significant. This allows us to reject Hypothesis 1, which suggested that the communication afforded by the asset market would result in higher output. These results also stand in contrast to the findings of Blume and Ortmann (2007), Cooper et al. (1992) and Van Huyck et al. (1993), which show that other forms of pre-play communication, including other kinds of pre-play markets, produce coordination on higher output levels.

To better understand what drives these results we next turn to study the two asset market dimensions that can influence behavior. First, we look at the influence of portfolio incentives on subsequent play. We focus on the ways in which security holdings influence input choices and the resulting output levels. Second, we look at the role prices play in aggregating and disseminating players' beliefs.

4.2 Portfolio Incentives

As we demonstrated in Section 2, players' asset positions can affect the set of Nash equilibria in the coordination game. Before turning to see whether portfolio incentives can account for the difference in equilibrium selection between the *Control* and the *Market* treatments, we ask whether individuals' input choices are influenced by their portfolio holdings.

Table 3 shows the results obtained from marginal probit regressions of individuals' input choices on their end-of-period portfolio holdings of assets X_1, X_2, X_3, X_4. These regressions estimate how the probability of choosing a given input level changes as the holdings of each of these securities change. For example, column 1 of the table measures how the probability of a subject selecting input level 1 is related to her portfolio holdings. Columns 1 through 4 report the pooled results for both *Market* treatments, while columns 5 through 8 separate the effect for the two *Market* treatments such that the coefficients reported in first four rows correspond to *Market L* only and the coefficients reported in the last four rows correspond to the incremental difference between *Market L* and *Market H*.

Overall, we find that subjects who choose an input level m hold more m security units and less non-m security units. For example, column 1 in Table 3 indicates that subjects are 1.4% more likely to choose an input level of 1 with every additional unit of asset X_1 held. In this case, increased holdings of assets X_2, X_3, and X_4 have a negative, although not statistically significant, effect. Similar patterns emerge if we look at subjects who choose other input levels; all diagonal elements in columns 1-4 are positive and statistically significant, while all off-diagonal elements in these columns are negative.[14]

Columns 5 through 8 in Table 3 separate the relationship between holdings and input choices by Market treatment. The top half reports the relationship for *Market L*, while the bottom half reports the incremental relationship for *Market H*. When market incentives are high (last 4 rows), the diagonal coefficients are all positive, while virtually all off-diagonal elements are negative. While this suggests stronger relationships between holdings and behavior for the *Market H* treatment, few of the relationships are statistically significant. Moreover, much of the statistical significance from the left panel (columns 1 through 4), persists for the *Market L* treatment alone (top 4 rows).

Given that individuals' choices appear to be related to their portfolio holdings, we turn to test the implications of Proposition 1 to determine the set of Nash equilibria after trading in the market. To do so, we compute for each group and period the set of pure-strategy equilibria that are incentive compatible with subjects' security holdings and the modified payoffs of the game. Recall that in the *Control* treatment, the set of equilibria is $\{1, 2, 3, 4\}$. Table 4 presents the observed distribution of group output for different realized sets of equilibria remaining in the game modified by asset holdings. For example, the first column, labeled "$\{1\}$" reports the frequency of different output levels observed when only matched

[14]These results are inconsistent with the idea that subjects primarily use the asset market to hedge. If that was generally the case, we should have found the opposite pattern; diagonal elements in Table 3 should have been negative.

input levels resulting in output level 1 satisfy Proposition 1. Likewise, the second column, labeled "{1,2}" refers to all instances in which only matched input levels of 1 or 2 satisfy this condition. Panel A reports the results for Small groups while Panel B reports the results for Large groups. For comparison, we include the corresponding distribution of output choices observed in the *Control* treatment in the last column.

While this analysis does not allow us to select among equilibria, it suggests which equilibria *will not* be played. We find that when all groups are predicted to select an output level of 1 (the first column), 82% of the Small groups and 98% of the Large groups do so. Likewise, 89% of Small groups behave accordingly when they are predicted to obtain output levels of 1 or 2, and 100% of Small groups do so when they are predicted to chose output levels of 1, 2, or 3. While group outcomes are not entirely consistent with the incentives induced by security holdings, these results suggest an important role for portfolio incentives.

At the same time, we observe that the presence of asset markets lowers efficiency in a way that cannot be explained by portfolio incentives alone. To see this, contrast the distribution of group output when portfolio incentives *do not* eliminate any of the equilibria (column labeled "{1,2,3,4}") with the distribution of group output in the *Control* treatment. Comparing the two, we find that for both Small and Large groups, output levels are substantially higher in the *Control* treatment than in the *Market* treatments, even when the set of equilibria are unchanged. For example, 70% of the Large groups in the *Market* treatments, for which portfolio holdings did not eliminate any of the equilibria, selected output of 1 compared with 33% in the *Control* treatment. Using the Kolmogorov-Smirnov test for equality of distributions, we reject the null hypothesis that distributions of output levels are the same across the two sub-samples for which all four output levels are equilibria, at the 1% level (for both Large and Small groups).

In summary, the results regarding the portfolio incentive effects provide partial support for Hypothesis 2. We find that both individual input and group output levels are influenced by portfolio holdings. At the same time, we find that portfolio holdings cannot alone account for the full set of findings. Moreover, the results obtained from the *Market L* treatment, where the portfolio incentive effect is unlikely to influence behavior, stand in contrast to the hypothesis.

4.3 Price Informativeness

Since portfolio holdings alone do not fully account for the effect markets have on play in the coordination game, we turn to study the role of prices. First, we show that prices affect individual input choices. Second, we examine the informativeness of market prices about the subsequent group output. This provides information about the ability of subjects to use prices as a coordinating device. In what follows, we use the average price over the last five trades (in each period) as our measure of *market price* for that period.[15]

Evidence on the connection between prices and input choices can be obtained from Table 5. In the table, we estimate a marginal probit regression of individual input choice on the closing prices of securities X_1, X_2, X_3 and X_4. We estimate these regressions twice: with the pooled data from both *Market* treatments (columns 1 through 4) and then with prices interacted with a *Market H* dummy variable.[16] As we can see from the pooled results, a low input level (of 1) is more likely to be selected when the price of security X_1 is high and the price of security X_4 is low (see column 1). Likewise, a high input level (of 4) is more likely to be selected when the price of security X_1 is low and the price of security 4 is high (see column 4). If we redo the analysis in Table 5 using only the first period we obtain similar results, indicating that market prices influence input choices from the outset of the experiment. Surprisingly, the results in columns 5 through 8 suggest that the relation between prices and input choices is somewhat weaker for *Market H*, compared with *Market L*.

Table 6 shows that prices affect not only input choices but also group output. The table uses ordered probit analysis regressing group output on maximal closing prices, and a number

[15]When less than five trades are completed, we average all the trades conducted in that market and period. Utilizing other measures such as the median of the last trades, the average of all trades, or the closing trading price yield similar results.

[16]Repeating the same set of regressions while including subjects' holdings yields very similar results.

of treatment and control variables. For each observation, a group in a period, the variable "Maximal Price" takes the value i if security i had the highest closing price among the four securities in that period. Since group output is path dependent, one may worry that prices adjust to past outcomes rather than influence subsequent outcomes. We therefore include the groups' prior period output in the regressions as a control. While there is a strong (positive) relation between a group minima at period t and $t-1$, prices additionally influence group output. Periods in which the maximally-priced asset corresponds to higher output are associated with higher actual group output, controlling for output in the previous period, market conditions, group size, and the period number. However, we find no support for Hypothesis 4, which postulated that prices would more accurately predict subsequent group behavior in the *Market H* treatment. Indeed, the interactions between maximal price and either the *Market H* dummy variable or the Large group dummy are insignificant (see columns 3-5).

Since prices appear to be informative about subsequent group behavior, it is natural to ask whether subjects in the *Market* treatments are less likely to mis-coordinate by choosing input levels that are higher than the minimum in their group. Recall that subjects are better off choosing input levels no higher than the minimum in their group. We measure "wasted input" in a group by averaging the absolute difference between subjects' individual input choices and the minimum in their group. Therefore, each observation consists of the average wasted input for a group in a period.

Table 7 examines how wasted input changes across treatments (*Control*, *Market H*, *Market L*) and group sizes, while controlling for group output and period number. Column 1 reveals that wasted input is slightly higher in the *Market* treatments. However, this result may be due to the higher likelihood of low output levels in the *Market* treatments; when output is lower, there is greater opportunity for wasted input, as confirmed by the results in column 3. When we control for the group output (column 4), wasted input is significantly lower in the *Market* treatments. In an attempt to control for the path dependency in individual and group behavior and to explore any immediate effect of the market on individual behavior, we consider the first period separately (column 5). Since there are very few group level observations for any single period, we look at individual wasted input, instead of average group wasted input. The results indicate that from the outset, subjects are able to use markets to coordinate their input choices and thereby reduce wasted input. Thus, consistent with Hypothesis 5, holding the group outcome constant, we find that subjects are significantly better at coordinating inputs in the *Market* treatments compared with the *Control* treatment.

The results on the effects of prices lend further support for Hypothesis 3. Recall that this hypothesis seems most consistent with the group output results: the output levels are significantly lower in both *Market* treatments. Here, we additionally show that prices convey information and affect group outcomes, individual input, and wasted input, beyond any effect of holdings. Prices seem to play two roles. They allow subjects to communicate doubt, which has negative effect on group output. At the same time, prices also serve to coordinate beliefs, thus resulting in more frequent equilibrium play and less input waste. Below we explore the effect of markets on Outsiders, where we find further evidence that prices, rather than portfolio incentives, are the channel through which the market treatments affect behavior.

4.4 Outsiders' Behavior

Recall that in the *Market* treatments each set of markets is populated by both Insiders, who play a game that is payoff-related to the markets, and Outsiders, whose game is unrelated to the markets. If the effect of markets on behavior is driven mainly by portfolio incentives, only Insider groups should be negatively affected. Outsiders' incentives in the game are unaffected by the presence of markets, so their output levels should resemble those in the *Control* treatment. However, Outsiders' beliefs may be affected by prices and trading in the market that is unrelated to their game.

Table 8 compares group output between Outsiders and Insiders groups and Outsiders and Control groups, while controlling for group size and market incentives. Panel A of Table 8 compares group output of Control and Outsider groups. The results suggests that Outsiders group output is significantly lower than that of Control groups. Panel B of Table 8 compares group output of Outsider and Insider groups. The results suggest that contrary to the hypothesis, Outsider groups are negatively affected by the market. In fact, they select output levels very close to those observed for Insider groups (the coefficient for Insider is not statistically significant). Interacting group size with Insider/Outsider treatments does not yield statistically significant differences associated with Outsiders. Crossing *Market H*/*Market L* and Insider/Outsider treatments yields marginally significant results for the interaction term (column 3) but not for the main effect. Thus, Outsiders seem to be affected by the presence of the market – reducing group output – almost to the same extent as Insiders.

These results, which stand in contrast to Hypothesis 6, are anomalous if one holds the view that the presence of markets affects behavior primarily through portfolio holdings. That is, Outsiders' incentives in the game are unchanged, so any explanation for lower output among Insiders that is based only on modified incentives cannot explain why Outsider groups change in a very similar manner. However, the results are consistent with Outsiders using market prices as a focal point for coordination. We repeated the analysis reported in Table 6, which relates group output with closing prices, using Outsider groups instead of Insider groups. As in Table 6, we find that Outsider groups exhibit strong path dependency in their group output (in fact, stronger than for Insider groups). However, maximal price is nevertheless a predictor of group output, even for Outsider groups. These results suggest that the coordination in the presence of asset markets can give rise to a linkage of behavior across strategically independent groups.

5 Conclusion

In this paper we explore the relationship between asset markets and underlying economic activity modeled by a coordination game. We find that incentives and beliefs created by the market influence aggregate behavior in strong and potentially negative ways.

Our work produces several important findings. First, the presence of asset markets can be sufficient to induce Pareto-inferior outcomes in an economic environment where coordination is important. This is true even when such influence is not produced directly by modified incentives. We observe this when the incentives from the market are small, and even when there is no connection in payoffs between the market and the economic activity (i.e., for Outsiders). Second, the asset markets do reduce one source of inefficiency, wasted input, by coordinating expectations and behavior on the resulting equilibrium. Thus, even though overall efficiency is reduced by the inferior group output, this is somewhat mitigated by a decrease in mismatched input choices. Finally, we also find that markets exhibit accuracy in forecasting the uncertain outcome of strategic interaction. Our results are consistent with the idea that the influence of markets operates mainly through communication via prices.

These results are relevant for domains in which underlying economic activity and asset markets are linked. While markets have enticing information aggregation and forecasting possibilities in regard to some kinds of economic activity, it is important to recognize that in some settings the markets themselves might influence the eventual realization of the economic outcome and, worse yet, may do so negatively.

In light of the recent proliferation of prediction markets (Wolfers and Zitzewitz 2004), it is important to understand the possible influence of such markets on the underlying activity. For example, many firms have implemented prediction markets to forecast outcomes such as sales and product quality (EricZitzewitz 2008). Given that in such settings market traders may have the ability to influence outcomes, our results suggest that the presence of production-linked asset markets may negatively influence outcomes both by creating incentive problems and pessimistically influencing beliefs.

Additionally, many macroeconomic models rely upon some relationship between expectations and productivity, as in our underlying game (Bryant 1983, Cooper and John 1988). Given markets' role in communicating and influencing expectations in our experiment, it seems possible that real-world markets may sometimes play an important role in contributing to shifts into inefficient equilibria. Thus, for example, economic crises may often be exacerbated by economic agents focusing their attention on market behavior. When agents are looking for information in asset markets, from which they form their expectations, our work suggests that the markets themselves may create self reinforcing pessimistic beliefs. Economic actors worry that others may select low strategies and this worry is aggregated and exacerbated by markets, thus leading to the inefficient equilibria.

It is also worth comparing our results to those of Van Huyck et al. (1993), who find that a pre-play asset market improves coordination. We believe the key difference between our experiment and theirs to be the symmetry in our asset market that is not present in their study. In their experiment, the market creates jointly-held positive expectations of group outcomes by eliminating those players who do not hold such optimistic beliefs. Therefore, the end result is the resolution of strategic uncertainty and mutual reassurance among those selected by the market to play the game (Crawford and Broseta 1998). In our setting however, the market creates *both* positive and negative signals to players, and in addition does not exclude players with beliefs that correspond to the inefficient outcome. Thus, our markets convey strategic uncertainty to players and allow it to "snowball" into negative expectations about the likely final outcome.

The difference between the two experiments also helps make an important point about the general relationship between markets and coupled economic activity. While Van Huyck et al. (1993) demonstrate that such a relationship can enhance efficiency, we demonstrate the opposite. Therefore, these can be viewed as contrasting existence results about how markets impact economic outcomes. Real economic contexts in which markets and economic activity are coupled will often resemble one experiment more than the other, and features of both our experiments may be present in many situations outside the laboratory. We show that considering the precise influence of markets on economic behavior is of significant importance.

More generally, our results also stand in contrast to the stylized fact that greater communication leads to more efficient coordination in games like these (Blume and Ortmann 2007, Cooper et al. 1992). We do find that communication through markets reduces wasted input and therefore aids coordination on *some* equilibrium. However, our work demonstrates that allowing players to interact via asset markets linked to multiple equilibria, which allows rich and costly communication of intentions and beliefs, has a significantly negative influence on *which* equilibrium obtains. In this regard, our work is similar to theoretical work demonstrating potentially harmful effects of public information in coordinating beliefs and behavior (Morris and Shin 2002). Our work similarly serves to highlight the potentially harmful effects of communication in situations where coordination is both critical and difficult.

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A Proofs

Proof of Proposition 1: In order for $e_i = m$ for all i to be a Nash equilibrium it must be that

$$\overline{\pi}_i(m, m; x_i) \geq \overline{\pi}_i(\ell, m; x_i)$$

for all $\ell \neq m$. Consider $\ell > m$, then we have

$$\overline{\pi}_i(m, m; x_i) = a + bm - cm + \beta x_{mi}$$

and

$$\overline{\pi}_i(\ell, m; x_i) = a + bm - c\ell + \beta x_{mi}$$

and obviously $\overline{\pi}_i(m, m; x_i) > \overline{\pi}_i(\ell, m; x_i)$ for all x_i. Now consider $\ell < m$. Nash equilibrium requires that

$$\begin{aligned}
\overline{\pi}_i(m, m; x_i) &\geq \overline{\pi}_i(\ell, m; x_i) \\
a + bm - cm + \beta x_{mi} &\geq a + b\ell - c\ell + \beta x_{\ell i} \\
bm - cm + \beta x_{mi} &\geq b\ell - c\ell + \beta x_{\ell i} \\
\beta x_{\ell i} - \beta x_{mi} &\leq bm - cm - b\ell + c\ell \\
\beta(x_{\ell i} - x_{mi}) &\leq (b - c)(m - \ell) \\
x_{\ell i} - x_{mi} &\leq \left[\frac{b - c}{\beta}\right](m - \ell).
\end{aligned}$$

∎

Proof of Proposition 2: If $p_m^* = \beta$ and $p_\ell^* = 0$ for all $\ell \neq m$ then the revealing beliefs that must support this equilibrium are fully revealing with $\mu_{mi} = 1$ and $\mu_{\ell i} = 0$ for all $\ell \neq m$ and i. Let $x_{mi}^* = k/n$ for all m and i. To see that this constitutes a rational expectations equilibrium note that, given these beliefs, $\Pi_i(e_i) = \overline{\pi}_i(e_i, m; x_i^*)$ Since the portfolio is constant across assets for each player, by Proposition 1, $e_i^* = m$ is a Nash equilibrium and therefore maximizes maximizes $\Pi_i(e_i)$.

Moving back to the market trading stage, we need that x_i^* is maximal given prices and each player's planned input choice. Given p^*, e^*, and the implied beliefs μ, each player selects x_i to maximize

$$\begin{aligned}\sum_{\ell=1}^{M}\left[\mu_{\ell i}\overline{\pi}_i(m,\ell;x_i) - p_\ell^* x_{\ell i}\right] &= \\ &= \overline{\pi}_i(m,m;x_i) - \beta x_{mi} \\ &= \pi(m,m)\end{aligned}$$

which does not depend upon x_i so any allocation is maximal, in particular, x_i^*. ∎

Proof of Proposition 3: We assume without loss of generality that feasibility requires that $x_{mi} \geq 0$ and that $k > \left[\frac{b-c}{\beta}\right](M-1)$.[17]

First, we show that the low output fully revealing equilibrium is stable. Note that by Proposition 2, we know that for all players other than player i that, given market prices, they are indifferent between different allocations. In addition, in the coordination game, it is always maximal to play $e_j = 1$ given their beliefs that $\mu_{1j} = 1$. For agent i, in the market, he or she will select an allocation x_i to maximize

$$\begin{aligned}\sum_{m=1}^{M}\left[\mu_{mi}\overline{\pi}_i(1,m;x_i) - p_m^* x_{mi}\right] &= \\ &= \sum_{m=1}^{M}\left[\mu_{mi}(a+b-c+\beta x_{1i}) - p_m^* x_{mi}\right] \\ &= a+b-c+\beta x_{1i} - \sum_{m=1}^{M} p_m^* x_{mi} \\ &= a+b-c+\beta x_{1i} - \beta x_{1i} \\ &= a+b-c\end{aligned}$$

[17]This is akin to not allowing short selling and insuring the aggregate endowment is sufficient to allow diverse portfolios. One could allow for short selling by permitting $x_{mi} < 0$ with a similar condition that would depend upon the cash endowment and margin requirement for each player.

which does not depend upon x_i so agent i is indifferent between allocations in the market stage. Let $x'_{1i} = k$ and $x'_{mi} = 0$ for all $m \neq 1$. The certain payoff from $e_i = 1$ is now given by $\Pi_i(1) = a + b - c + \beta x'_{1i}$. The expected payoff from $e_i = m \neq 1$ is defined by (5) and is

$$\Pi_i(m) = \sum_{\ell=1}^{M} \mu_{\ell i} \overline{\pi}_i(m, \ell; x'_i)$$

where

$$\overline{\pi}_i(m, \ell; x'_i) = \begin{cases} a + bm - cm + \beta x'_{mi} & \ell \geq m \\ a + b\ell - cm + \beta x'_{\ell i} & \ell < m \end{cases}$$

For any m given the definition of x'_i we have that

$$\begin{aligned} x'_{1i} - x'_{mi} &> \left[\frac{b-c}{\beta}\right](m-1) \\ \beta\left(x'_{1i} - x'_{mi}\right) &> (b-c)(m-1) \\ a + b - c + \beta x'_{1i} &> a + bm - cm + \beta x'_{mi} \\ \Pi_i(1) &> \overline{\pi}_i(m, \ell; x'_i) \end{aligned}$$

for all $\ell \geq m$. Further since for all $m \neq 1$ we have $x'_{mi} = 0$ it follows that for all $1 < \ell < m$

$$\begin{aligned} a + b\ell - cm + \beta x'_{\ell i} &< a + bm - cm + \beta x'_{mi} \\ \overline{\pi}_i(m, \ell; x'_i) &< \overline{\pi}_i(m, m; x'_i) \\ \overline{\pi}_i(m, \ell; x'_i) &< \Pi_i(1). \end{aligned}$$

Thus $e_i = 1$ given any perturbed beliefs for player i.

Next, we show that for any higher level $m > 1$, the fully revealing equilibrium is not stable. Let $e_i = m > 1$ and consider the market trading stage. Agent i will select an allocation to maximize expected payoffs given prices, or

$$\sum_{\ell=1}^{M} \left[\mu_{\ell i}\overline{\pi}_i(m,\ell;x_i) - p_\ell^* x_{\ell i}\right] =$$
$$= \sum_{\ell \geq m} \mu_{\ell i}\left[a + bm - c\ell + \beta x_{mi}\right] + \sum_{\ell < m}\left[a + b\ell - cm + \beta x_{\ell i}\right] - \beta x_{mi}$$

Thus, for any $\ell > m$ the marginal payoff is 0. For m, the first order condition is given by

$$\sum_{\ell \geq m} \mu_{\ell i}\beta - \beta = \left(\mu_{\ell i} - 1\right)\beta < 0.$$

For $\ell < m$ the first order condition is given by

$$\mu_{\ell i}\beta > 0.$$

Thus, player i has unbounded positive demand for all assets X_ℓ with $\ell < m$ and negative demand for the asset X_m. Therefore, the maximal feasible allocation is given by $x'_{\ell i} = 0$ for all $\ell \geq m$ and $x'_{\ell i} = k$ for $\ell < m$. Moving to the second stage, we see that this allocation cannot support $e_i = m$ as an equilibrium beliefs. Consider the alternative $e_i = m - 1$. The expected payoffs form $e_i = m$ is given by

$$\Pi_i(m) = \sum_{\ell=1}^{M} \mu_{\ell i}\overline{\pi}_i(m,\ell;x'_i)$$

where

$$\overline{\pi}_i(m,\ell;x'_i) = \begin{cases} a + bm - cm & \ell \geq m \\ a + b\ell - cm + \beta x'_{\ell i} & \ell \leq m-1 \end{cases}$$

and the expected payoff from $e_i = m - 1$ is given by

$$\Pi_i(m-1) = \sum_{\ell=1}^{M} \mu_{\ell i}\overline{\pi}_i(m-1,\ell;x'_i)$$

where

$$\overline{\pi}_i(m-1,\ell;x_i') = \begin{cases} a + b(m-1) - c(m-1) + \beta x'_{(m-1)i} & \ell \geq m \\ a + b\ell - c(m-1) + \beta x'_{\ell i} & \ell \leq m-1 \end{cases}$$

First consider $\ell \geq m$. By construction we have that

$$\begin{aligned} x'_{(m-1)i} &> \frac{b-c}{\beta} \\ a + b(m-1) - c(m-1) + \beta x'_{(m-1)i} &> a + bm - cm \\ \overline{\pi}_i(m-1,\ell;x_i') &> \overline{\pi}_i(m,\ell;x_i') \end{aligned}$$

For $\ell \leq m-1$, since $c(m-1) < cm$ it follows that $\overline{\pi}_i(m-1,\ell;x_i') > \overline{\pi}_i(m,\ell;x_i')$ so it must be that $\Pi_i(m-1) > \Pi_i(m)$ and $e_i = m$ cannot be an equilibrium in beliefs. ∎

B Tables and Figures

Table 1: **Group Output by Condition**

	(1)	(2)	(3)	(4)	(5)
	Group Output				
Market	-1.586***		-1.979***	-1.050**	-1.255**
	[0.384]		[0.527]	[0.458]	[0.615]
Market H				-1.185**	-1.541**
				[0.527]	[0.661]
Large Group		-0.893**	-1.378***		-1.424***
		[0.367]	[0.514]		[0.529]
Market x Large Group			0.13		-0.208
			[0.754]		[0.877]
Market H x Large Group					0.381
					[0.919]
Period	-0.011	-0.013	-0.014	-0.015	-0.019
	[0.022]	[0.019]	[0.026]	[0.024]	[0.029]
Observations	288	288	288	288	288
R^2	0.1679	0.0591	0.2701	0.2113	0.3251

This table presents ordered probit regression results of groups' output (across periods) on the following independent variables: *Market* treatment (*Control* treatment observations are coded as 0 and both (*Market*) treatments are coded 1); *Market H* treatment (*Market H* treatment observations are coded as 1 and all other observations as 0); Large Group (*Large* observations are coded as 1(0) if they were obtained with Large(Small) groups); interaction between *Market*, *Market H*, and group size, and period number. Outsider groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

Table 2: **Distributions of Median Group Output (Periods 4 - 8)**

	Panel A: Small Groups			
Median Output	Control	Market-All	Market H	Market L
4	0.750	0.100	0.000	0.250
3	0.250	0.200	0.167	0.250
2	0.000	0.100	0.000	0.250
1	0.000	0.600	0.833	0.250
Observations	8	10	6	4

	Panel B: Large Groups			
Median Output	Control	Market-All	Market H	Market L
4	0.250	0.000	0.000	0.000
3	0.250	0.000	0.000	0.000
2	0.125	0.100	0.000	0.250
1	0.375	0.900	1.000	0.750
Observations	8	10	6	4

The table presents the distribution of groups' output levels. Each observation represents the median output over the last 5 period of the session. Panel A reports results for Small groups and Panel B reports results for Large groups. Outsider groups are not included in the analysis.

Table 3: **Individual Portfolio Holdings and Input Choices**

Holdings	(1) Input = 1	(2) Input =2	(3) Input = 3	(4) Input = 4	(5) Input = 1	(6) Input =2	(7) Input = 3	(8) Input = 4
Security 1	0.014***	-0.005***	-0.004***	-0.004**	0.009***	-0.002***	-0.004	-0.001
	[0.002]	[0.001]	[0.001]	[0.002]	[0.003]	[0.001]	[0.002]	[0.002]
Security 2	-0.003	0.007***	-0.001	-0.004***	-0.002	0.005**	0	-0.004
	[0.002]	[0.001]	[0.001]	[0.001]	[0.004]	[0.002]	[0.002]	[0.002]
Security 3	0	-0.006***	0.006***	-0.001	-0.001	-0.004***	0.005***	0
	[0.002]	[0.002]	[0.002]	[0.001]	[0.004]	[0.001]	[0.002]	[0.003]
Security 4	-0.001	-0.001	-0.001	0.004**	-0.003	0	0.001	0.003
	[0.002]	[0.001]	[0.001]	[0.002]	[0.002]	[0.002]	[0.001]	[0.002]
Security 1 x Market H					0.010*	-0.006**	-0.002	-0.005
					[0.006]	[0.003]	[0.003]	[0.004]
Security 2 x Market H					-0.001	0.002	-0.001	0
					[0.006]	[0.003]	[0.002]	[0.003]
Security 3 x Market H					0.003	-0.003	0.001	-0.002
					[0.005]	[0.002]	[0.003]	[0.004]
Security 4 x Market H					0.004	-0.001	-0.004***	0.002
					[0.005]	[0.004]	[0.002]	[0.003]
Observations	720	720	720	720	720	720	720	720
Fraction	0.453	0.186	0.142	0.219	0.453	0.186	0.142	0.219
R^2	0.09	0.10	0.11	0.03	0.11	0.11	0.12	0.04

This table reports marginal probit regression results of individual input choices and portfolio holdings of securities 1, 2, 3, and 4. In column (1) the dependent variable is coded as 1 if the subject selected an input level of 1 (and 0 otherwise), in column (2) the dependent variable is coded as 1 if the subject selected an input level of 2 (and 0 otherwise), in column (3) the dependent variable is coded as 1 if the subject selected an input level of 3 (and 0 otherwise), and in column (4) the dependent variable is coded as 1 if the subject selected an input level of 4 (and 0 otherwise). Market H is a dummy variable that is coded with 1 if the observation was obtained under the *Market H* treatment, and 0 otherwise. Outsider groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

Table 4: **Portfolio Holdings and Equilibrium Selection**

	Panel A: Small Groups					
	{1}	{1,2}	{1,2,3}	{1,2,3,4}	Overall	Control
Output = 4	0.03	0.00	0.00	0.29	0.13	0.72
Output = 3	0.09	0.11	0.33	0.26	0.16	0.23
Output = 2	0.06	0.11	0.00	0.26	0.14	0.03
Output = 1	0.82	0.78	0.67	0.19	0.58	0.02
Observations	34	9	3	31	80	64

	Panel B: Large Groups					
	{1}	{1,2}	{1,2,3}	{1,2,3,4}	Overall	Control
Output = 4	0.00	0.00	0.00	0.00	0.00	0.23
Output = 3	0.00	0.00	0.00	0.00	0.00	0.30
Output = 2	0.02	0.00	0.00	0.30	0.10	0.14
Output= 1	0.98	1.00	0.00	0.70	0.90	0.33
Observations	46	2	0	23	80	64

This table reports the distribution of groups' output choices sorted by treatment ("All" denotes all *Market* treatment observations and "Control" denotes *Control* treatment observations) and with the *Market* treatment into sub-groups based on the set of equilibria that are consistent with subjects modified payoffs and their collective portfolio holdings. Panel A reports results for Small groups and Panel B reports results for Large groups. A small number of instances in which portfolios produced other sets of equilibria are excluded. Outsider groups are not included in the analysis.

Table 5: **Security Prices and Input Choices**

Ave Closing Price	(1) Input = 1	(2) Input =2	(3) Input = 3	(4) Input = 4	(5) Input = 1	(6) Input =2	(7) Input = 3	(8) Input = 4
Security 1	0.603***	0.034	-0.072	-0.509**	0.872***	-0.013	-0.136	-0.668**
	[0.225]	[0.102]	[0.130]	[0.217]	[0.289]	[0.118]	[0.149]	[0.280]
Security 2	-0.357	0.507**	-0.035	-0.036	-1.029***	0.905***	0.066	0.021
	[0.326]	[0.253]	[0.147]	[0.196]	[0.265]	[0.133]	[0.186]	[0.260]
Security 3	0.402	-0.158	0.136	-0.354	0.546	-0.370*	0.087	-0.274
	[0.357]	[0.225]	[0.164]	[0.293]	[0.447]	[0.192]	[0.267]	[0.412]
Security 4	-0.561**	-0.2	-0.08	0.868***	-0.886***	-0.34	0.093	1.156***
	[0.278]	[0.223]	[0.129]	[0.213]	[0.333]	[0.262]	[0.190]	[0.279]
Security 1					-0.504**	0.146*	0.136	0.279
x Market H					[0.240]	[0.081]	[0.112]	[0.226]
Security 2					1.534***	-1.242***	-0.266	0.079
x Market H					[0.353]	[0.196]	[0.232]	[0.330]
Security 3					-0.805	0.597**	0.302	-0.038
x Market H					[0.557]	[0.243]	[0.299]	[0.469]
Security 4					0.526	0.597*	-0.452*	-0.623*
x Market H					[0.487]	[0.346]	[0.251]	[0.370]
Observations	447	447	447	447	447	447	447	447
Fraction	0.378	0.201	0.152	0.268	0.378	0.201	0.152	0.268
R^2	0.12	0.04	0.01	0.14	0.18	0.08	0.03	0.16

This table reports marginal probit regression results of individual input choice and the average closing price of securities 1, 2, 3, and 4. In column (1) the dependent variable is coded as 1 if the subject selected input level of 1 (and 0 otherwise), in column (2) the dependent variable is coded as 1 if the subject selected input level of 2 (and 0 otherwise), in column (3) the dependent variable is coded as 1 if the subject selected input level of 3 (and 0 otherwise), and in column (4) the dependent variable is coded as 1 if the subject selected input level of 4 (and 0 otherwise). Market H is a dummy variable that is coded with 1 if the observation was obtained under the *Market H* treatment, and 0 otherwise. Outsider groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

Table 6: **Security Prices and Group Output**

	(1)	(2)	(3)	(4)	(5)
	Group Output				
Maximal Price	0.540***	0.620***	0.565***	0.596***	0.456***
	[0.110]	[0.110]	[0.174]	[0.090]	[0.161]
Market H	-0.818		-0.684		-0.859
	[0.520]		[0.496]		[0.623]
Large Group		-0.475		-0.72	-1.746**
		[0.431]		[0.641]	[0.775]
Maximal Price			-0.082		-0.157
x Market H			[0.362]		[0.513]
Maximal Price				0.138	0.571
x Large Group				[0.379]	[0.505]
Last Period	1.253***	1.230***	1.237***	1.230***	1.102***
Output	[0.217]	[0.251]	[0.243]	[0.252]	[0.214]
Period	-0.035	-0.013	-0.036	-0.01	-0.036
	[0.073]	[0.079]	[0.073]	[0.079]	[0.067]
Observations	132	132	132	132	132
R^2	0.55	0.54	0.55	0.54	0.58

This table presents ordered probit regression results of groups' output (across periods) on the following independent variables: *Market H* treatment (*Market H* treatment observations are coded as 1 and all other observations as 0); group size (*Small*(*Large*) groups observations are coded as 0(1)); Maximal price (coded as i if security i had the highest closing price); interaction between *Market H*, group size, and maximal price. Control variables include last period's group output and period number. Outsider groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

Table 7: **Wasted Input**

	(1)	(2)	(3)	(4)	(5)
	Groups' Average Wasted Input				Individual Wasted Input
	All Periods				*Period 1 Only*
Market	0.065			-0.370**	-0.315***
	[0.164]			[0.152]	[0.091]
Market H	0.329**			0.051	
	[0.154]			[0.183]	
Large Group		0.321**		-0.043	
		[0.147]		[0.112]	
Group Output			-0.296***	-0.382***	-0.633***
			[0.038]	[0.053]	[0.040]
Period	-0.065***	-0.065***	-0.067***	-0.068***	
	[0.017]	[0.017]	[0.016]	[0.016]	
Constant	0.796***	0.781***	1.596***	1.996***	2.600***
	[0.161]	[0.126]	[0.130]	[0.218]	[0.121]
Observations	288	288	288	288	162
R^2	0.13	0.12	0.41	0.45	0.31

This table presents regression results of groups' average wasted input (across periods) on the following independent variables. Wasted input is defined as the absolute difference between subject's input choice and the output in her group during that period. *Market* treatment ($Control(Market)$ treatment observations are coded as 0(1)); Market H (coded with 1 if the observation was obtained under the *Market H* treatment, and 0 otherwise); group size ($Small(Large)$ groups observations are coded as 0(1)); group output; interaction between *Market* and group output; period number. Outsider groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

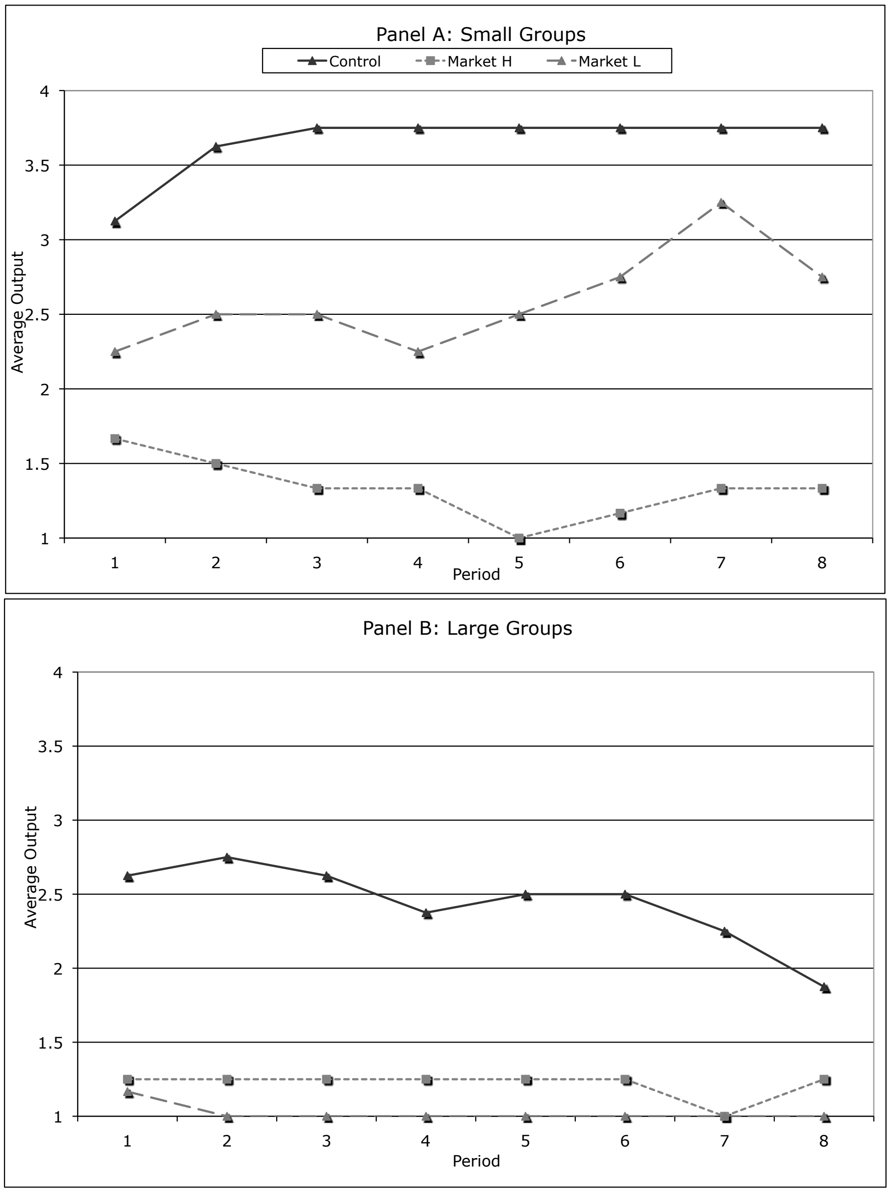
Table 8: **Group Output of Outsider Groups**

	(1)	(2)	(3)	(4)
	Panel A: Outsiders vs. Control			
Outsider	-1.646***	-2.410***	-1.611***	-1.744***
	[0.351]	[0.496]	[0.426]	[0.433]
Large Group		-1.523***		-0.927***
		[0.571]		[0.339]
Outsider x Large Group		1.103		
		[0.689]		
Market H			-0.058	-0.121
			[0.422]	[0.459]
Period	-0.038	-0.041	-0.038	-0.043
	[0.026]	[0.030]	[0.026]	[0.030]
Observations	288	288	288	288
R^2	0.174	0.248	0.174	0.229

	(1)	(2)	(3)	(4)
	Panel B: Outsiders vs. Insiders			
Insider	0.102	-0.211	0.736	0.174
	[0.346]	[0.478]	[0.494]	[0.337]
Large Group		-1.326**		-0.866***
		[0.558]		[0.324]
Insider x Large Group		0.908		
		[0.698]		
Market H			-1.264**	-0.670*
			[0.563]	[0.344]
Insider x Market H			-1.207*	
			[0.707]	
Period	-0.037	-0.042	-0.043	-0.049
	[0.027]	[0.029]	[0.030]	[0.031]
Observations	320	320	320	320
R^2	0.0035	0.0725	0.0645	0.0931

This table presents ordered probit regression results of groups' output (across periods) on the following independent variables. Insider treatment (Outsider(Insider) treatment observations are coded as 0(1); Outsider treatment (Control(Outsider) treatment observations are coded as 0(1); *Market H* treatment (*Control*(*Market H*) treatment observations are coded as 0(1)); group size (Small(Large) groups observations are coded as 0(1)); period number. *Control* treatment groups are not included in the analysis. Standard errors (reported in brackets) are clustered by group. *** denotes $p < 0.01$, ** denotes $p < 0.05$, and * denotes $p < 0.10$.

Figure 1: **Group Output by Period and Treatment**



The figure depicts average output (across groups) for Small (Panel A) and Large (Panel B) groups. The solid line corresponds to observation collected in the *Control* treatment, the dotted line corresponds to observations collected in the *Market H* treatment, and the dashed line corresponds to observations collected in the *Market L* treatment.