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Journal of Economic Theory 158 (2015) 407–426

JOURNAL OF Economic Theory

www.elsevier.com/locate/jet

Information, Coordination, and Market Frictions: An Introduction

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Available online 7 May 2015

Market frictions due to asymmetric information have received significant attention at least since the pioneering work of Akerlof [3] and Rothschild and Stiglitz [103] on adverse selection, Spence [105] on signaling, and the work on rational expectations equilibria (REE) by Lucas [78], Radner [96], and Grossman and Stiglitz [65]. The study of such frictions has had tremendous impact on all fields of economics and finance. Indeed, informational frictions constitute one of the three main sources of market failures, the other two being market power and externalities.

Information frictions have been incorporated in market competition models starting from the pioneering work of Lucas [78] in macroeconomics, Grossman and Stiglitz [65] and Kyle [73] in finance, Wilson [130] and Milgrom [84,85] in auctions, Palfrey [93] and Vives [114,115] in Cournot markets, and Kyle [74] and more recently Vives [124] in models of competition in schedules. Dynamic models followed with Kyle [73], Vives [117–119], Wang [127], He and Wang [68] and Spiegel [106]. Information externalities have also received significant attention (see, e.g., Vives [117,120], and Amador and Weill [8,9]).

Fostered by the contribution of Morris and Shin [87], a fast-growing literature investigates the welfare effects of different information structures in economies with strategic complementarity or substitutability in actions. In particular, Angeletos and Pavan [16] relate the social value of information to possible inefficiencies in the use of information in a family of large economies with quadratic payoffs and Gaussian information that includes as special cases Morris and Shin [87] and the early contribution by Vives [115], and which stylizes certain business-cycle applications.

Another strand of the literature starting with the pioneering work of Carlsson and Van Damme [35], investigates equilibrium selection in (global) coordination games with dispersed information. The applications of this approach, starting with Morris and Shin [86], have been very fruitful

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[1] Xavier Vives gratefully acknowledges the financial support of the Generalitat de Catalunya, AGAUR grant 2014 SGR 1496.

http://dx.doi.org/10.1016/j.jet.2015.05.001

in fields ranging from international finance, banking, debt and currency crises, and political change.

This symposium advances our understanding of the positive and normative properties of economies with informational frictions. Central themes are the efficient use of private and public information, information aggregation by prices, and coordination issues. The range of topics encompasses robust predictions in economies with dispersed information, the private and social value of information, anomalies in REE such as the possibility of sunspot-driven fluctuations and the potential non-monotonicities of the price impact to the number of traders or size of the market, the importance of market microstructure (e.g. the type of orders submitted and/or disclosure rules) on informational and economic efficiency, information acquisition (rational inattention, effects on security design, interaction with coordination motives), and the effects of dynamic trading in overlapping generations (OLG) economies and over-the-counter (OTC) markets. In many of the contributions, the interactions between informational frictions and other frictions such as market power, financial frictions, and externalities are also highlighted.

Several of the papers in this Symposium were presented at the workshop on Information, Competition and Market Frictions held in June 2013 at the Barcelona GSE Summer Forum, co-organized with the Public-Private Sector Research Center of the IESE Business School.

We structure the symposium in five areas: (1) Information structures and the value of information; (2) Information aggregation by prices; (3) Information acquisition and disclosure; (4) Coordination and information acquisition; and (5) Dynamics.

1. Information structures and the value of information

The study of information structures and the value of information has a long tradition since at least the work of Radner [95], followed by Basar and Ho [23], and Vives [114,115] – see also Vives [121] for an overview. As anticipated, renewed interest in the topic has been fostered by the contributions of Morris and Shin [87] and Angeletos and Pavan [16].

The papers in this section make progress by considering results that are robust to different information structures, extending the analysis of Cournot markets with dispersed information, and providing a general characterization of the value of information in games with quadratic payoffs.

In particular, the first paper in the symposium, Bergemann et al. [25] studies the determinants of aggregate volatility in an economy in which agents are subject to idiosyncratic and aggregate shocks. The authors are interested in understanding how asymmetric information influences the outcome. The problem is that usually the results depend on the information structure assumed, something which is typically not observable. The authors provide a characterization which is valid for all information structures in a particular setting: a continuum of agents interacting in a game with linear best responses that depend on the average action of others as well as idiosyncratic and aggregate shocks. Shocks, actions and signals are symmetrically normally distributed across agents under the maintained assumption of symmetry and normality of the information structure. This model with a continuum of players, quadratic payoffs, and normally distributed idiosyncratic and aggregate shocks was first proposed by Vives [116] to analyze information sharing in a monopolistic competition context and then used by Angeletos and Pavan [17] to analyze policy interventions under dispersed information. The characterization uses and extends the Bayes correlated equilibrium concept of Bergemann and Morris [26,27], which helps analyzing equilibrium behavior for a given description of the fundamentals, across all possible information structures.

It is found that the maximal aggregate volatility is attained under a "noise-free" information structure where each agent observes a one-dimensional signal that is a *deterministic* function of both his idiosyncratic shock and the aggregate shock. With this signal, an agent cannot distinguish the idiosyncratic from the aggregate shock, i.e., the two shocks are confounded. Maximal aggregate volatility is attained then when agents overweigh the aggregate relative to the idiosyncratic shock. In contrast, maximal cross-sectional dispersion is attained when signals overweigh the idiosyncratic shock relative to the aggregate one. The analysis is based on the insight that to characterize Bayes correlated equilibria, it is sufficient to consider one-dimensional signal structures where the signal is a linear function of the aggregate and idiosyncratic shocks as well as a noise term potentially correlated across agents. The boundaries of Bayes correlated equilibria can be written as the equilibria of some noise-free one-dimensional information structure.

The overreaction result to confounding shocks is related to Lucas [78] celebrated analysis of how monetary shocks can have real effects, which is based on informational frictions leading to an overreaction to monetary shocks. In Lucas [78], the confounding effect comes from the fact that firms observe a single price, which reflects both the labor market shock and the monetary shock, and therefore respond to the two shocks in the same way while under complete information hiring decisions would respond only to the labor shock.

The approach also sheds light on results pertaining to the modeling of "sentiments" in Angeletos and La'O [13] and on information sharing in large oligopoly markets (e.g., Vives [114, 116,121], Gal-Or [59], and Raith [97]). Angeletos and La'O [13] obtain that purely idiosyncratic shocks generate aggregate fluctuations when coupled with a common noise shock (the "sentiment"), which plays the role of the aggregate shock. The equivalence, in some scenarios, between the impact of aggregate shocks affecting fundamentals, but over which agents have no information, and that of common noise shocks in the agents' signals is well known (see, e.g., Section 2 of Manzano and Vives [80]). Indeed, a common noise shock in the agents' signals plays the role of the residual uncertainty about a payoff once the average information of the agents reveals part of the fundamental. With respect to information sharing, the paper clarifies why the optimal disclosure of public information is either no disclosure or full disclosure, whereas the optimal disclosure of private information depends on the degree of strategic complementarity in actions and can be intermediate.

The second paper in the symposium, Myatt and Wallace [90], studies the social value of public and private information in the context of a differentiated-product Cournot model where each supplier receives various signals about the uncertain demand. The model features a continuum of products and a finite number of Cournot firms, each producing a range of products and facing a common demand shock. Each firm receives a finite number of signals with both common (sender) and private (receiver) noise and that may differ both in their precision and correlation across agents, as in the sender-receiver model of Dewan and Myatt [47]. The cross-industry correlations of the signals differ, with more public signals having higher correlation coefficients. The model generalizes Vives [116], which considers a Cournot market in which each firm produces a single product and receives only perfectly private signals. As in Bergemann et al. [25], the combination of a quadratic payoff specification with a Gaussian information structure yields an equilibrium in which actions (outputs) are linear functions of the various signals.

Suppliers place greater weight on relatively more private signals because output choices are strategic substitutes. In equilibrium, information is used inefficiently. From the perspective of the industry, information is "over-used" (meaning that output choices respond excessively to all sources of information), and too much weight is placed on relatively public signals. Indeed, because output choices are strategic substitutes, a shift from more public to more private signals

reduces output correlation and improves aggregate profits, but an individual firm does not internalize this effect. From the perspective of consumers, information is under-used, and too much weight is placed on relatively private signals due to a consumer surplus externality and the convexity of consumer surplus in prices. This is because output variability increases with a more intense use of information and because a shift from more private to more public signals increases the correlation of output decisions, with both effects contributing to more price variability and therefore higher consumer surplus.

Finally, the paper shows that total welfare is enhanced by increasing the overall sensitivity of output choices to information, as desired by consumers (this is because consumer surplus is convex in prices and because the consumer surplus externality outweighs the effect that a higher sensitivity of output to information has on aggregate profits). Furthermore, welfare increases by inducing firms to respond less to public signals, as desired by the industry (this is because the profit externality is larger than the consumer surplus externality when it comes to the effects of variations in the relative sensitivity of output choices to public and private signals). If information is costly and endogenously acquired, then suppliers acquire too much information about demand, but they use it too little. This is so because suppliers can reduce the idiosyncratic receiver noise but not the common sender noise. This implies that they do not affect the competitors when acquiring information but they do hurt consumers.

The results have various implications for (and are related to) the literatures on (a) the use of information in quadratic-payoff games (e.g., Morris and Shin [87], Angeletos and Pavan [16], Ui and Yoshizawa [108]), (b) information sharing in oligopoly (e.g., Raith [97] and Vives [116,121]); (c) information aggregation in Cournot oligopolies (e.g., Palfrey [93], Vives [115]); (d) information acquisition in coordination games (e.g., Hellwig and Veldkamp [70], Myatt and Wallace [89], Colombo et al. [42]).

The third paper in the symposium, Ui and Yoshizawa [108], characterizes the social value of information in symmetric quadratic-payoff games. Angeletos and Pavan [16] suggest decomposing information structures along two dimensions, the accuracy and commonality of beliefs. Their key result shows how the welfare effects of variations in accuracy and commonality depend on the discrepancy between (a) the equilibrium and the socially optimal degrees of coordination, and (b) the complete-information equilibrium allocation and the first-best allocation. The results in Angeletos and Pavan [16] have implications also for the social value of private and public information, but only in a restricted class of environments. The contribution of Ui and Yoshizawa is two-fold. It provides a complete characterization of the social value of private and public information in the class of economies considered in Angeletos and Pavan [16]. It also establishes useful connections between this class and certain games with a finite number of players, which is useful for applications such as oligopoly games and games of public good contributions, and also for the analysis of the desirability of various information structures in coordination games (e.g., the work by Bergemann et al. discussed above).

The paper's main result provides a necessary and sufficient condition for welfare to increase with either the precision of public or the precision of private information, starting from an arbitrary precision of these sources. This condition involves the ratio between two coefficients, the one assigned by the planner to the volatility of the average action and the one assigned by the planner to the dispersion of the individual actions. The paper classifies all possible quadratic economies into eight groups, based on the ranges of the above two coefficients. For each group, it characterizes the information structure that maximizes welfare and identifies the optimal precision of public information for given precision of private information and the optimal precision of private information for given precision of public information.

The paper also relates to the recent literature investigating the set of joint distributions (over individual actions, aggregate actions, and fundamentals) that can be sustained as Bayes–Nash correlated equilibria (e.g., Bergemann and Morris [26]). It provides a complete characterization of optimal Bayesian correlated equilibria for the entire family of payoff specifications in Angeletos and Pavan [16], thus extending the analysis in Bergemann and Morris [26] who confine attention to large Cournot games. Finally, the paper relates to the literature that studies the social value of public information in economies in which private information is endogenous (e.g., Colombo et al. [42]). While the information structure in the present paper is exogenous, the complete characterization of the social value of private and public information can prove useful also in games with endogenous private information.

2. Information aggregation by prices

The informational role of prices has received significant attention in the REE literature with asymmetric information (see, among others, Grossman and Stiglitz [65], and Grossman [64]). REE have been implemented with auctions (Milgrom [85], Reny and Perry [98]) or with competition in schedules (Kyle [74], and Vives [124,125]). It has been noticed that fully revealing REE may not be implementable if we insist, as we should, that prices be measurable in excess demands (see Anderson and Sonnenschein [10]). Vives [124] shows how privately revealing equilibria arise when competition is in schedules and traders' valuations have both a common and a private component. Rostek and Weretka [101] extend the model in Vives [124] to asymmetrically correlated valuations and show that the equilibrium may fail to be privately revealing. Vives [125] shows how the Grossman and Stiglitz [65] paradox of informationally efficient markets can be overcome when traders receive bundled signals about a common and a private valuation component.

The fourth paper in the symposium by Rostek and Weretka [102] addresses the question of whether encouraging trader participation enhances market competitiveness and liquidity. The answer is in the negative when traders' preferences are interdependent: larger markets can be less liquid and associated with lower ex-ante welfare. The paper considers a uniform-price double auction in a market for a perfectly-divisible good with a finite number of traders whose valuations are potentially asymmetrically correlated and where the information structure is Gaussian (as in Rostek and Weretka [101]). As in Vives [124], traders compete in schedules contingent on their private information, and attention is restricted to linear equilibria. In Vives [124], the information structure is symmetric (that is, the correlation of valuations is homogenous across agents). In this case, the equilibrium is privately revealing, i.e., the pair (signal, price) is a sufficient statistics for all the agents' private information with respect to the trader's own valuation. Furthermore, the price impact (as measured by the slope of a trader's residual supply, otherwise known as "Kyle's lambda" in market microstructure models) is monotone in the number of bidders, n, and, as n grows large, the allocation converges to a Walrasian equilibrium with price-taking behavior. In fact, Vives [124,125] shows that the price impact is of the order of $1/n$ and that the deadweight loss converges to zero at the same rate. The paper by Rostek and Weretka [102] shows that, with heterogeneous correlation in valuations, the above results need not hold. To start with, the equilibrium is not typically privately revealing (it is so only if the heterogeneity in correlations among values is absent for *all* trader pairs). Furthermore, in general, the price impact is not monotone in market size. This is so because the arrival of an additional trader may change the informativeness of the market price so that the market power of all traders increases and the gains to trade are lower. The authors assume that each trader's value is, *on average*, correlated

with other traders' values in the same way, which is termed the commonality in values. When this is the case, the price impact of each trader decreases with n provided that the new market participant does not increase too much the commonality in values of all market participants.

As long as preferences are not perfectly aligned in a large market, as the number of bidders increases, the linear Bayesian–Nash equilibrium converges to the unique competitive rational expectations equilibrium in which bidders become price takers. However, since the equilibrium is not typically privately revealing and the price in general does not fully aggregate information in the considered class of auctions, even if inefficiency due to market power disappears in large (limit) markets, the aggregation of private information remains inefficient. This is akin, for example, to what happens in a large Cournot model (e.g., Vives [115,123]). Furthermore, it may happen that price taking does not obtain in the limit when the average correlation tends to one since the inference component of the price impact becomes unbounded.

The fifth paper in the symposium by Benhabib and Wang [24] shows the possibility of sunspot-driven rational expectation equilibria in a two-period market for a risky asset in which short-term traders interact with long-term investors and where traders are risk-neutral and competitive. Short-term traders are interested in capital gains while long-term investors hold the risky asset to maturity. The authors show that, in addition to fully revealing rational expectation equilibria (FRREE), there is a continuum of rational expectations equilibria where the asset prices are driven by sunspot shocks or "sentiments". The path of prices in those equilibria may resemble a random walk in an informationally-efficient market. The results are robust to the short-term traders observing idiosyncratically the sunspot and to both short-term and long-term investors having private signals about the fundamental, as well as investors trading in both periods.

The results are reminiscent of Keynes' beauty-contest analogy of financial markets: since short-term investors are only interested in the next period return, prices may respond only to the market's average expectation of the long-term investors' average expectations and may put a heavy weight on public information (as in Allen et al. [6]). However, as shown in a recent paper by Cespa and Vives [37], this is only part of the story: when liquidity trading is persistent, prices are also driven by average expectations about liquidity shocks. In this context, there are also typically multiple equilibria, with an extremal high information one and an extremal low information one. However, those equilibria are not sunspot-driven. The high-information one is fundamentals driven while the low information one is liquidity trading driven. This poses the question of whether Benhabib and Wang [24] sunspot equilibria can be implementable in demand schedules, that is, whether there exists a well-defined game whose equilibrium outcomes resemble those under sunspot-driven rational expectation equilibria. The authors answer the question in the affirmative provided that traders' valuations have an idiosyncratic component, as in Vives [125], where it is shown that FRRE can be obtained as the limit of Nash equilibria in demand functions as the idiosyncratic component vanishes.

The sixth paper in the symposium by Mäkinen and Ohl [79] studies information acquisition over the business cycle when prices partially aggregate information. The last fifteen years have witnessed a growing interest in business-cycle models with imperfect information. An increasing number of contributions to this literature explore whether agents' learning exhibits any systematic relation with the business cycle (that is, whether learning is pro- or counter-cyclical). Most papers on this subject provide microfoundations that support the prediction that learning is procyclical. Such pro-cyclicality is then used to explain asymmetric business cycle dynamics, that is, slow recoveries and fast collapses (see, among others, Chalkley and Lee [38], Veldkamp [111], Van Nieuwerburgh and Veldkamp [109], Ordoñez [91]).

The present paper contributes to this literature by investigating two questions: (i) whether the pro-cyclicality of learning is optimal, and (ii) whether such pro-cyclicality is robust to the possibility that equilibrium prices reveal information. To answer these questions, the paper develops a general-equilibrium model of firms' information acquisition in booms and recessions. The key findings are that, when prices aggregate information, (a) firms' investments in information acquisition can be counter-cyclical, and (b) the equilibrium price system moderates aggregate fluctuations by disincentivizing information acquisition. The paper also offers a possible explanation for the empirical finding in Coibon and Gorodnichenko [41] that the degree of informational rigidities (as measured by the predictability of forecast errors) is lower in recessions than in booms.

In the model, prior to hiring labor in a perfectly competitive market, firms choose whether to acquire an informative signal about the economy's true state (TFP) at a fixed cost. In addition, firms learn from the market-clearing wage. As is typically the case in these models, information acquisition choices are strategic substitutes: each firm's expected gain from acquiring information decreases as the fraction of informed firms increases, due to the fact that the informativeness of the equilibrium wage increases. The reason why information acquisition is counter-cyclical is that (a) the expected gain from acquiring the costly signal is decreasing in the equilibrium wage, which is lower at the bottom of the cycle, along with (b) the fact that equilibrium wages are less informative in recessions, increasing the firms' incentives to acquire information.

Finally, the paper relates to the literature on the inefficiency in the use of information in business-cycle models by showing that information acquisition in the economy under consideration is inefficient. As in Colombo et al. [42], the inefficiency comes from an externality due to employment dispersion, which is not internalized in equilibrium. Related is also Vives [126], where it is shown that optimal policy should be pro-cyclical in economies in which inefficiencies in the use of information originate in pecuniary externalities generated by the fact that agents condition on prices.

3. Information acquisition and disclosure

The papers in this section illustrate how models of information acquisition and disclosure can illuminate on a range of issues including security design, nominal rigidities stemming from rational inattention, order choice in financial markets, and the optimal design of disclosure rules.

The seventh paper in the symposium by Farhi and Tirole [56] studies how bundling (alternatively, tranching) securities with different risk levels affects the volume of trade, and hence the liquidity of the assets, in a common-value environment that stylizes a variety of situations. The paper considers both the case in which the information available to the parties is exogenous as well as the case in which it is endogenous. The paper shows that bundling favors investments that result in a higher level of information commonality between the trading parties and thereby facilitates trade.

The model features a buyer and a seller who can both privately learn (at a cost) the risky part of an asset. They can bargain separately over the safe and the risky part (in case of tranching), or bargain jointly over the two parts (in case of bundling). When information is exogenous, the cost and benefits of bundling (alternatively, of tranching) come from two effects. On the one hand, tranching insulates the safe component from the risk of illiquidity (the "insulation effect"). On the other hand, bundling increases the cost of not trading the risky component (the "trading adjuvant effect"). Whether or not tranching dominates bundling then depends on the overall liquidity of the bundle. When the bundle is liquid (meaning that, given the underlying information, there is

a price that can result in a transfer of the bundle from the seller to the buyer), then tranching can only be liquidity reducing. When, instead, the bundle is illiquid, tranching dominates by permitting the trade of the safe component.

The paper's core contribution is in showing how the above conclusions are affected by the endogeneity of information. More precisely, the paper studies how tranching and bundling affect the parties' incentives to acquire information about the risky component and ultimately the overall probability of trade of each of the two components. The key insight is that spinning off the safe component (a) increases the incentive to acquire information about the risky component when information acquisition is undesirable, for it leads to less commonality of beliefs (say because the cost of information acquisition for one party is high relative to the cost to the other party) and (b) reduces the incentive to acquire information when information acquisition is to be encouraged (e.g., because the initial distribution of information is already highly asymmetric). The paper thereby identifies an important cost of tranching. Once again, the intuition is that tranching reduces the cost of not trading. When both parties are initially uninformed, the value of information comes from the possibility of preventing trade from happening when privately disadvantageous. In this case, tranching induces too much information acquisition and hence is detrimental to liquidity. When, instead, the initial distribution of information is highly asymmetric (for example, when one party knows the value of the risky component, while the other holds a diffuse prior), then, in the absence of information acquisition, trade does not occur. Under tranching, the benefit of information acquisition comes from the increase in the probability of trading the risky component. Under bundling, instead, the benefit of information acquisition comes from the increase in the probability of trading the entire bundle. Because the value of trading the entire bundle is higher than the value of trading only the risky component, bundling is liquidity enhancing when information acquisition is to be induced. The insights are simple but relevant for a variety of markets. The paper also offers various interesting ideas for future research and policy analysis.

The eighth paper in the symposium by Matejka [81] provides a theory of price rigidities originating in consumers' limited attention. In contrast, most of the literature assumes that the rigidity originates in frictions at the price setter's level (menu costs, Calvo frictions, sticky information, seller's rational inattention). The issue is important since nominal rigidities are at the heart of New Keynesian economics.

The paper considers the problem of a monopolistic seller whose unit cost of production is subject to a shock that is not directly observable by the consumer. Both the consumer and the seller share a common prior over the shock distribution. Before observing the shock realization, the seller commits to a pricing strategy mapping the shock into a unit price. The consumer is rationally inattentive in that his ability to track variations in the unit price is limited. The paper investigates the shape of the profit-maximizing pricing strategy.

Recall that, when consumers are fully attentive, the profit-maximizing pricing strategy is given by the familiar inverse-elasticity formula. The optimal mark-up may be state dependent but is invariant in the distribution of the cost shock. Importantly, the price moves one-to-one with the unit cost. When, instead, consumers are rationally inattentive, the more dispersed the price is, the more difficult it is for the consumer to track the true realized price. Such a difficulty in turn makes the consumer buy less. The question is then what shape the optimal pricing strategy takes as a function of the consumer's attention capacity.

The paper first shows that, when the consumer's attention capacity is sufficiently low, prices are rigid, in the sense that the distribution of prices has low entropy (that is, prices respond less than one-to-one to cost shocks). In particular, when attention capacity is very low, the optimal

pricing strategy features a discrete number of prices (despite the shocks taking a continuum of possible values) and induces the consumer to perfectly monitor the price. For intermediate capacity levels, instead, higher profits can be achieved by a pricing strategy that is continuous in the unit cost but whose variance is low enough to still induce the consumer to purchase a strictly positive quantity.

Importantly, the paper establishes the above results allowing for a general distribution of the state variable (the cost shock). This is in contrast to most of the rational inattention literature where payoffs are typically assumed to be quadratic and the distribution of the state variable Gaussian. This generality is important, for it shows that the properties of the profit-maximizing pricing strategy (e.g., its lumpiness for sufficiently low capacity levels) are not an artifact of a special structure.

The ninth paper in the symposium by Challe and Chretien [39] studies the optimal choice of type of order by informed traders. The model features a static competitive CARA-Gaussian economy in which informed traders must choose between submitting market orders or generalized limit orders (demand schedules), and where prices are set by a competitive market maker observing only the total order flow (which includes the orders by noisy traders). The private signals of the informed traders are not restricted to be conditionally independent. It is shown that, in a pure market-order market, such as in Vives [119], the informativeness of the price is bounded above independently of the precision of private information. When instead, there is a positive-measure set of traders who use demand schedules, the price informativeness becomes unbounded as the precision of private information increases. The reason is that traders placing market orders face price risk and thus trade less aggressively whereas traders submitting limit orders (that is, demand schedules) face no price risk and thus react more strongly to their private information. The paper allows informed traders to choose the type of order and assumes that limit orders (i.e., demand schedules) are more costly. As in the models of Medrano [82] and Vives [123, Section 4.3], when the precision of the traders' private information is sufficiently large, some traders submit market orders while others limit orders. However, as the precision of information goes to infinity, the proportion of traders using market orders tends to one. This happens even when the signals traders receive are perfectly correlated, in which case the price conveys no information. The result comes from the fact that, when the precision of the informed traders' private information grows large, the impact of the noisy traders on the equilibrium price vanishes. The benefit of submitting a limit order then also vanishes, for the equilibrium price becomes predictable by the informed traders.

The results bear some relation with the models of information acquisition but here traders can purchase the right to condition on the price instead of acquiring a private signal about the fundamental. The key difference with respect to the models of Medrano [82] and Vives [123], as well as the early analysis of Verrecchia [112], is that, in these former papers, traders who self-select into purchasing the right to condition on the price (i.e., to place a demand schedule) are those with a high risk-adjusted informational advantage (that is, with a high combination of risk tolerance and information precision).

The last few years have also witnessed renewed interest in the question of whether mandatory disclosure of financial information can be welfare-enhancing (see Verrecchia [113] and Beyer et al. [28] for good surveys of the disclosure literature and Alvarez and Barlevy [7], and Goldstein and Leitner [61] for recent developments).

The tenth paper in the symposium by Kurlat and Veldkamp [72] addresses the question of whether disclosure of financial information should be regulated in the name of investor protection. It is found that mandatory disclosure may harm investors even when it improves the

efficiency of decisions in the real sector. This is so because disclosure makes payoffs less uncertain and consequently reduces returns. Disclosure may be good for investors only when it reduces asymmetric information (for example, because some investors had the information already), or when issuers have the ability to manipulate the supply of the asset and its price; or when the information disclosed induces firms to take more risk since in the CARA framework expected utility is increasing in the conditional variance of the asset payoff.

The base model is of the CARA-normal family and features a risk-averse monopolistic asset issuer, an asset market with a continuum of investors, an information market (where information can be produced at a cost, with an analyst producing it at a weakly higher cost than the issuer and where investors can purchase the information) and, in an extension, a real production sector. It is found that, when the monopolist's risk aversion is high enough, investors prefer to have no access to information. This is so because with high risk aversion the monopolist holds few shares in the firm and does not exploit much his monopoly power (as in Medrano and Vives [83]) and then disclosure does not help much investors. A second result is that investors benefit from mandatory disclosure when the cost of information is low (in which case, in the absence of disclosure, the asymmetry of information would be high). The results are shown to be robust to a CRRA preference specification. The paper also shows that, when disclosure also affects the real sector, mandatory disclosure either increases output while benefitting the issuers only, or it induces the firm to take more risk and benefits investors too. In a calibration of the model for credit ratings, it is found that mandatory disclosure has no effect on the amount of information available because it simply crowds out the information collected by analysts.

The model is related to the literature on (a) insider trading (e.g., Medrano and Vives [83]), (b) security design (e.g., DeMarzo and Duffie [46]) and (c) the interplay between the financial and real sides of the economy (e.g., Ozdenoren and Yuan [92], and Angeletos et al. [15]). On the insider trading front, Medrano and Vives [83] consider a model where a risk-averse monopolist chooses the size of his project and how much to float it in the market contingent on his private information relative to that of competitive investors (hedgers and speculators). The focus in Medrano and Vives [83] is whether to allow the monopolist to trade on his private information or whether it is better for social welfare that he discloses the information. The trade-off with regard to information disclosure is between reducing adverse selection, which reduces payoff uncertainty and increases market depth, and reducing insurance opportunities (Hirshleifer effect), which impairs the hedging effectiveness of the market. It is show that, when the second effect prevails, forcing the monopolist to disclose may lead to a Pareto inferior outcome. In contrast, in the production extension of Kurlat and Veldkamp [72], because the issuer is risk neutral, the Hirshleifer effect is absent, for information disclosure transfers risk from risk averse investors to a risk neutral issuer, which always contributes positively to welfare.

4. Coordination and information acquisition

The last twenty years have witnessed a great interest in models of coordination under dispersed information about payoff-relevant variables. Starting with the seminal contribution of Carlsson and van Damme [35], a subset of this literature investigates conditions (on the payoff and on the information structure) under which the lack of common knowledge about payoffs hinders coordination on multiple courses of actions. In particular, the so-called "global games" literature (e.g., Morris and Shin [86], and Frankel et al. [58]) investigates conditions under which a unique (interim rationalizable) strategy profile obtains in the limit in which the players observe the underlying payoff state with vanishing idiosyncratic noise. Various parallel literatures have

shown how the uniqueness and multiplicity results in these games depend on the supermodular nature of the payoff structure (e.g., Vives [122] and Van Zandt and Vives [110]), the properties of the hierarchies of beliefs implied by the assumed information structure (Weinstein and Yildiz [129]), and the absence of learning from endogenous channels (Angeletos et al. [11,12], Angeletos and Werning [19], Hellwig et al. [69]).

A family of such games that receives particular attention is games of regime change. These are coordination games in which a status quo is abandoned, causing a discrete change in payoffs, once a sufficiently large number of agents take an action against it. These games have been used to model a variety of crises phenomena: an attack against the status quo can be interpreted as speculation against a currency peg, as a run against a bank, or as a revolution against a dictator (see, among others, Morris and Shin [86] for currency crises; Goldstein and Pauzner [62] and Rochet and Vives [99] for bank runs; Morris and Shin [88] and Corsetti et al. [43] for debt crises; Atkeson [20] and Edmond [52] for riots and political change). Vives [125] presents a model encompassing most of those models as particular cases.

Another related and fast-growing literature aims at endogenizing the information structures in such games by considering the possibility that agents acquire information or pay attention, at a cost, to available signals. One of the key questions in this literature is whether economic activity and investments in information acquisition align. For example, Hellwig and Veldkamp [70] "Knowing What Others Know" result states that incentives for information acquisition are strategic substitutes (respectively, complements) when economic activities are strategic substitutes (respectively, complements). Vives [121, Exercise 8.15]; obtains the result in a linear-normal duopoly context. For more recent developments of this literature, see also Myatt and Wallace [89], and Colombo et al. [42].

The papers in this section deal with some of the issues above extending the results in a few important directions. In particular, the eleventh paper in the symposium by Yang [131] studies flexible information acquisition in a global coordination. A maintained assumption in most of the global game literature is that noise in the signal structure is additive, meaning that the signal is a linear combination of the state and the noise shock. In contrast, the present paper allows the players to pick any information structure of their choice, with the cost given by the induced entropy reduction. The choice is flexible in the sense that the players choose not only how much to learn (formally, the amount of entropy reduction) but also how to achieve such reduction (which is akin to the choice of the kind of information to acquire).

The key question the paper addresses is how such flexibility affects the players' ability to coordinate on multiple actions. The underlying game is a canonical two-by-two coordination game satisfying the usual conditions of state and action monotonicity of the global-games literature, with the payoff state drawn from a known distribution. To such game, the paper adds a first stage in which the players simultaneously choose their information structure (with the latter defined as a mapping from the state to a distribution over signals).

The first observation is that, in equilibrium, players optimally choose information structures that simply inform them of whether the state is below or above a cutoff value. This is intuitive if one fixes the opponent's action; because the payoff differential between the two actions changes sign only once with the underlying state, the most economical way of learning about the state is to choose a signal structure that informs the decision maker of whether the state is low or high (equivalently of which of the two actions is optimal). Interestingly, the same property continues to hold when one moves from best responses to equilibrium.

The most significant findings pertain to the implications of the above result for the determinacy of equilibria. The paper shows that, when the cost of information acquisition vanishes,

coordination on multiple courses of action is possible. In other words, when the realized state is away from the regions in which players have (under complete information) dominant actions, then in equilibrium players can coordinate on each of the two possible actions ("invest" and "not-invest"). This result is in sharp contrast to the predictions of the global games literature, where uniqueness obtains precisely when the cost of reducing the variance of the additive noise in the players' signals vanishes (see, e.g., the recent working paper by Szkup and Trevino [107]). The extent to which this result generalizes to richer coordination environments and to cost function other than entropy reduction remains an interesting question for future research.

Coordination in games of regime change is also the topic of the twelfth paper in the symposium by Iachan and Nenov [71]. This paper considers a canonical information structure with additive signals but a richer payoff structure. In particular, there is a continuum of players and payoffs are allowed to depend on fundamentals both in case of regime change and in case the status quo is preserved. A similar structure can be found in Angeletos and Pavan [18] who extend previous work by Angeletos et al. [11] to an environment in which fundamentals determine not only the fate of the regime but also the payoff differential between attacking and not attacking in the event of regime change. While the focus in Angeletos and Pavan [18] is the possibility of selection-free predictions in global games in which endogenous information (via signaling by a large player) brings back multiple equilibria, the focus in Iachan and Nenov [71] is the effect of exogenous variation in the quality of information on regime outcomes. In particular, the paper asks the question of whether deterioration in the quality of available information (such as the one experienced during the last crisis) increases the probability of regime change. The model features a unique equilibrium for any given information structure. Whether deterioration in information increases the likelihood of regime change is then shown to depend on whether the agents' payoff differential between attacking and not attacking is more sensitive to fundamentals in the event of regime change or in the event the status quo is retained. When the sensitivity of payoffs to fundamentals is higher in case of regime change, then deterioration of information increases the likelihood of regime change. The opposite conclusion holds when the sensitivity of payoffs to fundamentals is higher in case the status quo is preserved. To grasp some intuition, consider an agent who, before the deterioration in information is just indifferent between attacking and not attacking. The deterioration of information can be thought of as a shift in beliefs resulting in more weight assigned to extreme realizations of the fundamentals. When payoffs are more sensitive to fundamentals in case of regime change, such a shift necessarily increases the marginal agent's net payoff from attacking, thus inducing more agents to attack and increasing the set of fundamentals for which regime change occurs in equilibrium. This is because the increase in the net payoff from attacking in the event of regime change more than compensates the reduction in the net expected payoff in case of survival.

The result also highlights important differences between currency crises and bank runs. In the case of currency crises, it is customary to assume that payoffs are sensitive to fundamentals only in the event of regime change, which corresponds to devaluation of the currency (see, e.g., Morris and Shin [86]). In contrast, in the case of bank runs, it is customary to assume that payoffs are sensitive to fundamentals in the event the bank survives (see, e.g., Goldstein and Pauzner [62]). As a consequence, a decrease in the quality of information has a destabilizing effect in currency crises and a stabilizing effect in bank runs. The paper also present a nice application to debt rollover games in which payoff differentials respond to fundamentals both in the event of regime change and in the event of survival.

The thirteenth paper in the symposium by Rondina and Shim [100] also considers information acquisition in a coordination setting, but in a more microfounded model. The economy features

both a product market in which firms compete a' la Cournot as well as a financial market in which traders take positions on a risky asset whose payoff is a function of the firms' output decisions. The key result is that, while firms' output decisions are strategic substitutes, their investments in information acquisition can be strategic complements. The mechanism responsible for this result is the following. As firms become more informed, their output decisions become more sensitive to their private information and hence less predictable in the eyes of the traders. Because the latter are risk averse, their positions in the financial market become less sensitive to their own private information, in turn making the financial price less informative of the underlying state of Nature (say, a demand shifter). As the information contained in the price becomes less precise, firms may find it optimal to acquire more private information so as to better align their output choice with the underlying fundamental. Clearly, this novel effect must be contrasted with the more familiar effect of Hellwig and Veldkamp [70]. As firms acquire more precise private information, the correlation between aggregate output and the fundamental increases. Because of strategic substitutability, this induces each firm to acquire less precise private information. Whether in the end investments in information acquisition are strategic complements or substitutes then depends on which of the two effects prevails. The paper provides a characterization of primitive conditions under which the novel "information-aggregation effect" prevails over the familiar "strategic substitution effect", thus making investments in information acquisition strategic complements, despite output choices being strategic substitutes.

The paper also relates to the recent literature on the crowding out effects of public information. In a fairly general model with quadratic payoffs and Gaussian information, Colombo et al. [42] show that more precise public information always crowds out the acquisition of private information, irrespective of whether output decisions are strategic complements or substitutes. Whether such crowding out effects diminish or increase the social value of public information then depends on whether firms acquire too much or too little private information, for given precision of public information. The contribution of Colombo et al. [42] is in identifying primitive conditions responsible for inefficiency in the acquisition of private information and relating them to primitive conditions responsible for inefficiency in the use of information. The Rondina and Shim's paper is also related to the literature showing how more precise exogenous public information can crowd out the precision of endogenous public signals (e.g., Burguet and Vives [33], Amador and Weill [9]). Interestingly, Vives [126] shows that, when traders condition on prices, more precise (exogenous) public signals always increase welfare, while more precise private signals may decrease it.

5. Dynamic trading under asymmetric information

Models of dynamic trading under asymmetric information have proved useful to study information diffusion and percolation and their consequences for market quality. The relevant literature for competitive centralized markets includes Vives [117,118], Wang [127], He and Wang [68], Spiegel [106] and Cespa and Vives [36,37], whereas the one for decentralized markets includes Duffie et al. [49,50], and Golosov et al. [63], among others.

The fourteenth paper in the symposium by Albagli [4] studies a dynamic infinite-horizon OLG economy in which asymmetrically informed investors with CARA preferences, a fraction of whom are informed and a fraction uninformed, live for a finite number of periods and face shocks to the supply of a risky asset. The paper studies the comparative statics of various properties of the equilibrium set with respect to the traders' life spans. It uncovers two drivers for asset prices. First, as the traders' horizon lengthens, the age-adjusted risk aversion of the average in-

vestor falls since consumption can be smoothed over more periods. Second, the intergenerational risk transfer diminishes. It is found that if the traders' life span is long enough there are two equilibria: a stable low-volatility one, and an unstable high-volatility one (this result is reminiscent of Spiegel [106] and Watanabe [128]). As the life span tends to infinity, the low-volatility equilibrium converges to the equilibrium in Wang [127]. In this equilibrium, longer horizons reduce non-fundamental price volatility and incite more aggressive trading by the informed investors, which impound their knowledge into prices. For short life spans, market outcomes resemble more an economy with no private information.

The paper offers two applications. The first one is the analysis of the asset pricing effects of a baby-boomer generation. The second is the analysis of the effects of fund liquidations during the financial crisis. The model's predictions contrast with those of finite-horizon economies (e.g., He and Wang [68], and Cespa and Vives [36]). These models can also feature multiple equilibria, with some of them unstable (see, e.g., Cespa and Vives [37]). However, in these models, equilibrium multiplicity does not come from the bootstrap nature of expectations in OLG economies with an infinite horizon but rather from the inference dynamics under private information in a finite horizon economy. For example, in Cespa and Vives [37] it is shown that persistence of liquidity trading, when coupled with short horizons of privately informed traders, generates a retrospective inference channel on fundamentals which induces strategic complementarity in the responses to signals and potential equilibrium multiplicity.

The last paper in the symposium, by Duffie et al. [51], studies information percolation in segmented markets. The paper presents a dynamic model of over-the-counter trading in which traders may differ in the quality of their private information, in the expected frequency of bilateral trading opportunities, in their market connectivity, and in their preferences over the risky asset. A large number of such traders meets randomly, set prices according to a double auction mechanism (in the form of a "seller's price auction"), and trade a unit of the asset. Furthermore, ex ante, traders can invest in the quality of their private information. The novel aspect with respect to previous work by the same authors (e.g., Duffie et al. [50]) is (a) the generality of the analysis that allows for ex-ante asymmetric traders and (b) the study of information acquisition. The considered double auction mechanism has a unique equilibrium that reveals the conditional expectations of the counterparties in the bilateral trade and that maximizes expected gains from trade. One of the main results is that, when there are many periods left, there is strategic complementarity in connectivity and in information gathering, whereas, when there are only a few periods left, the opposite result may obtain. The intuition is that there is a tension about the effects of increasing information: while better information reduces sellers' expected gains from trade and buyers' incentives to gather information since they expect a good price anyway, at the same time better information increases the risk of meeting with agents of extreme beliefs making it more attractive to acquire more precise information. When there are many periods left, the second effect dominates while, when there are only a few periods left, the first effect dominates.

The result that, in an OTC market, individual investments in information acquisition may be strategic complements contrasts with the familiar result that, in centralized markets, incentives to acquire information typically decrease with the measure of informed traders. In other words, in centralized markets (e.g., Grossman and Stiglitz [65]), information acquisition choices are strategic substitutes, and this result is robust to the possibility that traders receive correlated endowment shocks as well as signals with correlated noise. Indeed, Manzano and Vives [80] shows that, in this context, whenever there is strategic complementarity in information acquisition, the market equilibrium is unstable. Other papers, like Barlevy and Veronesi [22] and Ganguli and

Yang [60], need special assumptions to obtain the strategic complementarity result (see the discussion in Section 4.2.2 in Vives [123]).

6. Directions for future research

We conclude with a brief discussion of a few avenues for future research.

(a) Dynamics of information acquisition and aggregation. One area that we expect will continue to attract attention is the analysis of information acquisition and aggregation through prices in dynamic economies. Some of the papers in the symposium touch on this theme (e.g., Albagli [4], Duffie et al. [51], Mäkinen and Ohl [79]). A lot remains to be done. In fact, we are still missing a tractable model that permits us to examine how agents' (consumers, firms, investors) incentives to acquire information evolve over time in response to changes in fundamentals and/or variations in the (endogenous) precision of market prices. Extending the analysis to richer information and payoff structures is essential for a deeper understanding of the positive and normative properties of these economies.

(b) Policy. The study of inefficiencies in economies with dispersed information is particularly relevant for its policy implications. Ongoing work by Angeletos and La'O [14], Llosa and Venkateswaran [77], Pavan [94], and Vives [126] studies how policies can be designed to correct inefficiencies in the use of information and how they affect incentives for information acquisition. The models in these papers, however, are fairly stylized and we are still far from a clear understanding of how inefficiencies in the use of information interact with inefficiencies in the collection of information (or equivalently, in the allocation of attention). What is missing is a general theorem identifying conditions guaranteeing that the market mechanism, when combined with policies implementing the decentralized efficient use of information, also induces the welfare-maximizing collection of private information. In a related vein, inefficiencies in the use of information interact with behavioral biases, such as neglect of the information content of prices (as in Eyster and Rabin's [54] cursed equilibrium) or limited recall of the informational content of sources (as in Pavan's [94] model of coordination with bounded recall). This interaction provides a fruitful area of future research, as some preliminary work shows (e.g., Eyster et al. [55] and Vives [126]), with potentially very relevant policy implications.

(c) Financial frictions. Both technological change and the great recession have spurred great interest in models with financial frictions. Algorithmic and high frequency trading account for a very large percentage of transactions in financial markets. At the same time, worries have arisen about market stability, witness flash crashes in some markets, and about the impact of machine trading on market quality parameters, such as liquidity, and the welfare of market participants. A particular concern is the possibility of front running by high frequency traders in a context of asymmetric information. Both empirical and theoretical work is in progress (see Brogaard et al. [30], Foucault et al. [57], Budish et al. [32], Biais et al. [29], Du and Zhu [48], and Sannikov and Skrzypacz [104]) but we are still lacking tractable models that permit us to conduct a proper welfare analysis in markets with heterogeneous traders. With respect to the great recession, most of the literature focuses on the role of collateral, moral hazard, and financial intermediation (see, e.g., Brunnermeier et al. [31]). A few recent contributions combine financial frictions with informational frictions. However, much remains to be done. For example, some authors (see e.g., Dang et al. [44,45]) have recently advocated for low-information-intense securities aimed at discouraging information acquisition.

The analysis in these models is, however, one of partial equilibrium. Extending the analysis to fully microfounded dynamic models appears essential for a more comprehensive debate of the welfare benefits and costs of disincentivizing investors' information acquisition in economies in which information asymmetries interact with financial frictions.

(d) Information flows in networks. The study of the economics of networks has progressed notably as of recently. Two areas that show promise in the relation between information frictions and networks are the modeling of over the counter markets (OTC) and systemic risk. Significant progress in the analysis of OTC markets has been done in the last ten years (for earlier contributions to this literature see Duffie et al. [49] and Lagos and Rocheteau [75]; for more recent developments, see Guerrieri et al. [66], Babus and Kondor [21], Chang [40], Guerrieri and Shimer [67], Lagos and Zhang [76], and Afonso and Lagos [2]). The welfare trade-offs between OTC and centralized markets, the effects of their co-existence on investors' incentives for information acquisition, and the shape of optimal policy in economies in which investors can choose in which of these markets to trade, remain fascinating topics for future research. Systemic risk has been modeled recently, among others, by Allen et al. [5], Caballero and Simsek [34], Acemoglu et al. [1], and Elliott et al. [53]. The study of the interaction between the network structure of financial intermediaries/markets and information flows in the presence of asymmetric information is expected to deliver important insights into how systemic crises develop and how contagion occurs.

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