FROM THE LAB

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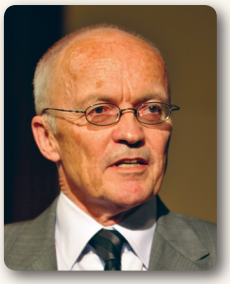
A Message from the Director

Finn Kydland



This issue is devoted to summaries of two conferences held earlier this year. As usual, the summary of each paper presented contains an overview of the key findings in that paper, as well as a summary of the discussion that took place during its presentation.

Markets are at the heart of developed economies. The standard paradigm describes markets as organized by a fictitious Walrasian auctioneer who fulfills two roles: bringing agents together and taking care of the logistic of trades, and setting prices. Most of the time, however, markets are not organized around such a Walrasian auctioneer. There are trading and informational frictions that make the tasks of matching buyers and sellers, organizing trades, and setting prices far from being seamless. In some markets, agents' information about trading opportunities is scarce and trades occur over the counter through bilateral meetings and bargaining. In many markets, intermediaries (banks, central banks, clearing agencies) and media of exchange (means of payment or collateral) are needed to facilitate exchange.

In summary, the organization of markets should not be taken as given: It emerges from the needs of market participants, given the imperfections of the economy in which they live. As a consequence, market regulations not only affect the strategies that market participants adopt, but also induce changes in the way the market itself is organized. So it is important to understand the drivers of the structure and organization of markets. The purpose of the conference on "Organization of Markets" was to bring together leading scholars to present and discuss current work on the organization of markets. It was organized by Cyril Monnet, Senior Economic Advisor at the Federal Reserve Bank of Philadelphia, Guillaume Rocheteau, Professor of Economics at University of California at Irvine, and Peter Rupert, Professor of Economics at University of California at Santa Barbara and Associate Director of LAEF.

The second conference was entitled "Putting Information Into (or Taking it out of) Macroeconomics" and was organized by Eric Young, Associate Professor of Economics at University of Virginia. Recent macroeconomic events have frequently been interpreted (informally) through the lens of an economic model in which information is incomplete, untrustworthy, or dispersed across individual agents. The development of formal models in that vein has been slowed by theoretical and computational obstacles, however, and, as a result, little is known about how to evaluate these explanations, let alone how to guide policymakers. The conference brought together researchers working on many aspects of such models, including price formation in the presence of dispersed information, decision making in the presence of information-processing limits, and the role of uncertainty and ambiguity in market economies. Some important lessons from the conference include that monetary policy can be quite different if prices are sticky because firms don't pay attention to changes in their environment, that changes in ambiguity may appear to be news about future productivity that turns out to be false, and that mandatory asset ratings can be good or bad depending on how many participants are in the market for those assets.

The next issue of From the Lab will feature proceedings of the "Advances in Macro-Finance II," the second conference on the topic, co-sponsored by LAEF and the Tepper School of Business at Carnegie Mellon University, in the Spring of 2012.

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Organization of Markets

MARCH 25-26, 2011

VISITING CONFERENCE PARTICIPANTS

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Stephen Williamson – *Washington University, St. Louis*
Yuet-Yee Wong – *Binghamton University*
Randall Wright – *University of Wisconsin, Madison*

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

Central Bank Lending and Money Market Discipline

by Marie Hoerova and Cyril Monnet

The Hoerova-Monnet paper seeks to explain the coexistence of money market and central bank lending. The central bank could centralize liquidity provision by setting the floor and ceiling on lending rates equal, closing the corridor. However, many central bankers feel that it is beneficial for banks to talk to each other. In this light, the authors decided to follow Rochet and Tirole (1996) and assume peer monitoring plays an important role. There is an endogenous adverse selection problem: the riskiness of the investments chosen by the borrowing bank is private information, and the project will have to be refinanced before returns are realized. If the safe project is not refinanced, the initial investment is recovered, but if the risky investment project is not refinanced, the initial investment is lost. The lending bank will find it optimal to refinance small loans, but will not always refinance larger loans, which indicate that the project could be a risky one. This threat of not refinancing is an incentive for borrowing banks to undertake safe projects. The equilibrium is sub-optimal: loans are either too small, or sometimes projects are liquidated.

The central bank could offer refinancing, but does not want to distort incentives. With unsecured lending only, the central bank can only make things worse. The central bank can improve welfare when secured loans are a possibility, specifically, by offering unlimited collateralized loans at a penalty rate. Collateral is an illiquid asset which matures too late to be used for refinancing. Verifying collateral will be costly, so the central bank will not be able to reach a first-best welfare level, but could improve upon the environment with no central bank. The penalty rate is equal to the return on safe projects less the collateral cost; anything lower would encourage risk-taking. The optimal haircut policy, that is, the percentage subtracted from the par value of the collateralized asset, is such that borrowers are indifferent between taking out a smaller than optimal loan and definitely getting refinanced, and taking out a larger, optimal size loan and facing random refinancing through the central bank. Welfare is greater because no safe project is ever liquidated.

The bargaining process allows the borrowing bank to make a take-it-or-leave-it offer to the lending bank. A conference participant asked why the borrower is the one to make the move. Monnet replied that this is the behavior seen in the money market: borrowers seeking lenders. Another conference participant wondered why the return to a safe investment is concave and the return to a risky investment is linear. One reason became clear once contracts were discussed: the safe project offers a higher return for small investments, and the risky project provides greater return only for larger investments, allowing the lenders to extract some information about project riskiness based on the loan size desired by the borrowing bank. Lending banks choose their refinancing strategy based on this information. In order to give all borrowers the optimal loan size, lenders must threaten to occasionally deny refinancing in order to deter risky investments. The central bank steps in to refinance when needed. By offering high penalty rates and collateral haircuts, the central bank ensures that borrowing banks are not tempted to take risky projects, and that no projects are liquidated. The cost of pledging collateral keeps welfare from attaining the first best level.

Trading and Liquidity with Limited Cognition

by Bruno Biais, Johan Hombert and Pierre-Olivier Weill

Modern financial institutions are complex entities. In response to an aggregate liquidity shock, these institutions have to unwind their positions in multiple markets, secure additional lines of credit, issue securities, enter into derivative contracts, etc. A large amount of information from various internal and external sources must be gathered and processed by traders to carry out trades. This process takes time and effort. In the presence of this friction, what are the equilibrium price processes after such shocks? How is trading affected? Biais, Hombert and Weill construct a model in which investors have limited cognition and study the response and recovery of financial markets when they are subject to aggregate liquidity shocks.

The model features a continuum of infinitely-lived, risk-neutral and competitive financial institutions. There is a fixed supply of one tradable asset. Each institution can hold any non-negative quantity of this asset. Institutions can have a high or low valuation of the asset. The utility function for high-value institutions (high-types) increases linearly in asset holdings until they hold one unit of the asset. After that, they derive no utility from holding any more of the asset. Low-value institutions (low-types) have concave utility functions with marginal utility less than one. The cost of holding the asset is equal to the interest payments minus capital gains. Initially, all institutions have identical asset holdings. At time zero, all institutions receive a liquidity shock which moves them to the low valuation state. Following Hombert's presentation, a conference participant asked if the liquidity shock could be interpreted as a preference shock. Hombert agreed with that interpretation. As time passes, institutions randomly and independently switch back to the high valuation. By the law of large numbers, the fraction of high-type institutions at any time is deterministic. Due to limited cognition, traders or institutions observe their types at infrequent random intervals. After each information event, traders use the new information and choose future asset holdings to optimize intertemporal payoffs.

If traders are perfectly rational, only the high-valuation investors hold the asset in equilibrium. With limited cognition, the information-constrained equilibrium is characterized by the time-threshold at which the fraction of traders who know they are high-type is large enough to absorb the entire asset supply. Before this threshold, prices are below their steady state because the marginal trader has a low valuation of the asset. Prices increase until they return to their steady state values. Before the threshold, it is optimal for high valuation traders to buy one unit of the asset. After the market has recovered from the liquidity shock, high-types are indifferent between buying and not buying. Low-type investors face increasing holding costs (a force to sell) and increasing probability of switching types (a force to buy). As a result, the low types buy the asset progressively at first, and eventually reduce their asset holdings.

The authors find that, compared to perfect rationality, prices take longer to recover when traders have limited cognition. A conference participant asked if prices revealed information. Hombert replied that prices were deterministic and revealed no information. Just after the liquidity shock, prices are higher with limited cognition; the marginal trader (a low type) assigns a higher value to the asset because he has a positive probability of becoming a high type. Even if the friction is very small, the trading volume is higher under limited cognition. The authors extend the model to the case where traders can only submit orders when they have an information event. This extension shows that the equilibrium with algorithmic trading is more efficient than the equilibrium with no algorithmic trading.

Repo Runs

by Antoine Martin, Dave Skeie and Ernst-Ludwig von Thadden

A repo is an arrangement between two parties involving the sale of a security coupled with a promise to repurchase the security at a future date. Before the financial crisis, the tri-party repo market was an important source of funding for investment banks; the size of this market was $2.5 trillion. The collapse of Bear Stearns and Lehmann Brothers was precipitated by a sudden decline in funding from the tri-party repo market. To explain this decline in funding, Martin, Skeie and von Thadden construct a model of bank runs applicable to repo markets.

The authors consider an infinite-period economy with one physical good. This good can be stored, consumed, or invested. There are two types of agents: investors and dealers. Investors are born each period with one unit of endowment and live for three periods. Each investor faces a privately observable liquidity shock in the second period (middle age). Based on the shock, investors are either "patient"- they consume in old age, or "impatient"- they consume now. There is a large number of infinitely-lived risk-neutral dealers. Each dealer has access to a long-term investment technology with decreasing returns to scale. Lending arrangements require collateral because returns are not verifiable by investors. Following Martin's presentation, a conference participant asked if non-verifiable returns were identical to non-observable returns. Martin said that this should be the case.

Dealers maximize the sum of their expected discounted cash flows and consume their profits. The market is characterized by Cournot competition among dealers. Hence, all dealers make positive profits in equilibrium. One conference participant wanted to know why positive profits were required in the model. Martin stated that positive

profits incentivize the dealer to borrow from investors instead of using his own funds. This requirement is the dynamic participation constraint. Another conference participant added that these profits are not economic rents. Profits make the dealer indifferent between using their own funds and borrowing. Martin agreed and added that the key requirement is that dealers have positive cash flow.

In the steady state, impatient investors withdraw their deposits while young and patient middle-aged investors continue to fund the dealer. A "bank run" on a dealer occurs if patient depositors and young investors withdraw their funds from the dealer. In a run, a dealer's survival depends on her liquidity and collateral constraints. A dealer is liquidity-constrained if her cash holdings are insufficient to pay back all investors. Such a dealer goes bankrupt if the liquidation value of her collateral is not enough to fulfill investor demands. On the other hand, if the dealer is well collateralized, investors have no incentive to run.

The tri-party repo market has a third player, the clearing bank, which facilitates exchange. Investors deposit funds overnight with dealers and receive collateral. The next morning, the clearing bank returns the investors' deposits in exchange for collateral; dealers are financed by the bank during the day. After this transaction, all investors hold cash. If investors do not invest this cash back with the dealer, the dealer could go bankrupt. The authors show that if the "unwinding" carried out by clearing banks is eliminated, however, patient middle-aged investors hold a repo with the dealer instead of cash. These investors have no incentive to run because they hold collateral which protects them from dealer bankruptcy, regardless of how other investors behave. Martin added that this finding has important policy implications regarding the financial stability of the tri-party repo market.

Counterfeit Quality and Verification in a Monetary Exchange

by Ben S.C. Fung and Euchuan Shao

At the beginning of the 2000s, counterfeit currency in Canada rose to 500 notes per million in circulation. The Canadian government wanted to maintain confidence in the currency, and promoted the use of verification methods. To understand how policy could affect counterfeiting, Fung and Shao present a model where both counterfeiting and verification decisions are endogenous. Counterfeiting is not just a threat, but an equilibrium outcome: counterfeit and genuine notes may coexist. The authors are able to explore why some countries, such as the United Kingdom and Mexico, suffer from much higher levels of counterfeiting than other countries, such as Australia and Korea. They ask if inflation has any effect on counterfeiting. Also, how costly is counterfeiting to society?

The model environment is similar to Rocheteau and Wright (2005). Every period consists of two sub-periods: a centralized market and a decentralized market. At the beginning of the period, the government decides the amount of currency in circulation through lump-sum transfers. Next, buyers make their decision to counterfeit or not. Buyers have a choice regarding the quality of the counterfeit notes: higher quality is harder to distinguish, but costlier to produce. Sellers then decide on verification technology investment. Better technology implies a better signal regarding the type of currency, and no technology implies no signal about currency type. Investment decisions may or may not be public information. First, the centralized Walrasian market opens up, where all agents produce and consume. The decentralized model with search follows. In this market, some agents are sellers, and some are buyers. Goods are non-storable so money is necessary. When buyers and sellers meet in the decentralized market, they will trade according to pre-specified terms. If an unlucky seller unknowingly accepts counterfeit currency, it will disintegrate at the end of the period. Since buyers cannot signal to sellers the type of currency they hold, a pooling equilibrium results where all buyers are treated the same. Perhaps counter-intuitively, the authors find that a higher cost of verification leads to less counterfeiting. With high verification costs, there must be more buyers using genuine money for sellers to agree to participate in the decentralized market. Inflation also leads to less counterfeiting, since the return to fake notes is smaller. Lastly, a policy that would add security features to bank notes does not necessarily reduce counterfeiting. Making counterfeiting more expensive reduces the profit margin for counterfeiters. Buyers will switch to a lower quality of counterfeits, but will produce more, as there is only a fixed cost of production.

A conference participant asked if an equilibrium might involve sellers offering smaller quantities, so that counterfeiting, with its fixed cost, would be unattractive. This was not the case for this model. Rather than sell small quantities, sellers adjust the verification technology, or the probability of detecting fake notes. Another conference participant wondered if one could study counterfeiting in a centralized market. Discussion arose, with a participant adding that even studying genuine money in an Arrow-Debreu world would require some friction. The key frictions in the Fung-Shao paper are record keeping and commitment, not really search. A question arose concerning why the price should not reflect the number of matches a seller or buyer encounters in the decentralized market. Shao explained that a buyer either meets one seller, or doesn't meet anyone at all, and vice versa. The matching probability depends on the ratio of buyers to sellers. A participant asked how the paper explains the drop in Canadian and the increase in British counterfeiting. Shao responded that his paper does not tackle this question, but does answer why some countries have counterfeiting problems and others do not.

Risk-sharing or Risk taking? Hedging, margins and incentives

by Bruno Biais, Florian Heider and Marie Hoerova

"In theory I'm an applied economist" - Bruno Biais

New derivatives are supposed to help share risk, but what if they also induce risk-taking? What does the optimal contract look like? What role do margins play? Biais, Heider and Hoerova propose a model where the moral hazard problem is on the side of the insurance seller, effectively turning the textbook model of corporate finance on its head. Suppose the seller is risk-neutral and the buyer is risk-averse. They each have an asset which could have a high or low payoff. Asset returns are not correlated with each other, and probabilities of high and low (zero) returns are observable. The return on the insurance seller's asset is affected by the seller's effort. Her incentives to exert effort are closely tied to a signal she receives about the return on the buyer's asset. A positive signal increases the probability of a high return, and the insurance seller expects to receive a payment from the insurance buyer. If the signal is negative, the seller is worried she will have to pay the buyer. In this case, she is less likely to put forth effort for two reasons. First, she enjoys a private benefit of not working. Second, if she is more likely to have to pay the buyer, the expected return of exerting effort is lower. If the contract does not lay out correct incentives for the seller to put forth effort, her return could be zero, and limited liability will protect her from obligations to the buyer.

In order to check incentives of the insurance seller, a margin call can be made by the buyer. After the signal is observed, the buyer can require the seller to liquidate some of her risky asset, and keep that fraction in a safe treasury bond. After a positive signal, the seller does not need additional incentive to exert effort, so no margin call is made. After a negative signal, a margin call might be made by the buyer, who is worried that the seller will now shirk on effort. Since less effort is required (the risky project is now smaller), the private benefit of shirking is reduced under a margin call. Also, the liquidated asset is ring-fenced from the moral hazard problem. A high margin call makes the contract more difficult for the seller to accept however, since liquidating part of the asset lowers expected returns. A conference participant asked if the margin call could have the interpretation of collateral. Biais responded that it is margin more so than collateral, because it is about the assets, not the liability. Another conference participant proposed the following scenario: if I hold a risky asset that must be partially liquidated, I give some risky asset away in return for a safe asset. The assets have changed hands but the aggregate resource allocation has not changed. Biais explained that one of the assumptions is that only the seller can manage her risky asset. This implies that a partial liquidation is a real decision. Interestingly, a contract with margins does not imply risk-control; a contract with margins and risk-taking could result if the pledgeable income of the seller is low, and the moral hazard problem is severe.

Extending the model, Biais allowed for multiple sellers, who are allowed to re-trade insurance contracts after the signal has been observed. Consider two sellers, A and B, and two buyers; each seller has insured one buyer. The two sellers can exploit limited liability by having seller A purchase the contract from seller B before the signal has been observed. The gains from trade arise because seller A doubles her payoff if return is positive, but limited liability keeps her from losing more than she would have otherwise. The private benefit from shirking on effort is higher, and if the seller holding all of the insurance receives a negative signal, she will not control her balance sheet risk. Biais explained that the optimal contract now involves an initial margin. The margin must be deposited before the signal is realized. This makes it costly to acquire another contract since it involves liquidating some assets. The results of the model emphasize that for well-capitalized institutions, margin requirements mitigate the moral hazard problem. On the other hand, poorly capitalized firms will take on risk under some conditions, even with margin calls. They are protected by limited liability, but they could impose costs on third parties. Therefore, their privately optimal behavior is not socially optimal, and they should not be able to sell such protection.

Asset Liquidity and Home Bias

by Athanasios Geromichalos and Ina Simonovska

People tend to hold a larger share of domestic assets in their portfolios. This empirical regularity, termed home-bias, is at odds with finance theory which purports that agents should hold a well-diversified portfolio of domestic and foreign assets. In this paper, Geromichalos and Simonovska consider a dual role for assets: they serve as claims to consumption, as in finance theory, and act as media of exchange. If domestic assets have liquidity value and agents trade more frequently in domestic markets, agents rationally hold a larger share of domestic assets in their portfolios. In addition, agents consume a larger share of domestic goods (consumption home-bias) and imported goods are expensive relative to domestic goods (border effects).

In the authors' model, there are two countries, each with a centralized (CM) and decentralized (DM) market. Infinitely-lived agents consume, work and trade in these markets each period. Each period, agents are randomly chosen to be buyers; the rest are sellers. Buyers are mobile: they consume the special good and participate in the DM home and abroad. Sellers are immobile: they incur a cost to produce the special good and trade in their domestic DM only. Both currencies can be used in the DM. But currency

areas arise endogenously if the validity of the foreign asset is costly to verify. Transportation costs, tariffs, or information costs also lead to currency areas. One conference participant compared a two-country cash-in-advance model to the authors' model with a large cost for holding the foreign asset. In the DM, an increasing, concave, and constant returns-to-scale function matches buyers with sellers. Buyers make take-it-or-leave-it offers. In the CM, every agent can work in exchange for consumption of a general good or agents can consume dividends from their assets.

The bargaining solution in the DM depends only on the size of the buyer's real balances. If the buyer is local and her real balances are bigger than the first-best quantity, then the optimal quantity is traded and consumed. Otherwise, local buyers purchase as much of the special good as their asset-holdings allow. Foreign buyers suffer a cost if they hold the local currency, while local sellers suffer a cost if they hold the foreign currency. According to the bargaining solution, if the foreign buyer had unlimited amounts of the local asset, she would buy a quantity greater than the first-best. This arrangement increases trade surplus by reducing the cost of holding the foreign asset for each party. Otherwise, she will purchase a lesser amount

Under this bargaining solution, buyers never bring the foreign asset to the local DM; carrying the foreign asset to this DM is costly with no countervailing benefit. A conference participant wanted to know if the results hold when buyers randomly go to one country only. Cavalcanti conjectured that, if buyers go to one country only, there might be equilibria where agents only hold one currency. Another conference participant urged the authors to work out this interesting case. The authors show the existence of unique symmetric steady-state equilibria. Depending on the parameters, there are two types of equilibria: the local currency dominance equilibrium and the international currency equilibrium. Local currency dominance means that agents use the currency of the country in whose DM they trade. In the international currency equilibrium, buyers carry both currencies to the DM. There is a range of parameters, where prices decide between the two equilibria.

In the model, asset home bias and consumption home bias exists is all of the cases above, as long as the probability of trading in the local DM is not much lower than the probability of trading in the foreign DM. In some cases, this model generates a foreign asset turnover rate that is higher than the domestic asset turnover rate, an empirical regularity not generated by other papers on asset home bias.

On the Coexistence of Money and Higher-Return Assets and its Social Role

by Guillaume Rocheteau

The coexistence of fiat money, an asset with zero return, along with capital, an asset with a positive rate of return, has been a long-standing puzzle in monetary economics. To explain the rate-of-return dominance puzzle, Rocheteau adopts a mechanism design approach to show that this difference in the rate of return on capital and fiat money is a property of all equilibria in an environment with explicit frictions. This dominance arises because fiat money is liquid and can improve welfare in an economy with a shortage of liquid assets.

Buyers and sellers participate in two markets: a centralized market (CM), where they choose their asset portfolios, and a decentralized market (DM), where they require liquid assets. The mechanism specifies the transfer of capital and fiat money from the buyer to the seller in exchange for the consumption good in the DM. Buyers with enough capital and real balances for the first-best level of trade receive a certain surplus. Buyers without enough assets receive no surplus. Buyers with assets above the first-best level receive no reward. Since capital and real balances are costly, buyers will never hold more assets than the first-best level. Rocheteau assumes that buyers cannot over-state their asset holdings. Under-reporting of asset holdings by buyers is never rational because their payoff is weakly increasing in reported levels of capital and real balances. Hence, buyers will always report truthfully.

Fiat money is essential if it leads to higher social welfare. Rocheteau shows that fiat money is inessential if there is no shortage of liquid assets in the economy; the first-best allocation can be implemented as the constrained efficient allocation. If there is a shortage of liquid assets, fiat money is essential. If the shortage is not too large, fiat money can implement the first-best allocation. Otherwise, the quantity of goods traded in the decentralized market is inefficiently low; under additional conditions, the level of capital is higher than the first-best. In all constrained efficient allocations, capital commands a higher rate of return than does fiat money. If rate of return across capital and fiat money are equalized, a reduction in the capital stock lowers the buyers' cost of holding capital, relaxes the participation constraint, and reduces the social costs from an over-accumulated capital stock. Thus, rate of return dominance must hold in equilibrium.

Rocheteau extended the model by adding inflation. In an economy with inflation, the first-best allocation can be implemented as long as the inflation rate is not too large. For large inflation rates, the equilibrium-traded quantities are too low. In all these cases, however, rate of return dominance prevails. A conference participant asked what would happen if, in real life, bank accounts paid the risk-free rate. Rocheteau replied that the puzzle would vanish.

Two participants made the following comments: (1) this puzzle is important because it is a fundamental failure of the law of one price; and (2) these rate-of-return puzzles are everywhere.

Private and Public Provision of Liquidity in a Banking Model

by Cyril Monnet and Daniel Sanches

How is aggregate investment affected when the role of intermediaries is considered in the savings-investment process? When bankers have the ability to issue liabilities as a medium of exchange, what role does monetary policy play? Monnet and Sanches propose a general equilibrium model where intermediary incentives are explicitly modeled and will affect the allocation of resources. There are two sectors: one is frictionless, but the other relies solely on external financing with limited commitment. The efficiency of competitive equilibrium under perfect enforcement is used as a benchmark and is compared to an environment with limited enforcement. In the latter case, bankers' abilities to issue notes allows them to compete for funds via prices, but financing is limited by the willingness of the public to hold their notes. Under limited enforcement, banks will pay monitoring costs to confirm borrowers' returns. Paying higher monitoring costs means higher expected returns, but the authors show that the tradeoff may not be profitable for bankers. When many equilibria are possible, the central bank can ensure that the equilibrium with the highest level of investment and production is reached.

There are three types of agents: households, entrepreneurs and bankers. Households produce a general good with effort only (no financing) in the first of two sub-periods. Entrepreneurs produce a special good in the second sub-period using the general good as input. They are born without wealth, so their input will need to be financed. They will sell their good in exchange for liquid assets. Both goods are perishable, but every agent has access to a storage technology, which is non-tradable. All agents enjoy linear utility from the general good, but only households consume the special good with diminishing marginal utility. Households are anonymous, so credit exchange between entrepreneurs and households will not be feasible. Bankers have a monitoring technology allowing them to confirm entrepreneur output of the special good, which is random and otherwise private information. The monitoring cost is heterogeneous across entrepreneurs, so loans will be conditional on this information. Bankers will issue bank notes to obtain the general good from households, which will be invested for entrepreneurial production of the special good. A record-keeping technology allows bankers' actions and histories to be publicly observable. It is the monitoring technology and the observability of bankers which makes them essential as intermediaries. Bankers compete by strategically choosing a price. Following this announcement, households decide with whom to trade. Next, bankers compete on the loan market; they simultaneously announce rates for the entrepreneurs who then decide which contract to accept.

A conference participant pointed out that there are three frictions at work here: monetary, anonymity and a commitment problem. He inquired about the third. Sanches elaborated that banks cannot commit – they can default if they do not have funds, but they can also strategically default. When asked if this behavior is observable, Sanches confirmed that it is. The same participant inquired further: is this similar to Bertrand? Banks earn profits? Sanches answered yes, banks charge for their liquidity service, otherwise they would have incentive to default. A question was raised regarding the necessity of all three frictions. Sanches explained that the commitment friction for banks gives interesting results, but is not necessary. There are two types of equilibria: equilibria with and without interbank arrangements. Under perfect enforcement, the equilibrium without interbank arrangements implements the benchmark. With interbank arrangements, all bankers trade with households, but all deposit their resources with one banker. By pooling resources, bankers can take advantage of market power and increase their return on their investments. Under limited enforcement, if there is no interbank arrangement, the best bankers can do is to promise zero net return on their notes. Under interbank arrangements, banks take advantage of market power and bank notes promise a higher rate of return (increased liquidity), at the expense of higher monitoring costs. A conference participant wondered if this chews up welfare. Sanches explained that this actually increases households' expected utility and the aggregate surplus. There is more lending from the collusion. The discussion concluded with the introduction of a central bank, which does not have a monitoring technology, but can issue fiat money to compete with bank notes. The authors found that the central bank has the ability to replicate any equilibrium, including the one with the highest amount of investment.

Buyers, Sellers and Middlemen: Variations in Search-Theoretic Themes

by Yuet-Yee Wong and Randall Wright

Wong and Wright develop a simple strategic borrowing model to generate endogenous intermediation. This allows the authors to ask fundamental questions such as: What makes an agent a buyer or seller? How is price determined? How many intermediaries get involved, and how? Flipping on the real estate market and financial intermediation are two examples of many potential applications. The focus of the paper is not why intermediation

occurs, but the exchange patterns that emerge because it is necessary. Terms of trade will depend on future negotiations when there exist further downstream intermediaries. The model varies network structure and preferences, but the technology is constant across all environments. There are two goods: one indivisible, and one divisible. The former is in fixed supply, and the latter can be produced at unit cost to any agent. One agent will be endowed with the indivisible good. She may or may not enjoy utility from this good. Similarly, other agents may or may not enjoy the good, with varying amounts of utility. Depending on preferences and search costs, these agents may have incentive to trade. A game for price negotiation yields the Nash solution. Here, Price is the amount of the divisible good used to buy the indivisible good. Bargaining power does not just depend on the trading agents' values of the good, but on the future value of the good by other agents down the trade path.

A three-agent environment is used as an example. Agent 1 is endowed with the indivisible good, but only Agent 3 derives utility from it. Suppose also that they are arranged in a linear network, so that 1 can only trade with 2, and 3 can only trade with 2. Agent 2 will purchase this good from Agent 1 even though she derives no utility from it, because of her ability to trade with Agent 3. This is extended to several intermediaries and networks where agents can trade with everyone, albeit with some search cost. Middlemen will be active if, and only if, they can meet end users faster than the agent with the endowment. Price increases over time, until the good is consumed by the end user. Interesting patterns emerge in the more complex networks. The interval times, that is, the time each intermediary agent holds the good, follow an exponential distribution. There is a high probability of holding the good for a short time, and a low probability of holding the good for a long time (an artifact of the Poisson arrival process). This produces an interesting path that resembles random market frenzies, characterized by many trades in a short period of time with a quickly escalating price, followed by periods of inaction where few trades occur and the price is slow to increase.

A conference participant wondered how the bargaining game differed from Rubinstein bargaining. Wright replied that his game ends in finite time, which is very useful. It is similar to posting in that, if crazy terms of trade are posted, the other agent will always reject and opt for bargaining. If the bargaining stage is reached, with some probability, the first agent makes a take-it or leave-it offer, and with complimentary probability, the other agent makes the offer. This probability determines the bargaining power of each agent. Another conference participant asked if the bargaining power is exogenous. Wright confirmed that it is. A question was raised regarding the possibility of interpreting the good as money. Wright emphasized the difference between fiat money and commodity money; here, the good can be considered commodity money because it will provide utility to some agent. However, if the indivisible good is thought of as money, then the price of the divisible good is decreasing over time. Which good is interpreted as money is important. Wright foresees this paper opening the door to future research into whole-salers, the legal system's stricter treatment of sellers over buyers, and financial intermediaries.

Enriching Information to Prevent Bank Runs

by Ricardo Cavalcanti and Paulo K. Monteiro

The classic Diamond-Dybvig environment is inherently financially fragile because of the possibility of a bank run in equilibrium. The sequential service constraint is usually considered responsible for this financial fragility. In their paper, Cavalcanti and Monteiro expand the message space in the Diamond-Dybvig model and show that backward elimination of strategies can be used to eliminate the bank-run equilibrium and restore financial stability. The authors show that the sequential service constraint can actually be used to promote stability in the Diamond-Dybvig environment.

The model consists of a two-period endowment economy with a finite number of ex ante identical agents. An investment technology transforms savings in period one to consumption in period two. The rate of return on this investment technology is greater than one. In period one, agents form a queue and are randomly chosen to be patient or impatient. Agents' types are private information. Hence, the social planner cannot observe any agent's true type and allocates consumption based on an agent's reports of her type. To capture the sequential service constraint, the authors assume that an agent's consumption cannot depend on the reports of agents who are behind her in the queue.

Patient agents are indifferent between consuming in period one or in period two. On the other hand, impatient agents want to consume in period one only. In the socially optimal no-run equilibrium, impatient agents consume in period one, while patient agents consume in period two. The suboptimal bank-run equilibrium arises because of sequential service and unobservability of agent types. If a patient agent thinks that patient agents behind her in the queue will misreport their types by posing as impatient agents, then she will also misreport her type. If she does not misreport, while all the remaining patient types misreport, there will be no consumption left over for her in period two. Agents cannot observe the announcements of others. Hence, they are also concerned about misreports in the past which reduce the amount of available endowment. A conference participant asked if the planner

could use his knowledge of the past to inform the agents. Cavalcanti replied that the planner only knows the announcements, not the true types of the people.

When asked by a conference participant if the challenge was to implement the optimal equilibrium uniquely, Cavalcanti replied "yes." To eliminate the suboptimal equilibrium, the authors propose a mechanism where the social planner asks agents to send two messages. In the first message, agents report their types. In the second message, agents report if they will accept or reject a contract in which the social planner takes away a small amount from their allocation today and promises to give them a larger allocation tomorrow. Impatient agents will never accept this contract. On the other hand, patient agents will always accept. To satisfy the resource constraint, the social planner takes away an arbitrarily small amount of consumption from the last person in the queue. Because of the second message, the planner will always be correctly informed about the past and can reallocate the endowment optimally among the remaining agents. Thus, patient agents in the queue do not have to worry about the planner making commitments that violate the resource constraint.

The last agent in the queue has no incentive to lie about her type. Given that this agent is telling the truth and the social planner is correctly informed about the past, the second-last agent has no incentive to lie about his type. This argument can be applied inductively to the entire queue. Thus, all agents report their types truthfully in equilibrium and the suboptimal bank-run equilibrium is eliminated. Cavalcanti noted that, if preferences satisfy a separation property, this mechanism can be used to promote financial stability in a larger class of environments.

Credit Markets, Limited Commitment, and Government Debt

by Stephen Williamson

In light of recent financial market events, it is important to ask which frictions are able to explain credit market observations, and if government debt can alleviate their effects. Williamson focuses on the inefficiencies that arise from a limited commitment friction, with limitations on punishment. In his model there is a centralized market where histories are observable, and a decentralized market where sometimes they are not. Two types of risk-averse agents produce a perishable consumption good. The first type of risk-averse agents are called buyers. Buyers can only produce in the centralized market. Sellers are the second type of risk-averse agents. Sellers can only produce in the decentralized market, so they trade with debt. Two environments are considered: a symmetric economy where buyers are ex ante identical, and an asymmetric economy which consists of good buyers who never default, and bad buyers who always default. In the former case, the threat of a global punishment keeps borrowers from defaulting. In the latter case, individual punishments are used. In the centralized market, those who have defaulted are not able to participate. They may still trade in the decentralized market, however, where histories are unobservable. The bad buyers are indistinguishable from the good. The limited-information loans will carry a default premium which depends on the fraction of bad borrowers. Incentive compatibility constraints are tightened, and consumption falls.

Sometimes government debt can help alleviate the adverse selection problem in the credit market by trying to replicate the allocation from the environment with global punishment. The government has the ability to issue bonds, paying interest by taxing buyers in the centralized market. The government is subject to the same limited commitment friction as the buyers and sellers: buyers cannot be forced to pay their taxes. In order to obtain a loan in the decentralized market, a bad borrower will mimic the behavior of a good borrower; that is, holding government debt. If the ability to punish globally is removed from the symmetric economy, and instead only individual punishments are possible, incentive compatibility constraints will tighten and consumption will fall. The government might be able to help. By providing enough bonds to crowd out private credit, the government may be able to restore efficient allocation. In the case of an asymmetric economy, even with government bonds relaxing the incentive compatibility constraints, welfare will not typically be as high as it would be with global punishment. It is possible to improve welfare with public debt, but in the optimal equilibrium government debt will coexist with private credit.

A conference participant asked what the state variable of a bad buyer would be. Wright reasoned that bad buyers have a different history. The same participant further wondered why the history is important. "What does the past have to do with the future? Why can't a bad agent change his behavior?" Another conference participant conjectured that if histories are forgotten, and buyers who have defaulted were treated the same as good buyers, they would have no incentive to behave well. The only way to satisfy incentive compatibility is to promise punishment for bad behavior. Williamson was succinct in his explanation: the equilibrium is supported by off-equilibrium paths.

Putting Information into (or Taking it out of) Macroeconomics

APRIL 22-23, 2011

VISITING CONFERENCE PARTICIPANTS

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Ken Kasa – *Simon Fraser University*
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Vaidyanathan Venkateswaran – *University of California, Los Angeles*
Todd B. Walker – *Indiana University*
Mirko Wiederholt – *Northwestern University*
Noah Williams – *University of Wisconsin, Madison*
Eric Young – *University of Virginia*

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

Exogenous Information, Endogenous Information and Optimal Monetary Policy

by Luigi Paciello and Mirko Wiederholt

Slow adjustment of prices in response to changes in aggregate conditions is central to monetary policy analysis in the New Keynesian framework. In the usual New Keynesian model, prices adjust slowly because they are assumed to be sticky. Paciello and Wiederholt study optimal monetary policy with commitment when prices adjust slowly due to an information friction: decision-makers in firms pay limited attention to aggregate conditions. Following Wiederholt's presentation, a conference participant asked if the authors' model was similar to models which distinguish between time-dependent and state-dependent price stickiness. Wiederholt responded that the degree of price-stickiness was not policy-invariant in their model.

The authors study two models. In the first model, the amount of attention paid to aggregate conditions by decision-makers in firms is exogenous. The authors find that the optimal policy response in this economy is similar to the standard New Keynesian economy: the central bank should always stabilize prices completely in response to Total Factor Productivity (TFP) shocks but never in response to markup shocks. Complete price stabilization is optimal for TFP shocks because it replicates the efficient response to such shocks by an economy with no information frictions. A positive markup shock increases the price and reduces consumption. If the central bank contracts the money supply to stabilize prices, it amplifies the drop in consumption. Thus, the central bank faces a trade-off between price stabilization and output stabilization under markup shocks. Complete price stabilization is never optimal under this trade-off.

In the second model, the authors endogenize the amount of attention paid to aggregate conditions by decision makers in firms. The optimal monetary policy with commitment in this economy differs significantly: the central bank should stabilize prices completely in response to TFP and markup shocks. The intuition for TFP shocks is identical to the exogenous attention case. However, the intuition for markup shocks is different. In addition to the two effects present in the exogenous attention case, there is a third effect: decision-makers in firms reduce the amount of attention they devote to the markup shock. This third effect reduces the responsiveness of prices to markup shocks and completely attenuates the fall in consumption.

Comparing the model economy to a standard New Keysenian economy, a conference participant asked if the optimal allocation or the implementation of the optimal allocation was different in the authors' model. Wiederholt responded that the optimal allocation was different. Another participant inquired about how sensitive the authors' results on TFP shocks were to their assumption regarding the feasibility of optimal allocations. Wiederholt replied that this assumption was crucial. He added that he and Paciello were working on a similar model in which households have limited attention and optimal allocations are not necessarily feasible. In this model, the optimal policy response to markup shocks is unchanged but the optimal policy response to TFP shocks changes.

[1.] *The authors show that the results can be extended to other general types of shocks.*

Sentiments: Decentralization, Communication, and the Origin of Fluctuations

by George-Marios Angeletos and Jennifer La'O

For decades, the neoclassical growth framework has served as the foundation in which quantitative real business cycle and DSGE models are rooted. A common test for any one of these models is that, when shocked, it should reasonably generate the co-movement of economic aggregates that is seen in the data. The sources generating these fluctuations have taken many forms. Typically, a source is modeled as an exogenous shock to either technology, preferences, or some other type of wedge (i.e. labor wedge). While these shocks have been shown to capture many characteristics of the business cycle, the literature is still searching for a better understanding of their sources. In their paper, Angeletos and La'O seek to find a source of fluctuations within the standard neoclassical rational expectations economy that does not directly shock model fundamentals. Rather, to generate fluctuations, the authors only need to remove one simplifying assumption in the standard business cycle framework – perfect communication. Instead of agents in the model trading on a centralized market with perfect communication, trade occurs in a decentralized fashion in a market with search frictions. The source of volatility is modeled as a shock to higher order beliefs.

The model is a version of the Lucas island model. Each island has a representative firm that uses labor and capital to produce a differentiated domestic good and a representative consumer who has tastes over both domestic and foreign goods. Islands are heterogeneous in productivity and are randomly matched to participate in barter trade. All fundamentals of the model are known with certainty and are time invariant. There only exists uncertainty in the particular trading partner with which an island will be matched. Agents on each island must make employment and production decisions before they meet their trading partner and therefore must form beliefs about the potential terms of trade.

Once trade occurs, islands are assumed to share all information relevant to each other. However, before trade, an island's beliefs are formed conditional on both common knowledge of model fundamentals as well as its idiosyncratic trading history. Since each island will have a different history, it will also possess a different information set. Universal common knowledge is never achieved. Forming beliefs about future trading partners requires forming beliefs of their beliefs, which are uncertain. It is this uncertainty in higher order beliefs that gives rise to a source of volatility in the model. Suppose, for example, all agents in the model believe that their trading partner believes that he will get a higher than average match. The belief is rational because your trading partner's information set is idiosyncratic. Further, your trading partner will have an incentive to produce more because he believes you will. As a result, you will indeed have incentive to produce at a higher level. Total output is above what can be sustained with perfect communication. Angeletos and La'O show that a unique equilibrium with the types of self-fulfilling fluctuations just described can only arise under imperfect communication.

A conference participant asked if tastes over home and foreign consumption along with matching frictions are a type of demand (preference) shock. Angeletos replied that the difference between these shocks and preference shocks are that they aren't tying the shocks to any fundamental parameter. Further, while it is true that the model will generate observables that are similar to those derived from a model with demand or preference shocks, Angeletos argues that those demand shocks are in some way misspecified.

Note: Paper circulated under the title "Sentiments: A Treatise on the Origins of Fluctuations" during the conference.

Heterogeneous Beliefs and Tests of Present Value Models

by Kenneth Kasa, Todd B. Walker and Charles H. Whiteman

Standard present value models have been dismissed over the last thirty years due to their inability to explain excess price volatility and excess return predictability. The standard model prices assets according to fundamentals observed by all agents. Extensions including time-varying discount rates have been pursued in the literature with limited success. The Kasa/Walker/Whiteman paper explores informational heterogeneity as a potential answer to the volatility puzzle. The authors vary the standard model in two ways: some fundamentals are unobserved by all speculative traders, and traders are heterogeneously informed about the observable fundamentals. Observed fundamentals consist of orthogonal components, and different traders observe different components. The environment is effective because the heterogeneous information translates to heterogeneous beliefs. That is, market data does not fully reveal the private information of the traders, even in this dynamic setting. The model is able to explain empirical anomalies such as the excess volatility of prices, excess return predictability and rejections of cross-equation restrictions.

In the standard present value model, price is determined by the discount factor, expected future prices, and observed fundamentals. Price in this model is determined by the factors just mentioned, and also unobserved fundamentals. The other deviation from the standard model is found in the expectations operator: each trader will have different expectations about future price because he observes different components of the observed fundamentals. Observed fundamentals are driven by an exogenous process which is a function of two zero mean Gaussian random variables which are uncorrelated with each other. Each trader observes a different Gaussian variable, giving both different information sets, and

causing their heterogeneous beliefs. A trader cannot use price to back out what the other trader observes because of the noise generated by the unobserved fundamentals. Given an environment where prices are determined by two traders with different information sets, the authors ask what kind of inferential errors could result if an econometrician outside the model interprets the realizations of prices and fundamentals. Asset prices appear to be too volatile relative to their fundamentals to the econometrician. Excess returns appear predictable. Cross-equation restrictions tests produced by the Rational Expectations Hypothesis would be rejected. These rejections have been interpreted as evidence of stochastic discount factors in the past, but this model shows heterogenous beliefs yield the same result.

Among conference participants, some discussion arose over the interpretation of the exogenous shock processes driving the asset price behavior. Kasa explained that the observed fundamentals which are subject to these shocks are the model's version of dividends. The shock process driving their evolution is not the only way to generate heterogenous beliefs. Later, when the asset price variance generated by the heterogenous beliefs model was compared to a benchmark perfect foresight case, one participant wondered why this environment was the benchmark for comparison. Kasa elaborated that the perfect foresight benchmark gives the theoretical upper bound on variance. The variance of price data violate this upper bound, leading to rejections of present value models in the past. The authors show that the variance produced in their heterogenous beliefs model also violates the theoretical upper bound obtained from the perfect foresight case.

Financial Instability via Adaptive Learning

by Noah Williams

The recent financial crisis and the subsequent recession have reinvigorated interest in theories that generate financial market fluctuations. One such theory has received a lot of attention from the popular press – Hyman Minsky's "financial instability hypothesis." In his paper, Williams uses a model of adaptive learning to formalize this hypothesis. Minsky hypothesized that most conservatively financed projects succeed in an expanding economy. This success leads investors to lower risk premia and increase leverage, causing a boom in debt financed investment and asset prices. The increase in debt results in growth of speculative finance. High levels of debt are sustainable until a sizable fraction of investments fail. After such an occurrence, investors withdraw their funds and asset prices rapidly collapse. Despite its intuitive appeal, Minsky's theory has not been formalized.

Williams considers a standard Lucas-type economy with two assets – a risk free bond with a fixed rate of return, and a risky stock whose supply is bound above by one. The rational expectations equilibrium of the model economy is such that agents do not borrow or lend in equilibrium. Thus, debt dynamics do not influence stock prices in a rational expectations equilibrium. Following the presentation, a conference participant asked if the number of Lucas trees in the model was ever less than one. Williams replied that the number of trees in the model is usually one; however, in some time periods, the representative agent's demand for trees is less than one. In such periods, the government buys the leftover trees.

Williams generalizes the benchmark economy by allowing agents to have fixed but arbitrary beliefs regarding the mean and the standard deviation of the dividend process for the stock. Debt levels influence equilibrium stock prices in this model economy, provided agents' beliefs are different from rational expectation beliefs. In particular, debt dynamics in this economy can lead to oscillatory stock prices: the economy is in equilibrium until debt levels are so high that dividends cannot adequately cover debt payments. Once debt crosses this threshold, stock prices collapse. A conference participant asked if the oscillatory behavior would continue forever. Williams replied in the affirmative. Another participant asked if the rational expectations equilibrium would be the unique self-confirming equilibrium in economies where interest rates adjust, so as to clear the bond market. Williams replied in the affirmative, and added that the rational expectations equilibrium is the unique self-confirming equilibrium even with open markets.

Finally, Williams analyzes an economy in which agents update their beliefs after observing realized returns. The equilibrium in this economy converges to the self-confirming equilibrium if agents weigh all observations equally. However, if agents put more weight on recent observations, then the economy goes through cycles in which debt run-ups are followed by stock price collapses. A conference participant speculated that an endogenous risk free rate would change the model's outcome, and Williams agreed.

Ambiguous Business Cycles

by Cosmin Ilut and Martin Schneider

In their paper, Ilut and Schneider study a model with shocks to uncertainty as the driver of the business cycle. Recent theoretical work in this vein have modeled these types of shocks as shocks to risk (i.e. stochastic volatility). The authors' paper considers uncertainty regarding both risk and ambiguity. In a setting with ambiguity, agents have uncertainty over the true probability assignment of a random variable. Shocks to ambiguity, then, are shocks to an agent's confidence in a probability assignment. A benefit of modeling shocks to ambiguity instead of modeling shocks to risk is that this method avoids the infinite regress problem of having to model higher order beliefs. Ambiguity shocks in the model are represented as shocks to conditional means, resulting in the forecast problem of the agents being linear in state variables.

At the conference, Schneider highlighted the key properties of an environment in which there are shocks to ambiguity

using a simple DSGE model. In the authors' model, agents have ambiguity toward the mean of a random productivity process. The level of ambiguity is parametrized by the mass of the set of possible means for the process. A confidence shock, then, is a shock to the size of this set of means. If the set increases upon the realization of a shock, it is viewed as an increase in the level of ambiguity, and vice-versa.

Agents in the model are averse to ambiguity. Specifically, Ilut and Schneider use recursive multiple priors preferences, as in Gilboa and Schmeidler (1989), in which agents act as if they evaluate plans using the worst case probability assignment. As a result, the economy studied is essentially linear because the worst case mean can be written as a linear function of state variables. This result allows the equilibrium to be characterized by linear approximations. There is no need to rely on higher order belief dynamics, as is standard in the literature on news shocks. The dynamics of the economy, however, are similar. Upon calibration of the model, a negative confidence shock can generate a concurrent decline in consumption, investment and hours worked. Additionally, there arises counter-cyclical premia on uncertain assets.

A conference participant asked why the underlying set parametrizing ambiguity never shrank to zero; or in other words, why the agents in the model were not getting more confident about the true mean of the productivity shock. Schneider related that idea to the behavior of news shocks in which news is, on average, realized in the future. A shock to ambiguity does not have to be correlated with events in the future, and so there is no learning necessarily taking place.

Man-Bites-Dog Driven Business Cycles

by Kristoffer P. Nimark

In news-driven models of the business cycle, fluctuations arise due to changes in expectations about underlying fundamentals – productivity for example. These changes are spurred by receiving signals, or news, about these fundamentals. In his paper, Nimark explores the implications of a particular characteristic of news – that these signals are more likely to be about unusual or rare events. As the title suggests, a story about a man biting a dog is much more likely to make headlines than one in which a dog bites a man. Nimark uses this characteristic of news to understand three features of business cycles: the existence of large changes in macro aggregates without correspondingly large changes in fundamentals, persistent periods of increased volatility, and the positive correlation between the volatility of macro aggregates and the cross-sectional dispersion of forecasts.

Nimark develops a model of business cycles in the style of Lorenzoni (2009) in which cycles are driven by shocks to expectations about aggregate productivity. The model is populated by a continuum of islands that are heterogeneous in productivity. Each island consumes only a fraction of the total available goods and sells its goods to a fraction of other islands. Agents on an island receive both private and public signals about aggregate productivity. Public signals are signals whose availability is positively correlated with tail events, termed man-bites-dog signals. Signals whose availability is uncorrelated with the underlying latent variable act to reduce uncertainty; however, with man-bites-dog signals, uncertainty can in fact be increased after the signal is received. Secondly, on average, agents' expectations of the latent variable respond more strongly to a deviation in that variable when man-bites-dog signals are available than when they are not. These two characteristics are the primary mechanism in creating the persistency of macroeconomic volatility and the link between large changes in aggregate variables without large changes in fundamentals. Nimark shows these results by developing and solving a Bayesian filtering problem where man-bites-dog signals are present.

The model is not capable of being solved by standard linear rational expectations methods. Since there is private information about common variables of interest, agents are concerned with forecasting the forecasts of others. This leads to the common problem of infinite regress as noted in Townsend (1983) and others. Secondly, the precision of agents' information is dependent on the realized history of the latent variable and is therefore time-varying. Nimark develops an algorithm that is capable of handling both infinite regress and a time-varying information structure. The algorithm places a structure on higher-order expectations and uses the property in rational expectations models that it is common knowledge that agents form model-consistent expectations.

The solved model is then estimated using standard likelihood methods. Nimark uses aggregate macro data including the federal funds rate, CPI inflation, and de-trended real GDP, as well as survey data on forecasts of CPI inflation and nominal GDP from the Survey of Professional Forecasters. The estimated model gives a potential explanation for the above-mentioned three business cycle facts. For example, during times that many man-bites-dog signals are received (man-bites-dog episodes) there can be large changes in macro aggregates without a proportional change in any fundamental. This result does not occur if the man-bites-dog structure is omitted. Finally, Nimark uses the estimated model to predict potential historical man-bites-dog episodes and finds strong evidence around recessionary periods. This result is of course expected since news reports about the economy are more frequent during these periods.

During the discussion period, questions arose regarding the underlying motivation about the nature of man-bites-dog signals. A conference participant suggested it may be important to more explicitly model the behavior of new agencies. Why should news agencies decide to report only unlikely events? It may be in their interest to behave differently.

Ambiguous Volatility, Possibility and Utility in Continuous Time

by Larry Epstein and Shaolin Ji

A growing body of literature has emphasized the importance of stochastic time-varying volatility in understanding features of asset returns, particularly in derivative markets. Evidence suggests these volatilities have complicated dynamics and lead to correspondingly complicated parametric laws of motion in standard models. Epstein and Ji question whether the agents in these standard models should ever become completely confident in one particular law of motion for volatility, or, rather, have some ambiguity over the set of all possible laws of motion. This paper takes the latter stance and develops a rich continuous-time utility framework that incorporates the decision maker's concern about ambiguity or model uncertainty (in particular over volatilities). The framework maintains the separation of key components: ambiguity, risk aversion, and intertemporal substitution.

To incorporate uncertainty about what is possible (i.e. model uncertainty), Epstein and Ji use a framework that has multiple priors forming a set of probability measures. This set need only be restricted by a few technical conditions, and importantly, the measures in the set do not need to be equivalent. Probabilistic equivalence implies that the measures must assign the same probability to null events, an assumption that has been common in previous literature modeling ambiguity but does not incorporate ambiguity about what is possible. To accurately capture model uncertainty, non-equivalence of prior measures is needed. This property is what separates Epstein and Ji's utility framework from other expected utility frameworks including Bayesian utility maximization.

The model presented at the conference focused on ambiguity about volatility. However, the paper presents a more general framework incorporating ambiguity about drift. The objective is to formulate a utility function over the domain of d-dimensional consumption processes. Therefore, the individual must form beliefs over these consumption processes. These individuals are assumed to know that the process is a martingale and has zero drift, however, they are not certain about the volatility or even the possible volatility intervals at each point in time. One possibility is that the consumption process follows a standard Brownian motion for all time periods, which induces one possible probability measure. However, this is only one possibility. For each possible volatility process, another probability measure is induced. This forms the set of priors in the utility specification. Again, these measures need not be equivalent and do not have to agree on null events.

A large part of the remaining technical details surround developing the notion of conditional expectation over the set of probability measures. The definition of utility follows in a recursive form that exhibits a weak form of dynamic consistency. Epstein and Ji show in an example of an endowment economy the comparison of standard capital asset pricing equations describing excess returns between a case with no ambiguity and the utility framework just introduced. Two key additions arise in the excess return equation in the authors' framework. First, due to the multiple priors setting, utility defined with the infimum takes into consideration the worst possible scenario. Second, with ambiguity, the CAPM equations must hold almost everywhere for every probability measure in the set of priors. If the set of priors is large and dispersed, this gives stronger restrictions on the model, implying more discipline.

In response to the capital asset pricing equations a conference participant asked how to relate these implications to observables in the data. Epstein responded that there was still more work to be done on how to explicitly use this extra discipline, but remains hopeful in the model's ability to do so.

De-Regulating Markets for Financial Information

by Pablo Kurlat and Laura Veldkamp

Before the Dodd-Frank Act of 2010, if issuers of non-junk debt wished to sell, they were obligated by the SEC to pay a ratings agency to rate the asset. In the absence of an asset rating, pension funds and banks were legally not allowed to purchase the asset. One provision of the Dodd-Frank act required the SEC to abolish any mention of ratings requirements. The market for information was effectively deregulated. A common argument for the provision was that if the ratings contained valuable information, then the issuer and/or buyer would nevertheless choose to pay for it. In others words, a private market would fill in the necessary gaps left from deregulation. In their paper, Kurlat and Veldkamp examine this argument.

The goal of the paper is to answer three main questions about the effect of the Dodd-Frank provision: Under what conditions would a private market (either investor- or buyer-driven) surface? How would asset prices and information flow change? and finally, Under what conditions would welfare increase? To address these questions, the authors consider an equilibrium model of portfolio choice, costly information acquisition, and real investment. A risk-neutral entrepreneur makes a risky real investment decision in time period zero that has an uncertain payoff in time period two. There is a continuum of risk-neutral investors that can purchase the risky asset in time period one in a Walrasian auction. The paper takes no stance on the quality or bias in ratings, and simply models a rating as an unbiased signal of future returns. Ratings agencies are perfectly competitive and can supply ratings to either the entrepreneur or to investors. If the entrepreneur buys the rating, the signal is revealed to all investors simultaneously. However, if the entrepreneur forgoes the rating, investors can individually purchase it with no option to resell on sub-markets. Investors have rational expectations about the investment decision of the entrepreneur. Therefore, those investors

who choose to stay uninformed can still determine the informativeness of the equilibrium price about the decisions of other investors. In essence, investors are not blind to taking in all information possible in the environment. This aspect of behavior will have important implications for the results

The results point to some interesting consequences of ratings provision. In the equilibrium with no ratings requirements, investors will choose to purchase ratings only if the informativeness of the ratings is neither too high nor too low. If ratings are not very informative, then the reduction in uncertainty simply isn't worth the cost of the rating. More surprisingly, if ratings are very informative, those investors who become informed take large positions in the asset. This increases the informativeness of the asset's price about its payoff, therefore decreasing the need to buy ratings. If the demand for ratings is sufficiently low, there exists no price at which ratings agencies choose to supply, and the investor-driven information market collapses. Additionally, the entrepreneur will only choose to buy a rating and supply it to investors as long as the informativeness of the rating is not too low, the agency's fixed cost is not too high, and his own prior belief about the asset's payout is not very precise. Since a rating supplied by the entrepreneur is seen by all investors, a more accurate rating will always raise the price of the asset and in turn raise the expected return to the entrepreneur. In the end, no private market for information will exist if ratings precision is too low or it is too costly to create.

The paper's authors then study the effect of ratings deregulation on asset prices and welfare. They find that asset prices will be higher under mandatory ratings only for assets that have a medium-sized investor base. If the investor base is too low, entrepreneurs will choose to have their asset rated and so the price will not change. If the investor base is very high, then a large number of investors will choose to buy the ratings and the price will converge to that resulting from mandatory ratings. Only for medium-sized investor assets will neither effect hold, and asset prices will decrease as a result of a lower amount of information traded. To evaluate the welfare implications of ratings requirements, the authors are somewhat open-ended. Entrepreneurs would always weakly prefer not to have ratings requirements because they could always choose to buy the ratings in the private market. In terms of investor welfare, the authors find that if information is relatively cheap to produce, investors will be better off ex ante with mandatory ratings. The reason behind this somewhat counter-intuitive result is that when information is cheap, then many investors will choose to become informed, leaving an individual investor the choice between buying the rating with little competitive advantage or competing with a large pool of better informed investors. In the end, they would rather receive the information for free.

Discussion centered around a participant's question as to why the paper only considers equity contracts. If only certain investors choose to become informed, there exists asymmetric information. This asymmetry potentially violates the Modigliani-Miller theorem that the entrepreneur's capital structure is irrelevant. It could be important to include a debt as a possible financing avenue. Another participant asked why investors were not able to choose the precision of the rating. Veldkamp responded that if investors were able to choose the quality of the signal, it would not capture the nature of an information market in which information is costly to acquire but cheap to replicate. The replication of a piece of information should contain the same quality.

Robustifying the Permanent Income Model with Rational Inattention

by Yulei Luo and Eric Young

Two classes of linear-quadratic permanent income models that generate precautionary savings are robust control problems as introduced in Hansen and Sargent (1995, 2007), and risk-sensitive control problems as introduced in Hansen and Sargent (1995) and Hansen, Sargent, and Tallarini (1999). Robust control problems introduce the notion that agents have a concern for model misspecification and therefore want decision rules that are insensitive to these mistakes. This insensitivity is the primary mechanism leading to precautionary savings. In risk-sensitive control problems, agents have preferences that increase their effective risk aversion by over-weighting negative outcomes. Again, it is this sensitivity that leads to precautionary savings. In their paper, Luo and Young explore and compare the implications between models of robustness and risk-sensitivity under an additional limited information-processing constraint, rational inattention.

Rational inattention introduces two important features into permanent income models: slow adjustment to shocks and endogenous noise. Under rational inattention, agents do not have the capacity to process all of the available information and therefore receive a constant and noisy flow of information. This leads to agents having to adjust their optimal plans gradually and with errors. Rational inattention leads to state uncertainty, where robustness and risk-sensitivity are concerned with model uncertainty. The primary goal of this paper is to explore the interaction between state and model uncertainty and how they respectively affect individual decisions and welfare. A secondary concern is to analyze the observational equivalence result between robustness and risk-sensitivity established in Hansen, Sargent, and Tallarini (1999).

The environment is a standard permanent income model where households solve a dynamic consumption-savings problem given a stochastic income process. Without any information processing constraint, consumption is determined by permanent income and under standard assumptions leads to consumption following a random walk. Under the assumption that agents have a finite information

processing ability, consumption still relies on permanent income but now also depends on agents' filtering problems. Luo and Young consider two types of robustness to add to the rational inattention-permanent income model, referring to them as type I and type II robustness. Under type I robustness, agents have concerns about the disturbances to the perceived state. Under type II, agents have concerns about the gain from their filtering problem. The two types of robustness have opposing effects on the marginal propensity to consume and on precautionary savings. Under type I, an increase in the preference for robustness leads to a lower marginal propensity to consume and therefore lower precautionary savings. Type II robustness has the opposite effect. Finally, Luo and Young introduce risk-sensitivity into the rational inattention permanent income model. Under certain conditions, the observational equivalence between robustness and risk-sensitive models still holds with rational inattention. However, a continuous and linear observational equivalence condition does not exist.

At the end of the talk, a conference participant suggested that it could be possible to use the observational equivalence implications between robustness and risk sensitivity under rational inattention as a way of disciplining calibration of the degree of inattention which has proven difficult in the past. Luo agreed, and said the authors hope to use the method of error detection probabilities, which is useful in calibrating robustness models, as a way of calibrating both robustness and inattention parameters.

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Information Equilibria in Dynamic Economies

by Giacomo Rondina and Todd B. Walker

Rondina and Walker study general dynamic rational expectations equilibria in competitive markets where agents have incomplete information. These agents have access to two sources of information – exogenous and endogenous – and form beliefs about both sources. In a rational expectations framework, agents face the problem of forming higher order beliefs or forecasting the forecasts of others. The common challenge faced in previous literature has been to characterize dynamic equilibria in this setting. Higher order beliefs make the typical recursive state formulation approach difficult because the state space might be infinitely dimensional. The authors' goal is to develop general existence and uniqueness conditions for a new characterization of equilibria with asymmetric information using an approach that does not require the specification of a state representation.

In order to avoid a state representation of dynamic variables, the paper relies heavily on non-fundamental moving average (NFMA) representations. As first demonstrated in Futia (1981), the benefit of using NFMA representations in constructing dynamic models is that these representations maintain asymmetric information in equilibrium. As in standard dynamic representative agent problems, Rondina's and Walker's solution strategy requires agents to solve a signal extraction problem. The NFMA approach yields an optimal signal extraction formula that is informationally equivalent to the standard signal extraction problem used in state space representations where agents receive a signal plus noise, however, the dynamics under the NFMA representations are markedly different. The NFMA representation leads to additional information frictions that do not occur in the standard framework. A conference participant pointed out that even though the two problems lead to informationally equivalent signals, the problems themselves are very different. There could, in fact, be other more complicated signals whose information content was the same as the traditional signal plus noise and whose dynamics are still different. Walker agreed, but pointed out that the authors' main concern was to show that an agent would be indifferent between receiving either of these two signals, but the NFMA representation added a layer of information frictions to the standard case.

Rondina and Walker use a generalized linear rational expectations model in which prices are a discounted linear function of agent's predictions of prices in the future plus a Gaussian shock process. The information structure is general and permits two sources of information – exogenous and endogenous. The equilibrium characterization is termed an information equilibria which can be summarized by two conditions: given a distribution of information sets, there exists a market clearing price determined by each agent's optimal prediction, and given a price process, there exists a distribution of information sets generated by the price process that is the basis for optimal prediction. The solution procedure consists of solving for a fixed-point condition in the information sets of the agents. To do this, Rondina and Walker use the analytic function approach as discussed in Futia (1981) and others. The benefit of this approach is the invertibility of an analytic function gives a precise mapping between observables and the shock process. The authors prove the existence of informational equilibria under both a symmetric and asymmetric information structure. The inclusion that agents have knowledge of the model is key in overturning Futia's (1981) non-existence result.

A conference participant asked exactly how Futia's (1981) results are overturned. Walker clarified that by not including knowledge of the model into an agent's information set, Futia gets a non-existence using his equilibrium concept. Walker argues that an equilibrium in information must include knowledge of the model, which leads to their result that there always exists an equilibrium.

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Heterogeneous Information and Labor Market Fluctuations

by Vaidyanathan Venkateswaran

A well-discussed puzzle in labor market models with search frictions is their failure to generate enough volatility in employment and other labor market variables over the cycle as compared to that observed in data (Shimer 2005). Several mechanisms have been proposed in the literature to resolve this puzzle, including slow wage adjustments, fixed costs of hiring, and alternative calibration strategies. In his paper, Venkateswaran introduces a new mechanism through information frictions that can account for much of the discrepancy between the standard model and the data.

In the standard search and matching model, the primary reason that employment does not respond as much as expected to aggregate productivity shocks is general equilibrium effects. For instance, a positive shock to aggregate productivity leads to increases in labor market tightness, or a lower probability that an individual firm will be matched to a worker. A positive shock also leads to higher wages which are costly to the firm. Both of these general equilibrium effects dampen an individual firm's incentive to hire, and lead to low volatility of employment over the cycle. This is in contrast to idiosyncratic firm-level shocks, which do not affect aggregate conditions or wages. As a result, a firm will respond more to an idiosyncratic shock than to an aggregate one. Venkateswaran introduces an informational friction in which firms cannot completely disentangle aggregate shocks from idiosyncratic ones. With Bayesian updating, firms mistakenly attribute aggregate shocks to idiosyncratic factors which increases their responsiveness.

Venkateswaran uses a search and matching model that is closely related to those used analyzing the employment volatility puzzle. Firms face uncertainty along two dimensions, aggregate and idiosyncratic, but only observe one productivity variable that is the sum of the two. Their task is to correctly disentangle aggregate shocks from idiosyncratic ones. Firms are only confused for a number of exogenous periods until full (lagged) information is revealed. This captures the notion that firms, over time, can accurately know aggregate shocks from equilibrium observables (i.e. asset prices). Venkateswaran solves for a rational expectations equilibrium in the neighborhood of a deterministic steady state using two different characterizations of wage determination: first, by assuming that wages are determined by a period-by-period Nash bargaining solution, and secondly, by assuming a direct relationship between wages and aggregate and idiosyncratic information. The latter allows for additional learning about aggregate conditions through wages.

Venkateswaran calibrates the model and compares it to a full information case. The results show that under heterogeneous information, learning about an aggregate productivity shock occurs slowly. Firms partially attribute the aggregate shock to an idiosyncratic one. Idiosyncratic shocks are more persistent and do not have an effect on aggregate labor market variables. Both employment and labor market tightness increase an order of magnitude more than they would under full information. Output is also more responsive due to the confusion.

A conference participant asked about the nature of the information structure assumed, specifically that firms receive one signal and cannot disentangle it perfectly into two components, compared to a case in which a firm just received two noisy signals about both aggregate and idiosyncratic productivity. Venkateswaran pointed out that under the latter, information-structure firms' responses would be dampened and delayed. Here the result is the opposite. Firms over-respond, which leads to higher volatility in employment.

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