From the Lab

LABORATORY FOR AGGREGATE ECONOMICS AND FINANCE

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Director's Message

by Finn Kydland

Trading Frictions in Asset Markets conference participants

Most of this issue of *From the Lab* reports on a recent conference held by LAEF entitled "Trading Frictions in Asset Markets." The vast majority of real assets, such as houses, cars, airplanes, innovations, and ideas, and a large volume of financial assets, such as derivative securities, federal funds, unlisted stocks, and most fixed-income securities, are traded in over-the-counter (OTC) markets. OTC markets operate in a completely decentralized manner: trade is bilateral, with prices and quantities negotiated by the parties involved in each trade. Trade in these markets is typically regarded as an instantaneous and costless process—and left unmodeled.

The objective of the conference was to bring together papers that model explicitly the trading process in various asset markets. The search-based approach is appealing because it can parsimoniously rationalize standard measures of liquidity, uncover new propagation mechanisms and understand venture-capital cycles while being very explicit about informational frictions. It can also help to understand the role of various middlemen as providers of liquidity in times of crises. Different formalizations of the trading frictions were discussed during the conference.

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Special thanks go to Bryan Lim, UCSB Economics Ph.D. student, for his accurate and concise summaries of each of the conference presentations, Michael Oliva for the photography, and UCSB Artworks for newsletter design and production.

I would like to take the opportunity to announce the recent publication of *Handbook of the Equity Risk Premium*, edited by Rajnish Mehra of the University of California, Santa Barbara. This book was published by North-Holland this year as part of their Handbooks in Finance series. The handbook brings together 14 papers by key researchers that span the spectrum of research efforts to resolve the so-called Equity Premium Puzzle, first uncovered by Rajnish Mehra and Edward Prescott. Most of the papers were presented and discussed at "The Equity Premium Puzzle Conference," held in October 2005 at UCSB to commemorate the twentieth anniversary of the influential article by Mehra and Prescott. The puzzle concerns the inability of standard economic models to replicate the magnitude of the average amount by which a well-diversified portfolio of stocks pays returns in excess of the risk-free rate: the equity premium. The conference was sponsored in part by LAEF and its program announced (without summaries) in the first issue (Winter 2007) of *From the Lab*.

In early May, LAEF hosted a conference entitled "Dynamic Political Economy and Optimal Taxation." Look for the conference proceedings in the next issue of "From the Lab."

Stefania Albanesi and Claudia Olivetti Visit LAEF

Stefania Albanesi is an associate professor of Economics at Columbia University. She is also a research fellow of the NBER and a research affiliate of the CEPR. She received her Ph.D. from Northwestern University in 2001.

Professor Albanesi has two main lines of research. The first is on optimal dynamic taxation in economies with incentive problems due to private information. In this work, she has dealt with optimal taxation of labor income, assets and entrepreneurial capital. She is currently exploring the properties of optimal taxes in economies with occupational choice. In addition, she is investigating the link between the process for family decision making and optimal taxes in economies where agents belong to households. In her second line of work, she has analyzed the status of women in the labor market. In a series of papers co-authored with Claudia Olivetti, she has explored the impact of medical progress on the rise in the labor force participation of married women in the 20th century, the link between gender earnings differentials and incentive problems in the labor market, and the possible determinants of the difference in the structure of compensation by gender for top executives.

While in residence at LAEF, Professor Albanesi presented a paper in the Economics Department seminar series related to her work on dynamic optimal taxation. The title of her presentation was "Intertemporal Distortions in the Second Best." The paper, co-authored with Roc Armenter, an economist at the Federal Reserve Bank of New York, explores the fundamental differences between economies in which some form of capital income taxation is optimal in the long run and the ones in which the optimal capital income tax is zero. The main result is that the government's ability to intertemporally shift other distortions, such as labor income taxes, underlies the optimality of capital income taxes.

Claudia Olivetti, is an assistant professor of Economics at Boston University. Olivetti received her Ph.D. from the University of Pennsylvania in 2001. Her research focuses on exploring causes and consequences for the changing roles of women in the family and in the workplace. Her current research interests include the investigation of:

- The role of medical progress for explaining trends in fertility, human capital and labor market decisions of U.S. women.
- International patterns of employment and wages by gender.
- The link between household decision making and the contractual relations of households' members in the labor market.
- The changing relationship between married women's labor force participation and marital instability.

While at LAEF, Olivetti presented "Gender and Dynamic Agency: Theory and Evidence on the Compensation of Female Top Executives" in the UCSB Department of Economics seminar series. Women top executives tend to be under-represented at the upper ranks of the corporate structure, tend to work in smaller firms, and receive lower overall compensation (earning about 30% less than their male counterparts—a gap comparable to the one observed for the overall population). The paper presented by Olivetti, which is joint work with Stefania Albanesi, documents a new fact about the compensation of top executives: the presence of a substantial and highly significant gender difference in the *structure* of compensation. Specifically, the paper shows that the incentive component of executive pay is much smaller for female than for male executives. The paper provides a theoretical rationalization for this finding based on a dynamic agency model of executive compensation, where it is assumed that female executives have higher cost of effort. This assumption is motivated by survey and experimental work documenting the existence of gender asymmetries in the cost of career investment (in particular, family-career trade-offs), and attitudes towards competition and towards initiating negotiations.

Trading Frictions in Asset Markets

December 6-8, 2007

The "Trading Frictions in Asset Markets" conference was held in December 2007 on the UCSB campus. Guillaume Rocheteau of the Federal Reserve Bank of Cleveland and Singapore National University, Peter Rupert of UCSB, and Pierre-Olivier Weill of UCLA were the academic coordinators of the event.

The conference began with a kick-off dinner on December 6, 2007, followed by two full days of presentations. UCSB Economics Department faculty and interested graduate students participated. Marc-Martos-Vila (UCLA) was scheduled to present "The Search for Corporate Control" but was unable to attend the conference due to illness.

Visiting conference participants were:

Nicolae Gârleanu, *University of California, Berkeley*

Alessandro Gavazza, *Yale*

Veronica Guerrieri, *Univeristy of Chicago, GSB*

Terrence Hendershott, *University of California, Berkeley*

André Kurmann, *University of Quebec, Montreal*

Ricardo Lagos, *New York University*

Benjamin Lester, *University of Western Ontario*

Ioanid Rosu, *University of Chicago*

Robert Shimer, *University of Chicago*

Pierre-Olivier Weill, *UCLA*

Randall Wright, *University of Pennsylvania*

Summaries of each of the presentations follow. Note that speakers are highlighted in author listings.

DECEMBER 7, 2007

Session One

REAL ASSET MARKETS

Liquidity in Real Asset Markets
Alessandro Gavazza

Search Frictions in Physical Capital Markets as a Propagation Mechanism
André Kurmann and Nicolas Petrosky-Nadeau

Session Two

TRADING FRICTIONS AND ASSET HOLDINGS

Portfolio Choice and Pricing in Illiquid Markets
Nicolae Gârleanu

Liquidity in Asset Markets with Search Frictions
Ricardo Lagos and Guillaume Rocheteau

Session Three

DEALERS' INVENTORIES AND LIQUIDITY

Crashes and Recoveries in Illiquid Markets
Ricardo Lagos, Guillaume Rocheteau and **Pierre-Olivier Weill**

Time-Variation in Liquidity: The Role of Market Maker Inventories and Revenues
Carole Comerton-Forde, **Terrence Hendershott**, Charles M. Jones, Pamela C. Moulton and Mark S. Seasholes

DECEMBER 8, 2007

Session Four

INFORMATION AND PRICES

Information, Coordination, and Prices
Benjamin Lester

Liquidity and Trading Dynamics
Veronica Guerrieri and Guido Lorenzoni

Session Five

STOCK-FLOW MATCHING: LABOR MARKETS AND LIMIT-ORDER BOOKS

Stock-Flow Matching
Ehsan Ebrahimy and **Robert Shimer**

Waiting Costs and Strategic Liquidity Traders in Order-Driven Markets
Juhani Linnainmaa and **Ioanid Rosu**

Session Six

CORPORATE FINANCE AND SEARCH

The Venture Capital Cycle
Randall Wright and Rafael Silviera

PRESENTATION SUMMARIES

ERRATUM

In the last issue of *From the Lab* (Winter 2008 Vol. 2, No. 1) the paper by Pedro Cavalcanti Ferreira, Samuel Pessôa and Fernando Veloso was incorrectly labeled. The correct title of the paper is *TFP in Latin America*. We regret the error.

Liquidity in Real Asset Markets
by Alessandro Gavazza

Defined as the ease of trading an asset, liquidity plays a significant role in the sale of real assets, which are typically exchanged in decentralized markets and resold several times over their productive lifespan. Buyers of real assets must consider not only the cash flows from owning the asset but also the costs they may expect to incur when reselling in the future. Gavazza examines the role of liquidity in a representative market for real assets, that for commercial aircraft. Measuring liquidity as the total stock of a particular type of aircraft in a given year, he finds that more liquid aircraft trade more frequently, are utilized with higher intensity, have lower dispersion of utilization levels, trade for higher prices, and have lower dispersion of transaction prices.

Noting that the observed results are not consistent with previous hypotheses regarding patterns of trade – symmetric information, asymmetric information, or reduction of diversification, for example – Gavazza constructs a bilateral search model to determine the conditions required to replicate the observed allocations and prices. In markets for two assets that are identical except in their existing stocks, buyers and sellers match in continuous time and choose whether or not to trade. A seller in an illiquid market may face the proposition of either selling at a disadvantageous price or holding on to the asset in hopes of selling at a better price in the future. While illiquidity acts like a sunk cost of investment and lowers the average transaction price, liquidity reduces the option value of holding on to an asset when the productivity of its user declines, shrinking the utilization dispersion. Numerical exercises indicate that when the rate at which matching occurs is an increasing function of the number of sellers, the model is able to generate the patterns demonstrated in the empirical analysis.

During the seminar, Gavazza was asked several questions regarding the structure of the market for commercial aircraft. *Who owns the planes?* Half are owned by airlines, and the other half are leased. Trades, he noted, simply constitute transfers from one operator to another. *Are transactions conducted through cash?* Some are, though most are financed with debt. *Are there data on prices during fire sales?* Gavazza referenced earlier literature, which showed companies near bankruptcy sell at a 15% discount, most often to financial intermediaries who will then try to turn over the plane for a profit. A participant commented that this discount implies either that these intermediaries aren't competing with each other or that there is a risk premium which is being priced. The participant added that neither case necessarily implies illiquidity. Gavazza explained that most transactions require securing large amounts of debt, a complicated process, as in the event of default, banks will

have an asset they have no idea how to manage. A participant expressed some reservation regarding the measure of liquidity employed. Stocks of a real asset, it was noted, may be endogenous: large stocks may not generate liquidity so much as liquidity generates large stocks.

Search Frictions in Physical Capital Markets as a Propagation Mechanism

by André Kurmann and Nicolas Petrosky-Nadeau

Physical capital is often firm- and location-specific, suggesting that its reallocation may entail potentially significant frictions. Kurmann and Petrosky-Nadeau observe that a substantial amount of physical capital is often unmatched at any given point in time and that congestion – defined as the probability of suppliers being unable to reallocate capital – is countercyclical. They model the potential effects of such frictions in a modified RBC framework where firms search at a cost for physical capital supplied endogenously by households. Once matched, capital may become separated from firms and returned to households, who reallocate it. Under weak assumptions, the model is able to generate countercyclical congestion. An implication of this result is that the availability of unmatched capital may amplify the economy's reaction to productivity shocks. However, a quantitative analysis of the model using calibrated parameters suggests that search frictions do not have a significant impact on output relative to the standard RBC model.

The model is extended to consider credit market frictions, with firms subject to idiosyncratic shocks which households may observe at a cost. In quantitative analyses, the extended model generates a substantially amplified response to a technology shock relative to the RBC model. The shock affects not only the factor productivity of the firms but also the stock of productive capital. More capital remains in use, as opposed to being returned to households for time-consuming reallocation. As in the earlier model, however, the calibrated results suggest the overall amplification effect is modest. The authors view their overall results as the physical capital counterpart to den Haan, Ramey and Watson (2000), who show that the introduction of countercyclical job destruction in a labor search model substantially magnifies and prolongs the business cycle effects of small shocks. Kurmann and Petrosky-Nadeau attribute this discrepancy to the fact that labor is twice as important a factor of production as capital, and job destructions fluctuate much more than capital separations.

Asked for examples of the time-varying congestion in the model, Kurmann noted that the reallocation of used capital goods is procyclical, whereas the dispersion of productivity or Tobin's q – a measure of the benefits of reallocation – is countercyclical. A participant asked how capital becomes separated from firms. That is, once invested, why does it not *stick*? Kurmann explained that he and his co-author don't specify any particular reason, positing that the separation could, for example, be a technological advance that puts a firm or an industry out of business. Kurmann was asked whether households, upon receiving back their no-longer-matched capital, could give it to firms with which they already have a relationship. He explained that their model isn't heterogeneous enough to handle such contingencies. A participant asked for clarification as to why the authors examined representative firms. Kurmann explained that in the model, some firms – perhaps because they go out of business or even if they stay in business – need to reallocate their capital. Because the production technology is constant returns to scale, only one firm is necessary, as all optimality conditions are independent of the size of the firm. A seminar participant questioned the authors' decision to use Nash bargaining to determine the rental rate of capital from households to firms, noting that in practice, households typically take their savings to banks that competitively negotiate with firms. Kurmann explained that to keep the model simple, he and his co-author bypass sectors of the economy (i.e., financial intermediaries) that are certainly important but can be abstracted away under simple assumptions. Nash bargaining, he argued, is a natural way to model price negotiations between two parties. A seminar participant noted that while the authors claim the adjustments in their model produce only small quantitative effects, they nevertheless represent quantitatively large improvements in comparison to classic models like Kydland-Prescott.

den Haan, Wouter J., Garey Ramey and Joel Watson (2000) "Job Destruction and Propagation of Shocks," *American Economic Review*, 90(3): 482-498.

Portfolio Choice and Pricing in Illiquid Markets

by Nicolae Gârleanu

In certain financial markets, completing a trade requires time. Agents may need time to locate potential trading partners, as in a block trade, or the investment itself may require time to gestate, as in private equity or venture capital markets. Gârleanu examines the role that illiquidity plays in portfolio choice and pricing. He presents a continuous-time model in which agents trade one safe asset and one risky asset, the former paying a fixed return and the latter paying a cumulative dividend with iid Gaussian increments. Agents differ both in endowments and in the instantaneous correlation between their respective endowment and the dividends of the risky asset. The latter defines an agent's type, and changes in this correlation

cause agents to want to trade, which they may do only at Poisson arrival times. Thus, an agent wanting to take a long position today must factor in the likelihood that she may be unable to liquidate her position in the future.

The model yields two main results. First, and rather intuitively, the less easily agents can trade in the future, the less extreme the positions they take currently. Trade size decreases with illiquidity, a result which, coupled with the presupposition that trade frequency declines, implies that overall trade volume decreases with illiquidity. Second, and at odds with much of the existing literature, the effect of illiquidity on price is minimal, though its effect on welfare may be substantial. Illiquidity generates lower demand from agents with high valuations of the risky asset and higher demand from agents with low valuations, with the net change in price being close to zero but agents' holdings being potentially far different from their Pareto-optimal levels. While this pricing result differs from that of the search literature, in which illiquidity typically leads to price increases, Gârleanu illustrates the dichotomy can be reconciled by introducing short-sales constraints into his model. More generally, if illiquidity is to have a significant effect on prices, it must be the case either that agents trading at a given point in time are not representative of all other agents in the economy or that the slopes of the marginal utilities vary significantly with asset holdings.

Noting that if endowments are correlated with dividends, agents want to trade in order to hedge their positions, a seminar participant asked why the model specifies that agents must change types over time. Gârleanu explained that without that specification, investors would only trade once. The desired dynamic is agents' stepping into and out of the market at various points in time. A participant observed that according to the model, as trading frictions decrease, the distribution of the positions for agents who have or have not traded will become more disperse. Gârleanu offered a clarification: the distribution of investor *types* becomes more disperse as trade frictions decrease. Asked whether he considered a model where the dividend process is persistent, Gârleanu acknowledged that he had, but had been unable to solve it, as the necessary linearization assumptions were more stringent than he was willing to make.

Liquidity in Asset Markets with Search Frictions

by Ricardo Lagos and Guillaume Rocheteau

Expanding on Duffie, Gârleanu and Pedersen's (2005) application of search theory to model trading frictions in over-the-counter markets, Lagos and Rocheteau consider the effects of trading frictions when agents are not restricted in their asset holdings. Their key insight is that agents can attenuate trading frictions by adjusting their positions, which depend on a weighted average of current utility and expected future marginal valuations. A decrease in frictions will cause high (low) valuation investors to take larger (smaller) positions, as they know that in the future they can more easily rebalance their portfolio. Thus, a decrease in frictions will increase the distribution of trade sizes, in a first-order stochastic sense. While it increases the number of investors who are able to trade, a decrease in frictions also decreases the number of investors who are mismatched with their current portfolio. The net effect of these conflicting dynamics is that, in general, trade volume increases.

In the model, investors maximize utility over one asset and one numeraire good, with access to the former granted only through trade with dealers. As frictions decrease, more trades are executed, trade sizes increase, and transactions costs fall. These competing dynamics give rise to non-monotonicities in the dealers' total revenues. At one extreme, where the market is very illiquid, dealers charge high fees per trade but only execute a few, relatively small trades. At the other extreme, where the market is extremely liquid, dealers charge low fees per trade but execute many, relatively large trades. With free entry of dealers, there may consequently be multiple equilibria, with dealers preferring to be in a market neither too illiquid nor liquid. Moreover, efficiency in the market requires dealers' bargaining power to be zero. In an extension, the authors allow investors direct access to the asset market, mimicking modern trading platforms such as Electronic Communications Networks. As investors' access increases, the distribution of their asset holdings becomes more disperse, which in turn encourages more dealers to enter the market. Thus, perhaps contrary to intuition, increasing investors' access to asset markets may in fact generate more dealer-executed trades.

During the seminar, participants discussed the restriction

that agents hold only non-negative positions in the asset – effectively a short-sales constraint. While one participant noted that the model's results should be robust to relaxing the restriction, another noted that the model specifies agents get utility from holding the asset, in which case the notion of short sales is not germane. Buying a house, he explained, gives the owner some utility, but one cannot live in a house with negative square footage. Asked whether "efficiency" in this market implied Pareto optimality, Lagos answered no, explaining that the measure of efficiency is the maximized sum of expected utilities for all agents in the market. He added that Pareto optimality could be achieved by pure wealth transfers from investors to dealers. A participant proposed extending the model to allow for multiple types of assets being traded, with investors' positions motivated by exogenous shocks. Lagos concurred with the spirit of the suggestion but feared that reframing their research as a portfolio problem would prove too complicated.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2005) "Over-the-counter Markets," *Econometrica*, 73: 1815-1847.

Crashes and Recoveries in Illiquid Markets

by Ricardo Lagos, Guillaume Rocheteau and Pierre-Olivier Weill

During market crashes, investors find it difficult to locate a partner for trade and liquidate their positions at substantial discounts. Dealers could potentially attenuate the magnitude of such crises by providing liquidity to the market. Lagos, Rocheteau and Weill analyze both the equilibrium and the socially optimal inventory policies of dealers during a market crash. In the model, investors maximize their utility over a tradable asset and a numeraire good. Investors are differentiated in type by the utility associated with a given position in the asset. These types—for example, high valuation or low valuation—are stochastic, changing over time. To trade, investors must contact dealers but can do so only at random intervals. The length of these intervals reflects the magnitude of trading frictions in the market. Dealers, by comparison, can trade with each other continuously. A market crash occurs in the form of a one-time shock shifting the distribution of investors such that the total demand for the asset falls.

During a crash, dealers may find it profitable to absorb the selling pressure, buying at discounted prices and liquidating at a more advantageous price in the future. Dealers accumulate inventories if (1) the market crash is abrupt and the recovery is (expected to be) fast; (2) trading frictions are neither too severe nor too small; (3) dealers' market power is not too large; and (4) idiosyncratic preference shocks are not too persistent and investors' asset demand is not too inelastic with respect to preference shocks. These conditions suggest there are situations where dealers do not need to intervene during a crash. When trade frictions are very low, for example, investors with higher-than-average utility for the asset are willing to hold larger-than-average positions, as they know they will be able easily to liquidate their positions in the future. These high-valuation investors may be able to absorb the selling pressure during the crash. At the other extreme, when trade frictions are high, all investors choose less extreme positions. Thus, during a crash, they may potentially require so little liquidity that dealers do not find it profitable to enter the market. A similar scenario holds when dealers' market power is high: investors take smaller positions and may require little liquidity. The authors note that all allocations in the model are inefficient unless dealers' market power is zero.

A seminar participant asked for clarification on the relationship between dealers' market power and efficiency. In particular, in the event of a market crash, when dealers have no market power and thus ostensibly provide liquidity, shouldn't efficiency decrease? Weill explained that in that case, efficiency decreases only if the objective of efficiency is based on prices. The benefit of the authors' environment is that it allows them to measure welfare in terms of Pareto criteria. A participant asked whether dealers in the model are under an affirmative obligation to provide liquidity, buying even when prices are falling, as is the case in markets like the NYSE. Weill answered no, dealers in the model face no such constraints. A participant noted that according to the model, dealers get no change in their continuation payoffs when they trade. Weill explained that dealers both hold inventory and have continuous access to trading markets. When investors want to trade, dealers can sell directly from their inventory, then go into the market and rebalance their holdings.

Time-Variation in Liquidity: The Role of Market Maker Inventories and Revenues

by Carole Comerton-Forde, Terrence Hendershott, Charles M. Jones, Pamela C. Moulton, and Mark S. Seasholes

While market makers ("specialists") may enjoy monopoly or near-monopoly benefits, they do so at the cost of being obligated to buffer order flow, buying when others want to sell. In doing so, they potentially incur substantial losses and unwanted inventories when markets decline. Their defense against such outcomes comes by adjusting the bid-ask spread, which the authors consider a proxy for liquidity. In this way, the liquidity of a market may reflect the financial constraints of the market maker's position.

Speculating that market makers reduce liquidity when inventories are high and increase liquidity when revenues are high, the authors examine 11 years of NYSE data to determine the degree to which inventories and revenues affect market makers' bid-ask spreads.

In regressions aggregating over all specialist firms in the data, the authors find larger end-of-day inventories and larger overnight losses associated with wider spreads the following day. These effects demonstrate considerable nonlinearity, with the marginal effects greatest when inventories are highest and/or revenues lowest. The results remain intact in disaggregated regressions: individual specialist firms post wider spreads when holding large inventories or suffering large losses. The authors note that specialists vary in type, with some being owners of the firm and others employees of a firm. They posit that owner specialists face more binding financial constraints than their corporate counterparts, as the latter generally represent substantially larger financial entities. Regressions over a limited sample support this hypothesis: the inventory effect on next-day bid-ask spreads is more than four times larger for owner-specialist firms than for employee-specialist firms.

During the seminar, Hendershott was asked for a theory explaining the link between inventories and spreads. In particular, a participant offered the possibility that a dealer's overnight position will push both the bid and ask in the same direction but not affect spread at all. Hendershott appealed to the mechanism advanced by Brunnermeier and Pedersen, who model risk-neutral market makers with some capital constraints absorbing order flow from traders. When the market markers end up having either lost money in their trading or taken a large position, they cannot provide as much liquidity in the immediate future. A participant offered a viable alternative narrative: when inventories go down, net worth goes down, so dealers face a higher premium for borrowing. As marginal costs go up, so should the bid-ask spread. A seminar participant posited that large inventory could be due to the risk or volatility of the asset being greater than anticipated. Hendershott interpreted this as suggesting a contemporaneous relationship between dealer losses and volatility. Asked why spreads aren't consistently as large as possible if dealers have market power, Hendershott explained that dealers do face competition from limit orders. Even absent such competition, he added, the spread would depend on the elasticity of demand. A participant asked for clarification regarding what exactly the dealers' financial constraints are. Hendershott explained that the market maker has a pool of capital at her disposal. If that pool gets depleted, she is out of business. Asked whether in practice there are quantities associated with bid-ask spreads, Henderson answered that there are, acknowledging the potential of examining depth in the market. Ideally, he noted, one would like some metric that captures the depth of the quotes, but the difficulty is a lot of the depth, especially on the NYSE, is never posted. While the floor brokers trade in great quantities, much of their activity is never captured in the system, so the magnitude of their participation is not known. Only when actual trades are transacted are their actions reported.

Brunnermeier, Markus, and Lasse Pedersen, 2006 "Market Liquidity and Funding Liquidity," NBER working paper.

Information, Coordination, and Prices

by Benjamin Lester

Economic theory typically predicts that price transparency leads to lower prices for consumers, but in practice, this is not always the case. Lester addresses this counterintuitive result by relaxing the traditional assumption that suppliers can always meet demand. Specifically, he models the market for a homogeneous good in which suppliers are capacity constrained. There are two types of consumers: those who are informed about the prices and locations of sellers and those who are uninformed. In the presence of capacity constraints, price transparency generates two opposing effects. As more buyers become informed about prices, sellers compete with other sellers, placing downward pressure on prices. At the same time, buyers are then competing with each other for the lowest-price good, suggesting that some buyers will be willing to pay a higher price for a higher probability of securing the good. Depending on the composition of consumers and the ratio of buyers to sellers, there may be multiple equilibria.

When the consumer's choice to become informed is endogenized at some fixed cost, Lester demonstrates that the value of information is non-monotonic in the fraction of informed buyers. That is, in some cases, informed agents would prefer to be uninformed, given that being informed alters their probabilities of securing the good. Echoing Grossman and Stiglitz (1980), there is no equilibrium in which all agents choose to become informed. A numerical example is presented, illustrating how increasing price transparency can lead to either an increase or a decrease in equilibrium prices. Holding the ratio of buyers to sellers constant, as the size of the market increases, the discrepancy between prices under varying compositions of consumers decreases. An interpretation is that for larger markets, even in the presence of capacity constraints, changes in the percentage of informed consumers have qualitatively smaller effects on prices.

During the seminar, a participant asked why it was not optimal for firms to expand production. Lester explained that the model assumes firms have fixed capacity in the

short run and that the results of the paper are driven by this capacity constraint. A participant noted that there are two ways to interpret the capacity constraint: one, that a buyer secures the good with some probability, or two, that buyers share the good – i.e., the good does not have to be indivisible. Lester was asked whether there exists a situation where, as more buyers become informed, they are worse off. He answered yes, that counter to intuition, such a situation does exist. "It's not so much that an uninformed buyer becomes informed," Lester explained. "It's that she knows other people know and act on her being informed." Lester was asked how much of the results are driven by the static nature of the game, given that in practice, buyers may potentially search at negligible cost for the cheapest seller. He acknowledged that in a finitely repeated game, there will be learning on the part of the agents as well as contracting of the market. In an infinitely repeated game, Lester conjectured that the dynamics should largely mirror those in his non-repeating game. The main departure would be that the reservation price becomes an endogenous variable: as buyers know there is some distribution of prices tomorrow, they won't have the entire surplus extracted today, knowing they can search again tomorrow.

Grossman, S. J. and J.E. Stiglitz (1980) "On the Impossibility of Informationally Efficient Markets," *American Economic Review,* 70(3): 393-408.

Liquidity and Trading Dynamics
by Veronica Guerrieri and Guido Lorenzoni

When the economy is in a downturn, agents typically turn to liquid assets such as cash or government bonds as a form of self-insurance. The authors consider the aggregate implications of this countercyclical demand for liquidity in the context of a general equilibrium model, investigating whether a lack of liquidity can amplify an economy's response to exogenous shocks. They find that when liquid assets are readily available, a negative aggregate shock results in a mechanical decrease in output, but there is no feedback effect. In contrast, when liquid assets are scarce, the aggregate shock has a magnified effect on the economy, as agents reduce consumption in order to protect their reserves. In this case, the "flight to liquidity" amplifies the effects of the aggregate shock. Risk aversion and idiosyncratic risk give rise to an insurance problem, and decentralized trade implies that agents can only self-insure using their money holdings. The amplification is driven by a form of complementarity in trading decisions: an agent is less willing to spend his liquid assets when he expects other agents to spend less. This happens because, in that case, it is harder for him to rebuild his reserves by selling goods to other agents.

The model supposes that households composed of one consumer and one producer populate a continuum of islands, where each island is identified by a local production shock that is unknown to inhabitants of every other island. Consumers and producers of one island travel to other islands, where they interact with consumers and producers of other households. The government sets a rate of return on money, the medium of exchange. The authors consider two extreme cases: a regime with a high rate of return, labeled a "Friedman rule" regime, and one with a low rate, labeled a "fully constrained" regime. The model economies are hit with a publicly observed aggregate shock which shifts the distribution of island-specific productivities, reducing the probability of low realizations and increasing that of high realizations. In both regimes, aggregate output increases. In the Friedman regime, there is no feedback effect from this shock, as availability of liquid assets makes idiosyncratic risk perfectly insurable. In the fully constrained regime, however, the linkages between trading decisions among the islands generate an additional effect on trading and output since the unavailability of liquid assets makes idiosyncratic risk completely uninsurable. For any household, the increase in output leads to an increase in consumer spending. Producers then expect to sell more, leading to an increase in production. In this way, an increase in the aggregate level of activity leads to an increase in the individual level of activity. A calibrated version of the model indicates that this amplification effect can be substantial. The crucial difference between the two financial regimes is the role of expectations in the trading decisions of individual agents.

During the seminar, Guerrieri was asked about the mechanics of the model. *What happens to unsold endowment?* Prices adjust in such a way that producers sell all units. Unsold units would yield zero payoff, as the good

is perishable between subperiods. *How does the shock affect the consumer?* Prices on a given island are going to be affected by an island-specific shock, so consumption on that island is going to be affected by that shock. *For a given island, the consumer does not know the revenue of the producer, nor can he use it?* Correct, and that aspect of the model is crucial: there is uncertainty about income. A seminar participant wanted a narrative for why there are no insurance contracts in the model. Why, for example, can households not insure against partners having been to a negative-productivity-shock island? A simple story, the participant suggested, was that the path that a producer travels is private information. Commenting that much of the action in the model occurs because agents run into constraints and that amplifies the effects of the shocks, a participant asked what happens if agents are allowed to borrow. Guerrieri answered that introducing a bond does not affect the results. With respect to the main results of the paper, a participant speculated that multiple equilibria may exist. Consumers might coordinate their spending at a higher-than-previous level, implying producers earn more income. In this case, all islands both spend more and earn more. A participant interpreted the paper as suggesting that monetary policy leads to an increase in real fluctuations: higher inflation or more costly liquidity makes the economy more volatile.

Stock-Flow Matching

by Ehsan Ebrahimy and Robert Shimer

The authors apply the stock-flow matching model to simulate labor market outcomes. Because workers and jobs are heterogeneous, not all worker-job pairs can match productively, leading to both unemployed workers and vacant jobs. In their model, unemployed workers may match with newly available jobs for which they have the appropriate skills. By the same token, employed workers may become separated from their jobs, as the job requires a different set of skills. Idiosyncratic productivity shocks affect the total number of jobs in the market, which consequently causes fluctuations in unemployment, vacancies, and worker flows. Based on these shocks, the authors are able to derive an exact formula for the distribution of the employed workers as a function of size of the labor force, the total number of jobs, and the probability that any worker-job match is productive. The authors additionally derive the distribution of employment and the transition rates from employment to unemployment and back again.

Calibrated with data from the United States, the model replicates two salient features of the U.S. labor market: the negative correlation between unemployment and vacancies at business cycle frequencies (the Beveridge curve), and

the positive correlation between the rate at which unemployed workers find jobs and the vacancy-unemployment ratio. The calibrated model explains more than a quarter of the volatility in the job finding rate, more than a third of the volatility in the vacancy-unemployment ratio, and more than 40 percent of the volatility in the separation rate of employed workers to unemployment in response to small productivity shocks. For future research, the authors suggest that the frictions analyzed in search models, mismatch models, and stock-flow matching models are complementary. "A more comprehensive model," they write, "might recognize that there are distinct labor markets with poor possibilities of substituting workers across labor markets; that not every worker can take every job within a labor market, as in this paper; and that switching labor markets or locating a suitable job within a labor market may require time-consuming search."

During the seminar, Shimer was asked to differentiate their model from those in the existing stock-flow literature. He explained that the analysis in those papers assumes that once a supplier and a demander meet, they disappear from the market. This characterization, he felt, is inapplicable to the labor market. As such, in their model, workers re-enter the market even after successful matches. A participant asked if it is the case that in the model, unemployed workers are unemployable. Shimer clarified that the employability of a worker is idiosyncratic: an unemployed worker doesn't have the skills to fill any currently available jobs, though the possibility exists that he has the skills for an already-filled job. Along these same lines, Shimer was asked whether an unemployed worker and employed worker could coordinate such that the employed worker finds a match among the available jobs and the unemployed worker takes his place. He explained that he and his co-author assume that scenario cannot happen, offering two possible justifications. One, there is an information cost that is rela-

tively small when looking for available jobs but expensive when looking for filled jobs. Or two, once employed, there is an investment in the employee which is not worth breaking off. A participant asked if wages decrease for employed workers when available jobs are filled. Shimer offered an illustrative example: "Start with an unemployed worker. A new job is created, she can match with that new job, and she gets that job. But she still can't match with existing jobs. So her wage is going to be at a low value. Now suppose a new job is created with which she can match but it stays vacant, then she's going to get a wage increase. If that job gets filled or disappears, her wage gets cut. So wages are going to bounce around in this fashion."

Waiting Costs and Strategic Liquidity Traders in Order-Driven Markets

by Juhani Linnainmaa and Ioanid Rosu

Financial markets increasingly operate without traditional market makers, instead favoring an order-driven process facilitated by limit order books. Liquidity is provided in these markets by agents who post prices at which they are willing to buy or sell some quantity of an asset. Rosu presents a model of limit order books in which agents are denoted as either sellers or buyers and are characterized by their time preference as either patient or impatient. Patient agents post limit orders and wait, while impatient agents post market orders, buying (selling) at the lowest (highest) possible posted prices. Patient agents are free to cancel or change their orders at any time. The model abstracts away any information revelation component of trading, focusing strictly on the role of liquidity. In this context, the determinants of price formation are the waiting costs (patience) of agents, the speed of the agents' arrival to the market, and the ratio of patient to impatient traders.

In a basic model with only patient sellers and impatient buyers who execute unit orders, equilibrium is characterized by patient sellers posting a series of prices cascading downward from some known maximum A. After the first patient seller posts her price at A, the second patient seller chooses a price less than A such that the expected utilities for both her and the first patient seller are equal. This outcome is ensured because agents are free to repost prices. Were the second seller to attempt to set a different price to extract higher expected utility, the first seller could adjust her price to equalize their expected utilities. This intuition extends to the generalized case with both patient and impatient buyers and sellers. Two queues of prices form, one cascading up from a minimum and one cascading down from a maximum. As the total number of agents in the market increases or as the proportion of sellers to buyers increases, both the average bid-ask spread and the price impact (the change in prices due to a market order) decrease. The maximum size of the limit order book is increasing with respect to the total number of agents but decreasing with respect to the ratio of sellers to buyers. Allowing for multi-unit market orders, Rosu finds that if such orders are of low probability, it is optimal for patient sellers to cluster away from the ask, thereby generating the hump-shaped limit-order book often observed empirically.

A seminar participant asked whether in practice there is a cost to placing limit orders. Rosu answered no, nor in general is there a cost to cancel. The markets want these players to provide liquidity. Asked for the difference between search costs and waiting costs, Rosu explained that in some sense, one can choose her search intensity, whereas waiting costs are fixed. "You can't wait more intensely but you can search more intensely," he said. A participant asked whether "liquidity" was equivalent to trading for unknown reasons. Rosu answered a qualified yes, clarifying that liquidity-based trading is meant to be differentiated from information-based trading.

The Venture Capital Cycle

by Rafael Silviera and Randall Wright

In the venture capital/private equity market, entrepreneurs with ideas but no capital partner with venture capitalists (VCs), who raise money and may help guide the project before eventually "cashing out" and moving on to the next project. The authors identify four basic phases of the venture capital cycle: VCs raise funds, match with an entrepreneur, implement the project, and, once the project has matured, exit to start the cycle again. The popularity of this market has exploded in recent years, from under $5 billion in 1980 to over $300 billion by 2004. In light of this rapid expansion, Silviera and Wright present a model to address key questions regarding the venture capital cycle: 1) what determines the duration of each phase of the cycle, and 2) what determines the size of the fund.

A basic model with project costs assumed to be zero yields several intuitive and potentially testable results regarding the payments to the VC upon the project's maturity. The more likely an unmatched VC can locate a suitable entrepreneur or the less likely an entrepreneur can locate a suitable VC, the payment should increase. The lower the project's total payoff or the less time-consuming the project is, the payment should decrease. With endogenous entry for VCs, the model implies that the number of VCs will increase as the cost of entry falls, as the payoff of projects increases, and as the project costs in terms of time or investment fall. More importantly, with endogenous entry,

(continued on back)

The Venture Capital Cycle *(continued from page 11)*

as the payoff of projects increases, the speed at which VCs match with entrepreneurs decreases, since there are more VCs in the market.

The model is expanded to consider random project costs and payoffs. The authors find that the reservation payoff required for VCs to participate is decreasing with respect to the discount rate and to the time required to implement the project. As the reservation payoff decreases, so does the expected duration of the partner search phase for VCs. Finally, the VC's once-per-venture-cycle decision about how much money to raise is endogenized, a treatment the authors refer to as "liquidity". The model implies that an equilibrium always exists, but if the payoff of the projects is sufficiently small, VCs choose not to participate. As the payoffs increase, so does the size of the funds VCs raise prior to investment.

A seminar participant asked whether agents differ in quality in the model. In practice, he noted, the experience of a VC matters a lot in the matching process. Wright answered that while it does contain heterogeneity among firms, the model does not capture a VC's desire to signal its quality to others. The literature suggests that VCs may want take a new company public to signal to the world how good they are, but this type of learning is not featured in Silviera and Wright's model. Wright was asked whether an entrepreneur with a superior idea such as the iPod generates more interest from VCs than other entrepreneurs. He answered no, there is no search intensity in the model, but speculated that adding search intensity would not change the main results of their paper. A participant asked why the model features free entry on one side of the market (VCs) and not the other (entrepreneurs). Appealing to Pissarides (1990), Wright precluded free entry on both sides because of the assumption of constant returns to scale. Otherwise the overall size of the market is not pinned down. In response to a participant's asking why Europe doesn't have a VC market, Wright offered several possible stories consistent with their model: maybe the entry cost is high; maybe they don't have many good ideas; maybe Europeans are slower; or maybe European VCs invest less.

Pissarides, Christopher A., *Equilibrium Unemployment Theory*, Oxford: Basil Blackwell, 1990.

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