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FROM THE LAB

UC Santa Barbara | Laboratory for Aggregate Economics and Finance

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Director's Message

Finn Kydland

Carmen Earle has relocated to San Diego. Carmen had been our business manager since the inception of LAEF in 2005. As those of you know who have attended one or more of the three dozen conferences we have put on, Carmen was the one who always made everything work smoothly. We can't thank her enough for her cheerfulness and attention to detail.

Fortunately, we have a great replacement, Laurie Preston, who comes to us directly from the Department of Economics. From her previous position there she knows the university in and out, and she's excited to take on this new challenge. We're lucky to have her be the one to take over from Carmen.

This issue of "From the Lab" provides summaries of the proceedings of two conferences. One was organized by LAEF in Santa Barbara and was titled "Ambiguity and Robustness in Economics." Economists, mathematicians, cognitive psychologists and other researchers have developed theories about how people make decisions when faced with uncertainty, i.e., something they do not understand completely and which also may be in conflict with what they believe to be the case. Consider, for example, the situation where you have no news and do not know the probability for rain to occur today. Should you go out without your umbrella and risk getting wet? An individual with low tolerance for ambiguity may react by taking into account the worst possible state that can occur, i.e., what will happen if she goes out without an umbrella. In economics and finance a key issue is how individuals negotiate the terms of a contract in ambiguous situations. They would like to write incentive compatible and efficient contracts. Can this be done? Can ambiguity prevent an individual from being cheated in a contract, making ambiguity intolerance beneficial? What about a government or firm that makes decisions about the future of the economy or the firm? Should the decision maker adopt risky policies that could lead to bankruptcy or should the decision maker hedge against the worst possible state that can occur to avoid bankruptcy?

Related to such questions, there is a new stream of thought in asymmetric information economics based on non-expected utility theory (ambiguity/robustness). When we deal with uncertainty, the choice of Expected Utility plays an important role. Even with the same primitives in an economy, if one computes a certain equilibrium concept with different Expected Utilities (which means a different functional form, as different expected utilities provide alternative functional forms) one will get different results. But then, which formulation of Expected Utility is better? Can one compare Expected Utilities, and on what criteria?

Such questions have led economists to adopt ideas from statistics/mathematics, e.g., robust optimization, robust control, robust contracts, robust implementation, ambiguity, etc. The objective of the conference was to bring together researchers on the above topics to find out what has been achieved, explore common grounds, see where the new path is leading, and perhaps raise further questions. The conference was organized by Nicholas Yannelis, University of Iowa.

As faithful readers of "From the Lab" will have gathered, LAEF is open to co-operation with other universities and institutions. The most extensive example is the sequence of annual conferences – five so far – on Advances in Macro-Finance in co-operation with the Tepper School of Business at Carnegie Mellon University. In this issue, we report on the first conference organized abroad in co-operation with

a foreign university, Koc University in Istanbul, along with its research institutes ERF and TUSIAD. The initiative was taken in large part by Sumru Altug, who has also been a two-time visitor to LAEF. In the organization of the conference, she was subsequently joined by Sumru Oz.

This conference aimed to discuss policy choices in the aftermath of the Great Recession. It examined the issues from the perspectives of both developed and emerging economies. From the viewpoint of developed economies, the conference discussed the implications of forward guidance in monetary policy as well as fiscal policy issues. It injected, also, an historical and institutionalist perspective in the policy discussion by examining the implications of cultural differences in the EU as well as the historical experience of financial crises. Finally, the conference provided empirical evidence regarding key policy choices facing emerging economies in terms of the effects of capital controls and the derivation of an index of financial conditions. In attendance were academics, business economists as well as practitioners from policy institutions such as the Central Bank of the Republic of Turkey, the Istanbul Bourse, and others.

This conference in Istanbul is one of many international activities in the academic year 2014-15. Each year, both LAEF's Associate Director, Peter Rupert, and I give several public speeches. There's a certain division of labor in that Peter gives most of the domestic ones, many in California, while I spend more time internationally. Below is a list of my international activities during the academic year 2014-15.

KEYNOTE SPEECHES AND PUBLIC LECTURES

July 4: SUMA Colombian Scientific Convention, Cartagena

July 9: Public Lecture (along with Timothy Kehoe, University of Minnesota), Afundación y la Zona Franca, Vigo, reported on in several Spanish newspapers

Oct. 2-3: IV Baku International Humanitarian Forum, Azerbaijan

Nov. 4: Public Lecture, Jamnanal Bajaj Institute of Management, Mumbai (organized by Nobel Media, Stockholm)

Nov. 6: Public Lecture, Savitribai Phule Pune University, Pune (organized by Nobel Media, Stockholm); according to the university, broadcast to up to 200,000 students all over India!

April 6: Public Lecture, Dean's Lecture Series, Carnegie Mellon University Qatar, Doha

April 20: Public Lecture, Comenius University, Bratislava

April 21: Workshop at School of Mathematics and Physics, Comenius University, Bratislava

April 23: Public Lecture, CERGE-EI, Prague

May 21-22: VIII Astana Economic Forum, Kazakhstan

June 24: Public Lecture, Narodowy Bank Polski (Central Bank of Poland), Warzaw

PANELS AND COMMITTEES

Sep.-March: Post 2015 Consensus, Copenhagen Consensus Center (CCC), to rank UN goals to 2030 (outcome of ranking commented on in magazines and newspapers all over the world)

Feb.-March: Oslo Business for Peace Prize, member of selection committee; decision meeting in London

June 1: Premios Jaime I (prestigious Spanish Prize), member of committee for Economics; selection meeting in Valencia

EDUCATIONAL ACTIVITIES OF NOTE

July 8-10: XIX Workshop on Dynamic Macroeconomics, Vigo, Spain (opportunity for PhD students and beginning assistant professors from Europe and the United States to present their research in front of five seasoned professors)

Aug. 19-22: 5th Lindau Meeting on Economic Science, organized by the Bernadotte family (relatives of King of Sweden) as a forum for talks by Economics Nobel Laureates and interaction between them and 2-300 doctoral students from all over the world

Perhaps the most interesting of these was the Copenhagen Consensus Center's panel to evaluate the new UN goals. Under the leadership of CCC's head, Bjørn Lomborg, during a period of several months, the panel, consisting of Tom Schelling, Nancy Stokey, and me, evaluated the analyses of the initially proposed 169 goals by assigned experts in the different areas to which the goals belonged. After the end of that entire process, here's the op-ed CCC submitted in April to a few newspapers all over the world. (I didn't keep track of who actually took it, although I did see that some did.)

SMART DEVELOPMENT GOALS

By Finn Kydland, Bjorn Lomborg, Tom Schelling and Nancy Stokey

By September, the world's 193 governments will meet in New York and agree on a set of ambitious, global targets for 2030. Over the next 15 years these targets will direct the $2.5 trillion to be spent on development assistance, as well as countless trillions in national budgets

Based on peer-reviewed analyses from 82 of the world's top economists and 44 sector experts organized by the Copenhagen Consensus, three of us – Finn, Tom and Nancy – have prioritized more than a hundred of the proposed targets in terms of their value-for-money. They are certainly not all equal. Some targets generate much higher economic, social and environmental benefits than others, per dollar spent.

The natural political inclination is to promise all good things to everyone, and the UN is currently poised to pick 169 well-intentioned targets. But the evidence at hand, although limited, indicates pretty clearly that some of these targets are much more promising than others. The analyses of the experts suggest that some of the targets are barely worthwhile, producing only a little more than $1 in social benefits per dollar spent, while others produce much higher social returns.

We have selected the 19 targets that we expect to produce the greatest benefits. The expert analyses suggest that if the UN concentrates on these top 19 targets, it can get $20 to $40 in social benefits per dollar spent, while allocating it evenly across all 169 targets would reduce the figure to less than $10. Being smart about spending could be better than doubling or quadrupling the aid budget. Our short list covers a lot of ground, but the thread that connects the individual targets is the benefits they will provide for people around the world in terms of health, the environment, and economic well-being, the three headings the UN has dubbed "people, planet and prosperity."

Consider a couple of targets that help people directly through health benefits. Tuberculosis (TB) is a 'hidden' disease. Over two billion people carry the bacterium that causes it, about 10% of those people will develop TB at some point, and about 1.5 million people each year die from TB. But treatment is inexpensive and, in most cases, highly effective. Spending a dollar on diagnosis and treatment is a low-cost way to give many more years of productive life to many people. Ebola may get the headlines, but TB is a much bigger problem.

People

Lower chronic child malnutrition by 40%

Halve malaria infection

Reduce tuberculosis deaths by 90%

Limit new HIV infection by 50%

Cut early death from chronic diseases by 1/3

Reduce newborn mortality by 70%

Increase immunization to reduce child deaths by 25%

Make family planning available to everyone

Eliminate violence against women and girls

Planet

Phase out fossil fuel subsidies

Halve coral reef loss

Tax pollution damage from energy

Cut indoor air pollution by 20%

Prosperity

Reduce trade restrictions (full Doha)

Improve gender equality in ownership, business and politics

Boost agricultural yield increase by 40%

Increase girls' education by x years

Achieve universal primary education in sub-Saharan Africa

Triple preschool in sub-Saharan Africa

Reducing childhood malnutrition is another excellent target. People of every age deserve to be well nourished, but nutrition is especially critical for young children. A good diet allows their brains and muscles to develop better, producing life-long benefits. Well-nourished children stay in school longer, learn more and end up being much more productive members of society. The available evidence suggests that providing better nutrition for 68 million children each year would produce over $40 in long-term social benefits for every dollar spent.

There are excellent targets involving the planet as well. Governments around the world still subsidize the use of fossil fuels to the tune of over $500bn each year. Cutting these subsidies would reduce pollution and free up resources for investments in health, education, and infrastructure. Protecting coral reefs turns out to be a surprisingly efficient target as well. There are benefits in terms of biodiversity, but healthy reefs also produce more tangible and immediate benefits. They increase fish stocks---benefitting both fishermen and consumers, and attract visitors who explore their beauties---benefitting everyone working in the tourist industry, as well as the tourists themselves.

Perhaps the most important, over-arching problem facing the world is poverty, which still afflicts billions of people. Poverty is the ultimate source of many other problems. Poor families have trouble providing their children with adequate food, education, and medical care. The immediate result is high rates of infant mortality, as well as poor cognitive skills and reduced productive capacity among surviving children. The ultimate result is a cycle of poverty.

Better nutrition and better schools will help alleviate poverty, but there is another target that promises to be even more effective: lowering barriers to international trade. The historical evidence on this point is compelling. In China, South Korea, India, Chile and many other countries, reducing trade restrictions has lifted incomes and reduced poverty, and triggered decades of rapid income growth. Poverty reduction was the first item in UN's list of Millennium Development Goals, and the numerical target was achieved. Why? Income growth in China was a big part of the story. And how did the Chinese achieve that remarkable feat? Most evidence suggests that international trade was a key ingredient. Trade produces immediate benefits by opening up markets, but it also facilitates the flow of ideas and technologies, producing even greater benefits over a longer horizon. A successful Doha free trade agreement could lift 160 million people out of extreme poverty.

Our list of targets will not solve all the world's problems, but neither can any list under realistic budgets. Our list can help the UN make its choices like a savvy shopper with limited funds. Choosing good targets will vastly increase the benefits to people around the world, as well as generations to come. Governments should forgo the instant gratification of promising everything to everyone, and instead focus on choosing smart development goals.

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Policy Analysis in the Post Great Recession Era

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Labor Market Upheaval, Default Regulations, and Consumer Debt

Kartik Athreya, Juan Sanchez, Xuan Tam, and Eric Young

The consumer credit market experienced a sharp and rapid transition during the Great Recession. First, average household debt-to-income reversed a nearly three decade upward trend, falling to levels not seen since the mid-1990s. Second, households defaulted on debt at unprecedented levels. A majority of default during this period occurred in the form of "informal" delinquency instead of "formal" bankruptcy, marking a distinct change in the behavior of default in previous recessions.

In this paper, Athreya, Sanchez, Tam, and Young investigate the causes of the rapid deleveraging and increase in delinquencies. They point to two main features of the Great Recession and time period immediately before: (1) an increase in labor market risk during the downturn and (2) new default regulations entailed in the Bankruptcy Abuse Prevention and Consumer Protection Act (BAPCPA), enacted in 2005. The BAPCPA lowered the relative cost of delinquency and bankruptcy in favor of delinquency. They develop a life-cycle, incomplete markets model in which households face idiosyncratic risk in both wages and employment opportunities. Households are able to partially insure against these risks through saving, risk-free or borrowing. Households are given three options regarding the repayment of debt. They may repay the loan entirely and remain solvent, they may choose to repudiate all debt through formal bankruptcy and incur a transaction cost, or they may choose not to repay the loan and go delinquent. Delinquency also entails paying a transaction cost, but in turn it allows the household to renegotiate the terms of the loan.

The value of using delinquency to renegotiate the terms of the loan is dependent on the current labor market state. Households with better labor market prospects (i.e. a high match-specific quality) find bankruptcy a better option than delinquency, as households that renegotiate with lower debt tend to face a penalty while households with higher debt receive a form of debt forgiveness. Further, the amount of debt forgiven rises as a household's labor market shock gets worse. Households with worse labor market prospects get better deals out of delinquency.

The model is calibrated to the United States in 2004, pre-BAPCPA. The calibration targets include the rate of job flows, the standard deviation of employment and wage shocks, and features of the unemployment insurance and disability system as in Low, Meghir, and Pistaferri (2010). The calibration generates a substantially larger utility cost associated with bankruptcy than for delinquency: 2% versus 0.12% of quarterly consumption, respectively. The main implication, then, is that the BAPCPA most likely prevented a substantial increase in bankruptcy filings but only had a small effect on delinquencies.

References:

1. Low, H., Meghir, C., and Pistaferri, L., (2010). "Wage risk and employment risk over the life cycle," American Economic Review 100(4), 1432-67. ◆

Quantitative Easing in Joseph's Egypt with Keynesian Producers

Jeffrey Campbell

Liquidity trap models (i.e. Krugman, 1998; Eggertsson and Woodford, 2003) consider macroeconomic outcomes in which there is an unexpected increase in households' desired saving that creates downward pressure in interest rates. If this downward pressure is strong enough, the zero lower bound makes monetary policy restrictively tight, causing a recession. In this paper, Jeffrey Campbell, analyzes the role of households' access to a frictionless storage technology in mitigating the liquidity trap. The title of the paper comes from a biblical story in Genesis in which Joseph suggested that harvest yields in good times should be partially stored and used to prevent famine in bad times. The key question is: will giving households access to a store of value outside bond markets mitigate liquidity traps?

The model is New Keynesian in nature and features monopolistically competitive firms, nominal rigidities, and a market for nominal bonds with an interest rate set by a policy authority subject to the zero lower bound. Feasts and famines, as in the biblical example, are modeled as an expected shock to labor productivity in which the first year of the model is a feast and every following year is a famine. Therefore the key policy functions need to explain what occurs in the initial time period. Finally, agents are given access to a storage technology that could be potentially costly. In addition to setting the nominal rate of interest, the policy authority can also issue nominal bonds and invest the proceeds in the storage technology. This type of transaction is interpreted as a form of quantitative easing.

The introduction of storage introduces a potential for multiplicity into the standard model. Without storage, given a fixed real interest rate, the household's Euler equation determines current and future consumption through optimal bond purchases. With storage, however, future consumption is a free variable and can be consistent with a set of firms' price

setting decisions. For instance, if firms expect deflation, they choose low prices. This lowers real aggregate consumption and marginal costs and thereby confirms their expectations. This multiplicity exists with many choices for the nominal rate because the return on storage naturally bounds the real interest rate from below. Multiplicity in this setting generates a role of policy to increase savings in the economy's initial period and thereby increase future consumption. This policy eliminates equilibria that generate confidence recessions, or those with low consumption and investment, thereby improving macroeconomic outcomes. ◆

Sovereigns versus Banks: Credit, Crises, and Consequences

Oscar Jorda, Moritz Shularick, and Alan Taylor

Financial crises are often associated with elevated levels of debt and leverage. However, what is less understood is whether public or private debt poses a greater risk to financial stability. This paper takes a first step in answering this question by establishing a set of empirical regularities on the relationship between macroeconomic variables and private and public debt. The authors develop a long-run annual panel dataset that covers the years 1870-2011 for 17 advanced economies.

They find that total debt outstanding has risen across the developed world since the late 1970s. The majority of the recent increase, however, has come from the private sector. Public debt levels spiked during World War II but rapidly declined until the late 1970s, increasing since. Private debt levels, however, began increasing globally in the early 1950s and have risen almost monotonically. At its peak, private debt to GDP was above 120%.

Which type of debt has been historically correlated with financial instability? The authors show that financial crises tend to have their roots in private debt markets and not in fiscal positions. Private credit booms predict financial crises better than increases in sovereign debt. This result is robust to a country's GDP growth rate or financial crises in pre- versus post-World War II times.

The authors then analyze the business cycle properties of public and private debt and discuss several regularities that emerge. They find that expansions have become longer in duration over the 140 year period examined and real GDP growth over the typical expansion has declined, peaking at 5.5% (annually) before World War II and currently at 2.7% (annually). In terms of debt, the authors find that private bank lending is pro-cyclical, while public debt tends to be counter-cyclical, growing faster in recessions than expansions. Total debt (private and public) has grown at an unprecedented rate in the past four decades. The annual growth rate of total liabilities has average 8.5% (annually) in expansions and 4.0% (annually) in recessions. Finally, relating GDP growth to debt growth, they find that in financial crises preceded by a credit boom, output tends to fall by more and recover more slowly than in other financial crises. When public debt levels are high, these effects tend to be amplified. ◆

Fiscal Austerity Measures: Spending Cuts vs. Tax Increases

Gerhard Glomm, Juergen Jung, Chung Tran

How should a country faced with a mandate to impose fiscal austerity reduce its debt level? Are policies aimed at tax increases or spending reductions (or a combination of the two) more beneficial in terms of welfare? Do the welfare effects change over time or across the distribution? In this paper, Glomm et al. address these questions by developing an overlapping generations model with skill heterogeneity, private and public sector production, government expenditures with transfers, and government consumption and investment infrastructure.

The benchmark model economy is calibrated to Greece at the beginning of the 21st century in which they agreed to implement fiscal adjustments worth about 12.5% of 2009 GDP with a goal of reducing the deficit by 3% of GDP by 2014. First the authors demonstrate that a small increase in the interest rate due to a risk premium shock arising from underreported public debt leads to large macroeconomic and welfare effects in a small open economy with debt-to-GDP of Greece in 2010. Despite severe austerity measures, the recession persists.

The authors then consider the effects of several austerity reforms including increases of the value-added tax (VAT) rate from 21% to 23% as well as cuts to public sector wages, pensions and employment numbers. They find that all reforms result in immediate contractions but long-run expansions in aggregate output and consumption. Spending-based austerity measures increase steady state output over 5% while tax-based austerity measures lead to smaller increases of around 4.3%. In terms of welfare, both types of austerity measures result in welfare gains of almost 4% of pre-reform consumption in the new steady state but include welfare losses to generations along the transition path. Finally, they find that spending-based austerity reform is dominated by tax-based reform in terms of welfare effects in the short run. However, this result

is reversed in the long-run where spending-based austerity reform is dominant. Therefore, austerity measures that are mixed between tax- and spending-based result in the largest income and welfare effects. ◆

Are Capital Controls Prudential? An Empirical Investigation

Andres Fernandez, Alessandro Rebucci, and Martin Uribe

The authors of this paper discuss the use of capital controls in economies during business cycles. They note that the conventional view of capital controls is that restricted policies cause investors to be hesitant to move funds into a country. The reason is that investors may face difficulties in retrieving funds during recessions, subjecting them to additional risk. More recently, however, economists have suggested that "prudential" capital controls may be better for the economy. This means that during booms, capital inflows should be restricted in order to stop over-borrowing by citizens of the home economy. Likewise, during busts, outflows of capital should be restricted in order to decrease the severity of recessions in the presence of nominal rigidities. While this seems to be the suggested policy in academia, the authors note that many countries may not employ such policies. In order to assess whether these policies are in place, the authors use a dataset of capital controls and determine the cyclicality of these controls for inflows and outflows of capital during business cycles.

To determine whether or not economies have implemented prudential capital control policies, the authors employ a dataset from 1995-2009 (and expand it to 2011) that rates the restrictiveness of controls on inflows and outflows on a scale from 0 to 12, with 0 being the least restrictive and 12 being the most restrictive. They then consider the response of capital control policy under a number of different scenarios and for different types of capital. First, they assess the correlation between capital controls and business cycles. Next, they look at the correlation between capital controls on inflows and outflows, which should be inversely related per current theory. Then, they look at policy during particularly bad business cycles, as well as by exchange rate regimes and levels of indebtedness. Finally, they check across asset classes, including equities, bonds, money market, and perform robustness checks using different measures of capital controls.

Under the first test, which assesses the degree of correlation between business cycles and capital controls, the authors find that for both developed and low-income economies, controls on inflows and outflows are negatively correlated with output. For emerging economies, capital controls are positively correlated, though the magnitudes for all tests are small. Additionally, the correlation for all groups between controls on outflows and inflows is positive, which is precisely the opposite of what theory says should be done. According to these tests, the only countries that demonstrated negative correlation between their capital controls at significant levels were Egypt and the UAE. Turning to the cyclicality of policy, they find that both inflows and outflows remain virtually unchanged during business cycles. These results hold when dividing economies into advanced, emerging and low-income, though the magnitudes of the low-income responses are larger than the other types. When they consider policy during large recessions (for their panel, the Great Recession), they find the same results: that economies make little to no changes in their capital controls. For economies facing exchange rate crises as well as economies with high external indebtedness (measured as a ratio of current accounts to GDP), the results hold as well. When they check to see if the cyclicality of capital controls differ across asset classes, they again come to the conclusion that there are very few differences during the business cycle. To check robustness, they consider an alternate index during the period from 1995-2007 and reach the same conclusion. As a result, they suggest that either countries are not following prudential capital control policies, or that theory is lacking an important dimension and should be reconsidered.

The paper's discussant, Kerstin Bernoth, noted that there are a number of economies that do not use capital controls, and including these countries may bias the overall results of the study. Uribe responded that they have run the data excluding these countries and that the results are still robust. Bernoth also noted that many papers don't believe that capital controls are important, and for that reason policymakers might be hesitant to implement them. She also wondered why all of the analysis was graphical rather than based around fixed effect regressions, a sentiment shared by the audience. Uribe noted that they were not attempting to address the effectiveness of capital controls, but that such a critique was noted in their conclusion. ◆

Interest Premium, Sudden Stop, and Adjustment in a Small Open Economy

Peter Benczur and Istvan Konya

In this paper, Benczur and Konya seek to analyze the effect that a large change in the cost of external finance has upon small, highly-indebted economies that are exposed to cost of borrowing fluctuations. They focus on economies whose balance sheets consist of large foreign-currency denominated debt left un-hedged by the central bank. In doing so, they mirror several European economies, while focusing on Hungary immediately before the 2008 recession. In their model, small economies are faced with a challenging choice following a series of exogenous shocks. In particular, the central bank can either allow their currency to devalue, or defend the exchange rate. In the first case, devaluing the currency reduces the severity of a large shock to the economy: foreign economies demand larger numbers of home-produced goods, leading to smaller declines in GDP and employment. On the other hand, much of the debt in the economy (public and private) is held in foreign-denominated bonds. If the central bank chooses to defend the exchange rate instead, the effect on government and private debt is smaller, as it is easier to repay, but the cost is greater for the macroeconomy. The authors take both of these approaches into consideration, and compare the outcome for Hungary under a number of different regimes following the crisis in 2008.

The model is a simple two-sector economy in which a representative agent makes decisions over consumption, investment, and asset holdings (bonds and money). The representative agent can choose to produce non-tradeable intermediate goods, or exports, and purchase imports to also be used as intermediate goods. Each of these forms of production (non-tradeables and exports) require a separate production technology, into which some of the intermediate goods must be invested. In particular, some amount of each of the imported and non-tradeable intermediate goods must be used to invest in new productive capital. Likewise, consumption requires inputs from both non-tradeables and imports. As a reduced-form proxy for money demand, the authors include money in the utility function. They also include adjustment costs in both capital (for both exports and non-tradeables) and wages, which causes households to be less willing to adjust their labor in response to a shock. To determine the optimal role for monetary policy, the authors implement a large tightening of credit conditions, which they model as a rise in the foreign interest premium. Simultaneously, they include a one-period decrease in export demand, in order to model a global economic slowdown.

The authors take the Hungarian economy in 2008 as a baseline and consider four alternate regimes: two "full float" regimes, one in which the exchange rate adjusts completely in the face of a shock (money stock is constant), and one in which the central bank pegs the exchange rate at some constant value. They also consider two exchange rate policies in which the exchange rate is allowed to fluctuate by more than it did during the recession. Their baseline calibration does a good job matching the economy following the recession, once the shocks are taken to be exogenous. Their counterfactuals demonstrate both positives and negatives of alternate regimes: under more flexible regimes, the consumption decline is larger (households suffer more from a balance sheet shock), but exports are higher and employment declines by less. Under the fixed exchange rate regime, consumption declines by the least, but the recession is the deepest. These results lead the authors to conclude that the Hungarian Central Bank did a good job by defending the currency—a more flexible policy would have damaged household balance sheets further and caused a longer and larger decline in consumption. They run another comparison starting at a lower level of initial indebtedness (a level comparable to the Czech Republic). Of note, as the level of initial debt decreases, it becomes more beneficial for the economy to employ a flexible exchange rate regime. This is because the shock to consumption due to the household balance sheet depreciating declines in size, while the benefit of maintaining employment and GDP increases.

The discussant, Hakan Kara, had a few comments about the methodology of the paper. First, he noted that the imposition of shocks in the economy seemed ad-hoc and played a large role in determining the results. He noted that it didn't appear that either had empirical support, and that after agents are hit with the shock, they don't alter their expectations about future shocks. He further noted that there was no systematic way of measuring welfare and comparing the various exchange rate regimes, which makes the results difficult to interpret. Benczur noted that because money was in the utility function, it was difficult to perform a welfare analysis, since there would be a wealth effect present that could alter results. ◆

Constructing Coincident Economic Indicators for Emerging Economies

Cam Cakmakli and Sumru Altug

In this paper, the authors use data series of mixed frequencies to construct an indicator of economic health for emerging economies. These "coincident indicators" are meant to provide information about the state of the economy at faster frequencies than alternate indicators by using a variety of data sources. The challenge for these emerging economies is that data is sparse, often with few data points, and inconsistently distributed. To construct coincident indicators with these limitations, the authors turn to a "dynamic factor model," which allows for variables with different frequencies to be summarized by a single index, under the assumption that there is a latent process driving the co-movement of all of the variables. Because very few of their datasets are available at higher frequencies, they choose to construct their indicator at a monthly frequency. Having constructed an indicator best suited for emerging economies, they apply their analysis to Turkey and analyze the results.

The dynamic factor model that the authors employ requires that all relevant macroeconomic variables are driven by some underlying latent or unobservable process. Each other variable may respond at varying leads or lags, but all move directly as a result of the latent driver. Their method additionally allows for mixed frequency data, which includes both series that appear at different time intervals (quarterly, monthly, etc.) and data that changes frequency. In addition, it allows for "unbalanced" panels, meaning that series need not all start at the same time. These are important considerations for emerging economies, whose data are often inconsistent. Each series is assumed to be composed of two deterministic components: a coincident factor (common to all series) and a seasonality factor, of which there is a monthly-, quarterly-, and series-specific error term. Flow variables are modeled to be the sum of a series of stock variables, and seasonal components are modeled by including dummies for both quarters and months. The estimation is performed by placing the model into "state-space" form, in which the coincident factor is included in the transition equation and performing Bayesian Estimation, using a Markov-Chain Monte Carlo algorithm.

They find that their coincident factor tracks the cyclicality of the economy very well, declining during four major crises in Turkey: 1991, 1994-1995, 1998 and 2008-2009. For the seasonality factors, they note that the monthly components are more variable during the 2000s, while the quarterly factors are more variable during the 1990s. They argue that this might cause problems for "ad-hoc" seasonality specifications if different frequencies are ignored. They further note that the components appear to change during periods in which frequency changes, which suggests that economic indicators must account for these changes in frequency or risk being incorrect.

The discussant, Peter Benczur, acknowledged that the estimation strategy was very involved. He noted, however, that it was unclear what was gained by using this strategy relative to other better-known strategies. He also wanted to know if the parameters of the latent process could be observed to change in real time. That is, could we relate the change in the underlying process driving the economy to some observable events and thus gain better insight into the performance of the economy? Additionally, he noted that it appeared that the results would not be robust to changing the detrending process—that if detrending didn't quite work, the results might change quite drastically. Cakmakli responded that the low content of information limits the degree to which time-varying components contribute to the estimation. He also noted that there are other filtering techniques for detrending, but they add additional identification requirements, which increases the burden on the data. ◆

Panel Discussion: Turalay Kenc, Fatih Ozatay, Saruhan Ozel, Peter Rupert, Martin Uribe

Moderator: Selva Demiralp

The panel included presentations from five different economists, each of whom spent several minutes describing what they believe happened during the Great Recession and what could be done in the future. Subsequently, they answered questions jointly asked by the moderator and the audience.

The first of the presenters was Turalay Kenc, an economist at the Central Bank of Turkey. He argued that monetary policy must be "calibrated" more effectively, noting that the Federal Reserve used unconventional monetary policy that might have been effective but resulted in volatility because the markets were unsure how to react. In emerging economies, however, this additional volatility appeared to be muted. He noted that this has helped us to better understand emerging economies, and improved economic policies in these countries as a result.

The second presenter was Fatih Ozatay, a professor of economics, who focused on the emerging markets response during the Great Recession. He noted that central banks in

emerging economies broadly chose not to increase the money supply in the immediate aftermath of the Great Recession; this was because they feared causing a sudden stop, meaning a large decrease in lending to the emerging economies. He noted that the developed economies, and in particular, the United States, did a poor job coordinating their policies with the developing economies. Further, the unconventional policies negatively impacted the emerging economies. He noted that the developing economies with current account deficits did a good job performing macroprudential policy, but were negatively affected by the unorthodox policies of the United States. He argued that it might be a good idea for the larger economies to inform the emerging economies about policies prior to implementing them.

The third presenter, Saruhan Ozel, an economist at a commercial bank in Turkey, argued that central bankers need to do a better job paying attention to private banks. He noted that the current policy regime has improved substantially on past work by having more flexible responses and allowing the real exchange rate to fluctuate. However, he noted that while the policy may be good for the economy, it is harming private banks who hold nominal Turkish assets. He believed that the Central Bank of Turkey should do a better job incorporating private banking into their policy responses in the future.

The fourth presenter was Peter Rupert, a professor of economics at UCSB. He broadly focused on some of the outcomes of the Great Recession as well as the current events in the Eurozone. He noted that many of the periphery countries were beginning to push back against the anti-inflationary policies of Germany, and that the labor market still suggested substantial weakness throughout the Eurozone. He noted that households had de-levered, and that net worth to GDP was at an all-time high.

The fifth and final presenter was Martin Uribe, a professor of economics at Columbia. He noted that a large current account deficit caused large increases in wages, which were a problem because they weren't driven by growth. When the economy was hit by shocks, in particular, a "sudden stop," aggregate demand fell and companies were unable to support such high wages. Because these economies were stuck in the Eurozone, they were unable to increase inflation and decrease real wages. He further noted that this action occurred in the periphery, and was driven by foreign investment. For these economies, he argued it was a bad idea to join the Eurozone, because the lack of a fiscal union means that there are no automatic stabilizers.

During the discussion section, Kenc took issue with Ozel's view of the role of the central bank, noting that they must be impartial and that they don't have a mandate to operate in a way that affects the balance sheets of private banks. Much of the subsequent discussion surrounded the optimal balance sheet of emerging economies. Rupert noted that current economic theory doesn't have that much to say about optimal balance sheet size, and Kenc noted that the ECB and Federal Reserve achieved many of the same outcomes with very different balance sheets. Uribe argued that when the interest rate is at or close to zero, the rate of return for money and bonds is the same, making the optimal balance sheet size unclear. Finally, the presenters noted that in the US there are a number of automatic stabilizers linked to the fiscal unities of the states, while in the Eurozone, the absence of such stabilizers was a driver of many of the problems. ◆

Ambiguity and Robustness in Economics

MARCH 13-14, 2015

CONFERENCE PARTICIPANTS

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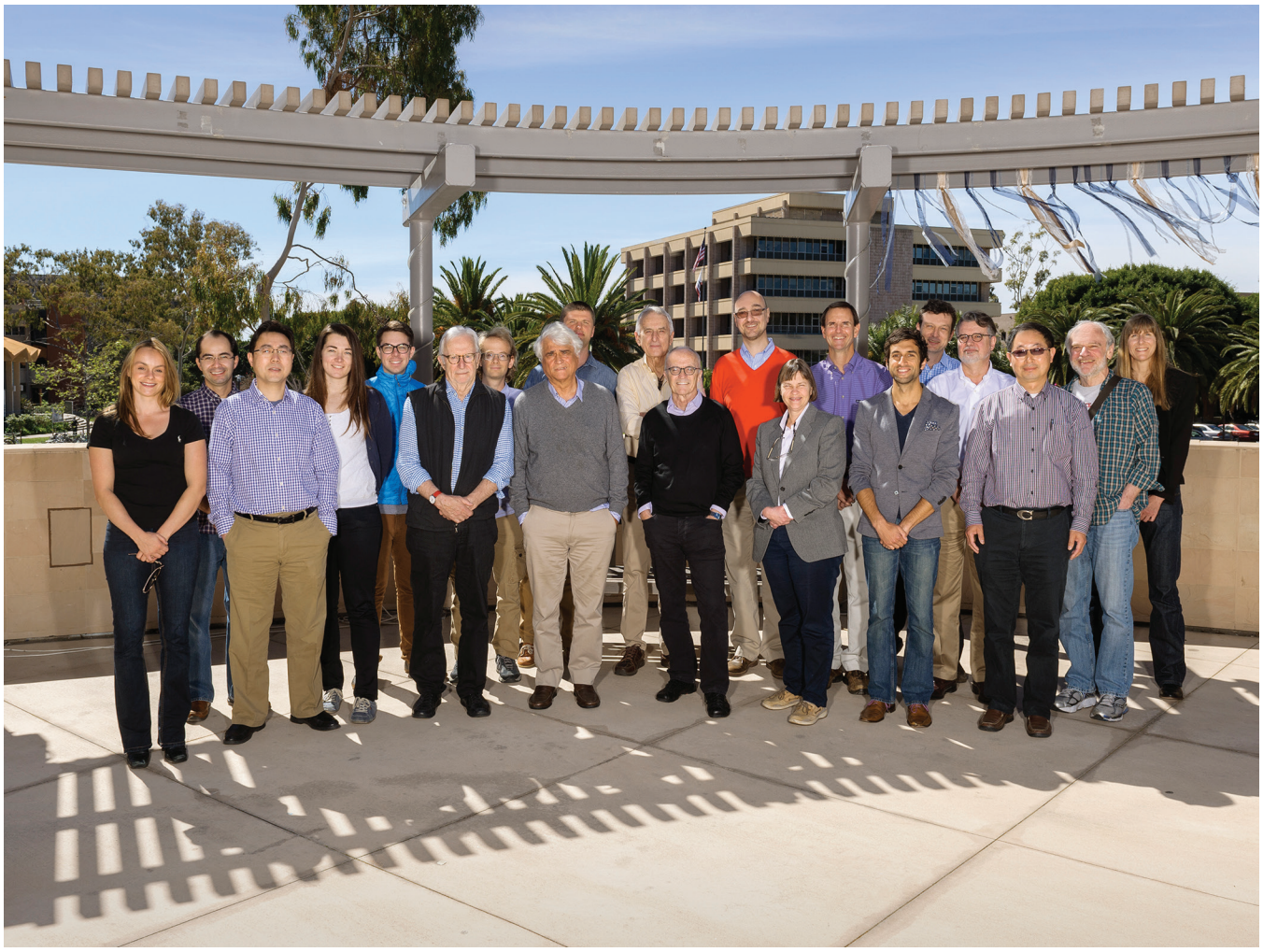

Participants and Attendees shown at Mosher Alumni House at Whalen Plaza Terrace

Equilibrium and Implementation under Ambiguity

Wei He and Nicholas Yannelis

The authors consider an environment in which ambiguity averse agents with asymmetric information interact in an Arrow-Debreu state contingent commodities model. The issue of asymmetric information in an Arrow-Debreu framework was originally raised by Radner (1968, 1982). Radner's model considered an Arrow-Debreu economy in which agents' information forms an (agent-specific) partition on the potential states of the world. Instead of fully realizing the state of the world—as in the standard Arrow-Debreau framework—agents merely learn the atom of the partition that includes the state of the world. The equilibrium in such a model is known as a Walrasian expectations equilibrium. Yannelis (1991) proposed a core concept called the "private core." Though Radner's extension and its accompanying equilibrium and core are of obvious importance, the literature has been somewhat unsatisfactory.

This dissatisfaction hinges on the question of whether or not agents can freely dispose of goods without the ability of other agents to observe disposal. As shown by Glycopantis and Yannelis (2005), free disposal may result in inefficient outcomes. Specifically, agents may be able to strategically dispose of goods to influence other agents' beliefs over the realized state of the world. This is clearly an undesirable outcome, but the alternative to assuming free disposal is worse: without free disposal, a Walrasian expectations equilibrium with positive prices may not exist. Strikingly, he and Yannelis show that introducing ambiguity aversion into Radner's asymmetric information framework guarantees efficiency and an equilibrium with positive prices under the assumption of free disposal.

Ellsberg (1961) was the first to show that people systematically violate the assumptions of the Bayesian expected utility model. Gilboa and Schmeidler (1989) developed an alternative utility model—maximin expected utility—to explain the choice data of Ellsberg and others. Agents with maximin expected utility have multiple priors over the state of the world and behave pessimistically regarding these priors. That is, the utility generated by a set of priors is equal to the lowest utility among those priors. Since maximin expected utility has been proven to reflect experimental choice data better than standard Bayesian expected utility, the authors' contributions are twofold: their model adds a layer of realism in introducing ambiguity aversion while simultaneously resolving the issue of free disposal from which Radner's earlier work suffered.

The authors establish appropriate equilibrium and core concepts, named, respectively, the maximin expectations equilibrium and the maximin core. They show that the maximin expectations equilibria are a subset of the maximin core, and thus, the equilibria are always efficient. Finally, the authors consider two environments: those with a continuum of agents and those with a countably infinite number of states. They provide conditions under which existence of the maximin expectations equilibrium and maximin core are guaranteed to exist in these environments.

The speaker concluded the talk with a simple example using a two-agent, three-good economy with free disposal. Under the Radner model's equilibrium, one agent would have disposed some of their goods in one of the states of the world. By introducing ambiguity aversion into the model, this quirk was resolved, and both agents were shown to keep their entire allocations. ◆

Information and Market Power

Dirk Bergemann, Stephen Morris and Tibor Heumann

Asymmetric information is a critical issue in economics. Empirically, the asymmetric information structure is usually hard to observe, while theoretically, the limits of what can be explained by asymmetric information are poorly understood. Instead of following common practice in game theory by posing an information structure and analyzing its economic consequences, the authors characterize what can happen for all information structures. This novel approach exploits the limit of asymmetric information, and leads to results robust to information structure. To be specific, the model not only lays an informational foundation for rational expectation equilibria but also facilitates the discussion of information aggregation and market power.

Building on the solution concept of Bayes correlated equilibrium (BCE) in their previous work, the researchers accommodate demand function competition in markets with a finite number of agents. The agents are assumed to submit a price-contingent demand, before the Walrasian auctioneer sets the price to clear the market. The authors assume incomplete information over the marginal valuation of agents, which is symmetric and normally distributed with arbitrary interdependence.

As the standard solution concept, rational expectations equilibrium (REE) in demand functions characterize the equilibrium demand and prices, given certain information

structure. The idea of BCE, however, is to describe the equilibrium in terms of a joint distribution of quantities traded, realized states/agent types, and a new parameter that identifies the market power. BCE is free of information structure, but the joint distribution is proved to be sufficiently informative of the information structure behind it. This yields the fundamental equivalence of the set outcomes described by REE in demand functions, as well as those described by BCE. The realized traded quantity and states in the former correspond to the joint distribution in the latter; the slope of the submitted demand in the former is interpreted as the market power in the latter. The finding is also empirically relevant. When information structure is unobservable, the equivalence result guides us how to infer market power and maps the distribution observed from data into game-theoretic setting with a rationalized information structure.

The authors further discussed two different characterizations of the set of feasible outcomes of an REE. First, using a canonical information structure including a one-dimensional noisy signal, the researchers show that the equivalence result illustrates how to decentralize the set of feasible outcomes under demand function competition. Given a signal structure and an associated REE, the presenters showed that one can find out the ex ante distribution of types and traded quantities. Such distribution, together with the market power, provides an alternative description of the equilibrium, which is exactly BCE. Second, the set of feasible outcomes of an REE can be characterized in statistical terms. With the assumed information structure that is described by jointly normal distribution, it is enough to characterize the corresponding first and second moments (mean, variance and correlation).

These two characterizations provide an understanding of market power in an REE in demand functions, and of the informational constraints imposed by agents' conditioning on prices. The former emphasizes that the more information is aggregated by prices, the bigger the market power; market power is strongly dependent on agents' private information structure. As to the information constraints, the paper compares competition in demand function and competition in quantities (Cournot). The authors find that BCE provides an additional restriction on the set of feasible information structures considered, but provides an extra degree of freedom, i.e., the market power. This implies that agents cannot condition on prices of a centralized market.

At the end of the presentation, one participant doubted the robustness of the results presented. The presenter argued that linearity and normality assumptions are made to simply focus on first and second moments. However, the logic of the argument and the restrictions on the extreme information structures are in some sense independent of payoff structure. This implies the robustness of the results. Another participant asked what if some agents rejected certain information structure. The presenter related the question to an earlier work about robust prediction. Instead of making no feasibility restriction on information structure, we could also specify the game with minimum information. The question then becomes how sensitive the predictions could be with different information constraints. The presenter's intuition was that more information required more optimality conditions to be satisfied, which narrows the predictions. This could be the next step in the research. ◆

On the Efficiency of Monetary Equilibrium When Agents are Wary

Aloisio Araujo, Juan Pablo Gama-Torres, Rodrigo Novinski, and Mario R. Pascoa

This presentation considered the role of money in an environment in which agents are "wary." The utility of a wary agent is the weighted average of two terms: the agent's present-discounted stream of consumption utilities, and the infimum of possible lifetime utilities. This creates an interesting asymmetry in agents' preferences over consumption streams: agents tend to ignore distant gains, but are not willing to do the same for distant loses. Wariness is inspired by the work of Gilboa and Schmeidler (1989) and Schmeidler (1989), who developed the maximin expected utility model. Agents with maximin expected utility hold a pessimistic view about the future state of the world. In a process similar to the maximin expected utility model, wary agents are uncertain about the future discount rate. They address this uncertainty pessimistically by explicitly incorporating the lowest-utility discount stream into their utility function.

The authors consider perhaps the simplest environment in which to study money: an infinite-horizon deterministic economy with a single asset—fiat money—which is used to transfer wealth across dates. Agents are infinitely lived. The concepts of sequential equilibrium and monetary equilibrium are defined in the obvious ways.

The majority of the presentation was dedicated to analyzing the effects of wariness on equilibrium outcomes in this environment. The authors note that, if agents are merely impatient (as opposed to wary), under the Inada condition, the money supply must to go zero in the limit in any efficient

monetary equilibrium. However, this is not the case with wary agents. Because agents wish to keep large money balances for long-run hedging, the Inada condition does not preclude agents from maintaining a constant, positive money supply in efficient equilibria.

An issue that can arise when incorporating the infimum of utilities into the utility function is time-inconsistency. The authors show the two conditions under which these consistency problems will not arise. First, at every moment in time, there must be some later date when consumption will be lower; in other words, the infimum can never be realized in finite time. Second, net trades cannot be converging sequences. To summarize these requirements, the authors state that "endowments oscillate around some trend that always has a worse outcome later on."

The authors consider optimal taxation under impatience and wariness. In the case of impatient agents, taxes may require consumers to hold money, though in the limit, these money holdings must to go zero in equilibrium. However, the authors show that, under wariness, optimal taxes will never require cash balances to go to zero in the limit. Moreover, efficient monetary equilibria may not require taxes.

A line of discussion arose regarding experimentally testing for wariness. The author admitted that a direct test was not possible, though he pointed out that wariness is heavily influenced by the maximin expected utility model, which was based off of experimental choice data. This line of discussion raised the fundamental question of whether models of human behavior that cannot be experimentally verified were worth considering—a divisive issue among those in attendance. ◆

Robustness and Linear Contracts

Gabriel Carroll

While in contract theory, textbook models often predict more complicated contract forms, in practice linear contracts are much more common. The paper attempts to address this longstanding discrepancy. By investigating a forthrightly non-Bayesian model of robustness, the author is able to provide concrete advice to people faced with the practical task of designing incentive contracts under non-quantifiable uncertainty. When a principal is uncertain about what the agent can and cannot do, how should the principal write a contract that is robust to such non-quantifiable uncertainty? Models introduced by the paper provide not only a novel explanation for linear contracts, but also a flexible approach that accounts for ambiguity and non-quantifiable uncertainty.

In the presentation, the presenter introduced two models: the basic moral hazard model of robustness; and the information acquisition model. In both models, the principal's knowledge of agent's actions, called technology, is assumed to be limited. The principal knows of some available actions, but other unknown actions may also exist. The author employs a simple criterion to evaluate contracts: any contract is judged by its worst possible performance, given the principal's knowledge. As the latter model inherits the major modeling framework of the former, more attention is focused on the moral hazard model.

The main finding is that, in the moral hazard model, if the principal is to obtain a worst-case payoff guarantee, the best such guarantee, out of all possible contracts, comes from a linear contract, regardless of the structure of the set of known actions. With an additional and stronger full-support assumption, linear contracts are uniquely optimal. As to the information acquisition model, restricted investment contracts, not necessarily the linear contracts, turn out to be optimal in the principal-agent model. That is, the agent names a decision from a restricted set and gets paid according to the restricted decision's payoff in realized state.

Besides technical details, the presenter graphically introduces the intuition behind the results in the moral hazard model. When the principal proposes a contract, he or she knows little about what will happen. But the one thing he or she does know is a lower bound on the agent's expected payoff from the actions known to be available to the principal. The only effective way to turn this into a lower bound on her own expected payoff is via a linear relationship between the two. Even when a contract is nonlinear, there exists a linear contract that in turn does at least as well as the nonlinear one. Hence, whatever guarantee a nonlinear contract gives is still driven by a linear relationship, which is an inequality that carves out a half-plane. Linear contracts are the ones in which this relationship is tight, and this is why they are optimal.

When the agent's action is extended to the experiment defined as the Borel distribution on the distribution of the output, the set of experiments is interpreted as information acquisition technology. The contract is also enriched by the message sent by the agent. One crucial finding in the second model is that linear contracts may not be optimal. The intuition is that extreme posteriors may not be contributing much to payoffs under the contract. As a result, if the principal trims extreme decisions away from contract, the agent's incentive will not be substantially changed. This implies linear contracts could be considerably relaxed; the principal could be better off paying less to the agent.

At the end of the presentation, one participant raised a question about applicability and significance of the finding that linear contracts are optimal. The presenter said the framework could be generalized to accommodate several produced outputs. The main result predicted that the optimal contract would just be the linear function of the total output. The presenter also mentioned another generalization about the bounds of the cost of action. With some observable variables that are not payoff-relevant to the principal but are informative of the cost of action, a similar reasoning shows that the optimal contract is some linear combination of the observable variables.

Another participant was curious about the relationship of the paper to the scoring rule. The presenter agreed that the paper could be considered to be part of the scoring rule literature, because the contracts in the paper were indeed scoring rules. It seemed no one had considered the optimal scoring rule vis-à-vis the tradeoff between incentives of information acquisition and the cost of scale-up payment. This could constitute a line of investigation for future work. ◆

Robust Contracts in Continuous Time

Jianjin Miao and Alejandro Rivera

Optimal contracts in principal agent models often require rational expectations and common beliefs. Miao and Rivera's paper represents a departure from that approach and allows for a distinction between risk and ambiguity. The paper addresses the central question of how to design robust contracts under hidden actions in continuous time. Their approach maximizes the principal's utility in the worst case scenario, subject to incentive and participation constraints. After writing and solving the model, Miao shared a number of examples of how the model can be used, including the study of capital structure and asset pricing implications.

Miao begins with a discussion of crucial issues and his approach. First, there is the question of how to model decision-making under ambiguity. He discusses the possibilities in the literature and benefits to each (max-minimum utility, smooth ambiguity, and others), deciding on multiplier utility as the best way to model in continuous time, stating others are better suited to static models. Then, there is the question of who faces ambiguity. The paper takes the approach of the principal as ambiguity-averse about the cash flow distribution. He argues that this is a good, intuitive starting point, because the principal has less information and does not know about the agent's actions. Once the principal's ambiguity aversion is introduced, endogenous belief heterogeneity can be generated in the model. Ambiguity aversion in the end means that there is pessimistic behavior, and the principal puts more weight on the worst-case scenario.

Miao then discusses the benchmark models, DeMarzo and Sannikov (2006), and Biais et al. (2007). Consider an entrepreneur that has a project with cash flows given by a differential equation. Seeking funding, the entrepreneur (agent) writes a contract with investors (principals) who can provide funds for the entrepreneur. Both the entrepreneur and investors are risk-neutral, but the entrepreneur is more impatient and liquidation is costly. We can use the martingale representation theorem to rewrite the incentive constraint as a backward stochastic differential equation.

Then, Miao introduced belief distortions—an element of robustness. One conference participant asked about how the perturbation in beliefs worked and Miao explained that they simply perturb the mean. Robustness yields a number of different insights from the benchmark DeMarzo and Sannikov model.

One of the paper's major findings is that the incentive constraint does not always bind. For a low continuation value, the principal is concerned about inefficient liquidation. At this point, the principal wants the agent to be minimally exposed. However, when continuation value is high, the principal wants to be more diversified. The result is non-global concavity, which is a special feature of the model.

Miao shows that an optimal contract can be implemented using cash reserves, equity and debt. Special dividends (or cash injection) can occur only for large cash reserves. They pay out dividends or repurchase shares in bad times and inject cash or issue new equity in good times. This is a hedge against model uncertainty.

Recall that in this model, the dynamics are distorted under the principal's beliefs. The aversion to model uncertainty in an agency model can generate an equity premium that is state-dependent and time-varying. Miao shows that the equity premium is high for low-cash reserves. The intuition is that with low-cash reserves, the incentive constraint binds and the ambiguity-averse principal bears more uncertainty, demanding a higher equity premium. Unlike the benchmark model that cannot generate either the equity premium or credit yield spread, Miao and Rivero's model can partially explain both.

Miao ends with a discussion of observational equivalence: risk aversion versus ambiguity aversion. So what are the differences if we assume the principal is risk-averse and the agent is risk-

neutral but neither is ambiguity-averse? Using an exponential utility function and a few assumptions, he finds that it is not necessary that the incentive constraint always binds because the principal wants to diversify. Under some conditions, he finds that the robust contract and optimal contract with risk aversion deliver the same liquidation time and payout policy to the agent. However, while there is observational equivalence, there are differences in interpretation: for example, the equity premium with risk aversion (as opposed to ambiguity aversion) does not include a hedge component. ◆

Robust Confidence Regions for Incomplete Models

Larry Epstein, Hiro Kaido and Kyoungwon Seo

Epstein, Kaido and Seo's paper discusses robustness for econometricians instead of for agents in the model. The objective is to construct robust confidence regions for unknown parameters in incomplete models.

Incompleteness in the model implies the econometrician is not imposing a theory of selection, though other aspects of selection are well understood. If econometricians want to be agnostic about how selection works, it requires that inference be robust to heterogeneity and/or dependence of an unknown form. Such robustness is not addressed in the literature, which emphasizes agnosticism about selection but (almost) universally assumes that samples are independent and identically distributed.

Epstein, Kaido and Seo take a frequentist approach where incomplete models lead naturally to belief functions, they come up with a Central Limit Theorem for belief functions, and they use that Central Limit Theorem for belief functions to construct confidence regions for these incomplete models.

As a motivating example, Epstein begins with the classic Jovanovic (1989) entry game, where there are two firms and many markets. In the game, there are realizations that are known to players but unknown to analysts. Selection may differ or be correlated across markets. There is also a structural parameter that we are interested in identifying, common across all realizations. Their model accommodates any solution concept, as long as it defines a correspondence consistent with the framework. The Jovanovic example uses a normal form game with pure strategy Nash equilibria, but a solution concept such as rationalizability can also be used.

Epstein defines a belief function and the core of a belief function. The core has a very nice characterization: by fixing one parameter, we know the truth lies within a certain set. There is complete agnosticism about what happens in that parameter. Then, with a distribution over the parameter, we can use the distribution to form mixtures. He explains more specifically belief functions for the binary state space, generalizing probability numbers into probability intervals.

One participant asked where mixed strategies cause a problem. Epstein explains that with mixed strategies, we would get a belief function over the simplex over strategy profiles, but the problem is that we do not observe when a particular mixed strategy was played. Rather, we only observe the realization. Therefore, the approach using belief functions doesn't work without the introduction of further assumptions.

Most of the literature assumes that there is a true probability law, and that while it is unknown, it can be approximated by the empirical distribution for large samples, because the experimental outcomes are independent and identically distributed. However, if there are omitted variables that influence selection, then the distribution depends on how the omitted variables play out across experiments, and the econometrician's theory provides no guidance. If the econometrician takes into account all the probability distributions that are consistent with the given endogeneous variables, latent variables, correspondence between the two, probability measure of unobservable characteristics, and a structural parameter, then the econometrician is truly agnostic about selection. This set is the core of a belief function. This takes the place of an independent and identically distributed measure for the purpose of establishing a Central Limit Theorem. From the Central Limit Theorem, confidence intervals are a natural extension.

Epstein discusses the extension of adding covariates (observable heterogeneity). He also shares that his co-author is running Monte Carlo simulations, and he and his co-authors are finding that they do not pay a big cost. With respect to these examples, it appears these models can be implemented and perform reasonably well. ◆

Awareness of Unawareness: A Theory of Decision Making in the Face of Ignorance

Edi Karni and Marie-Louise Viero

A Theory of Decision Making in the Face of Ignorance models and analyzes decision-making when agents are not fully aware of the consequences of their decisions. The paper starts with the Bayesian paradigm concept of a shrinking universe, because more information leads to smaller sets of possibilities. Conversely, this state space can expand due to new technologies—a phenomenon called the reverse Bayesian paradigm.

The objective is to model new consequences that are unimaginable or neglected and analyze their implications. The key idea is to augment the set of consequences with an abstract item called "none of the above." The methodology is axiomatic to characterize choice behavior using language and structure of decision-making under uncertainty.

The state-space starts with a finite, nonempty set of feasible acts, a finite, nonempty set of feasible consequences, and a consequence complement to mean "none of the above." A function maps actions to consequences. Some states are partially unknown, while one is completely unknown. If a new consequence is discovered, the decision-maker merges it with the set of feasible consequences and the unknown consequence becomes its complement. When asked if two feasible acts are a pair of actions that can coexist together. The author explained that they can be exclusive events, but are kept potentially independent for a general form.

The basic preference structure satisfies weak order, mixture continuity, monotonicity, replacement, non-triviality, and invariant risk preferences. Linking preferences of prior and posterior beliefs allows expected utility calculations. From these the authors determine: 1) that the decision-maker's ranking of objective versus subjective uncertainty remains unchanged after updating to include the new discovery, and 2) that this ranking is also the same in the a posteriori state space.

Concerned about identifying the empirical content of someone's being aware of unawareness, one participant asked, "How do I determine if person 1 is aware or if person 2 is unaware? What behaviors do I observe to infer their awareness?" Karni replied, "Ramses defines subjective probability are odds people place on practical events, so the states are observable outcomes here. You can conceivably place bets on the outcomes of taking these actions." Asked whether there were ultimately some states you cannot bet on, though, Karni did agree.

The author discusses that the decision-maker may feel a decreased sense of ignorance upon obtaining new information, so he becomes bolder or more confident in making his decision. Also, in assigning utility to outcomes of the unknown, people may feel excitement, but also fear. ◆

Risk-Sharing in the Small and in the Large

Paolo Ghirardato and Marciano Siniscalchi

Risk-averse expected-utility-maximizing agents in an exchange economy with a single consumption good, symmetric information, and no aggregate uncertainty will fully insure one another if and only if they have a common prior over the probabilities of states. It is known, however, that agents may violate subjective expected utility when some relevant events are more ambiguous than others. A previous paper by Rigotti, Shannon, and Strzalecki (2008, henceforth RSS) showed that, as long as preferences are convex and sufficiently well-behaved, agents will completely share risk when beliefs coincide. Yet others have questioned if convexity fully captures the behavior associated with ambiguity-aversion. Ghirardato and Siniscalchi show that convexity is not required for the equivalence between consistent beliefs and the absence of betting in such an exchange economy.

Specifically, the authors analyze risk-sharing when agents have ambiguity-sensitive preferences that are not necessarily convex and there is no aggregate uncertainty in the economy. In response to a question from the audience, Siniscalchi clarified that they use risk-sharing to mean that an allocation is Pareto-efficient if and only if it is a full-insurance allocation. This is sometimes referred to as a "no betting" result. That is, betting will not occur in equilibrium as long as agents agree on event probabilities.

The authors follow RSS by considering an Arrow-Debreu economy with uncertainty over states. A single good can be consumed by consumers. Preferences are defined over consumption bundles using a continuous, strictly increasing, and strictly concave utility function and a preference functional defined over the utilities generated by the state-contingent consumptions. For example the preference function would be the expectation with respect to some set of probabilities if agents are expected utility maximizers. Concavity restrictions are not imposed on the preference functional.

In order to generalize the result from RSS, Ghirardato and Siniscalchi use tools from nonsmooth calculus to describe the necessary conditions on preferences. The most important of

these tools are the Clarke differential and the core. In a 2002 paper, Ghirardato and Marinacci showed that a preference relation can be described as ambiguity-averse if and only if the core of the preference functional is non-empty. This is related to the notion that agents' local beliefs coincide. The authors introduce a "local" non-convex Second Welfare Theorem using these concepts. With some assumptions about quasi-concavity, this local behavior has global implications. Finally, Siniscalchi uses Machina's reflection as an example of when their result holds.

Conference participants did not have many questions at the end of the presentation as they were busy trying to digest all of the information that had just been presented. One attendee suggested referencing one of his own papers on non-convexity that has intersections with the paper being presented. Siniscalchi took note, and with that, the talk was concluded. ◆

Uncertainty in Mechanism Design

Chris Shannon, Giuseppe Lopomo and Luca Rigotti

In the mechanism design literature, the ex-post incentive compatibility criterion represents a fully robust alternative to the more classical Bayesian incentive compatibility criterion. What is the character of incentive compatibility rules that fall between these two polar notions, and what can be achieved by these partially robust mechanisms?

The Bayesian incentive compatibility (BIC) criterion associates each type with a single probability distribution corresponding to that type's belief about the state. A mechanism is BIC when every type of agent maximizes their expected value (taken over the unique type-specific belief) by reporting their true type. A mechanism is said to be Ex-post incentive compatible (EPIC) when instead, every type of agent maximizes their expected value by reporting their true type for any belief about the state.

The key distinction between these two concepts is the allowed set of beliefs that each type is permitted to use in calculating expected values. In BIC, the allowed set is a singleton for each type, while in EPIC the allowed set is the entire space of probability distributions on the state space. In this way, the EPIC requirement produces mechanisms that are fully robust to misspecification of beliefs. What comes "between" BIC and EPIC?

Giuseppe Lopomo, Luca Rigotti and Chris Shannon characterize an additional incentive compatibility constraint in "Uncertainty in Mechanism Design." The concept they introduce is Optimal Incentive Compatibility (OIC). In OIC, each type is permitted to have beliefs from a generic set of potential beliefs. If this set is a singleton, then OIC corresponds to BIC, and if this set is the entire space, then OIC corresponds to EPIC. Their concept nests the full robustness of EPIC and the classical Bayesian constraint while also allowing intermediate cases characterized as being "locally robust".

To provide a link between this work and the general topic of the conference, Shannon suggested that an intermediate set of potential beliefs may be endogenously generated by agents who face ambiguity over the state (in the sense of imprecise beliefs about the probability distribution). The size of this set can then be interpreted as measuring the amount of ambiguity faced by an agent of a certain type.

After motivating the need to consider the intermediate case either due to ambiguity at the level of the agents or the need for "local robustness" in terms of misspecification of beliefs on the part of the planner, Shannon presented the main result. Even a small amount of ambiguity (generating a relatively small set of potential beliefs) can make OIC just as restrictive as EPIC. In these cases, OIC is equivalent to EPIC in terms of the set of feasible mechanisms; every OIC mechanism is also EPIC.

More precisely, the requirement for this equivalence is given by a condition referred to as "fully overlapping beliefs." This requirement is that, for each type, there is a neighborhood of types such that intersection of the potential beliefs of those types has full dimension. Furthermore, Shannon presented a straightforward and compelling example, the epsilon-contamination model, which allows for sets of beliefs arbitrarily close to singletons that maintain the fully-overlapping requirement for the equivalence of OIC and EPIC.

After the presentation, an audience member asked about the focus on direct mechanisms in the paper. Shannon responded that a form of the revelation principle, ensuring the equivalence between direct and indirect mechanisms, is straightforward with a caveat about subtleties regarding what should be taken as exogenous in the model. Shannon also discussed with another audience member the fact that OIC, like BIC, is an interim concept, where the ex-post nature of EPIC may permit additional robustness in terms of the structure of communication in mechanisms (except in the case where OIC mechanisms correspond to EPIC mechanisms). ◆

Subjective Probability, Confidence, and Bayesian Updating

Igor Kopylov

Classical literature has derived subjective probability from observable preferences over monetary bets and other uncertain prospects, rather than from objective symmetries or frequencies. However, this treatment does not apply to the model when agents are ambiguity averse. Ambiguity aversion occurs when agents have limited information about the true probability law. In this case, Bayesian updating might not be dynamic consistent. The main contribution of this paper is to define subjective probabilities for an ambiguity averse agent whose information on the true probability law is limited, and to characterize the Bayesian updating rule for the subjective belief system.

Igor Kopylov started the presentation by introducing different representations of subjective probabilities between standard and ambiguity models. In standard models, subjective probability represents betting preferences over all relevant events and can be combined with expected utility, and the Bayesian updating of the subjective belief system satisfies dynamic consistency. In ambiguity models, subjective probabilities can be replaced by non-additive Choquet capacities, or replaced by second-order beliefs, or selected in a way that depends on the evaluated uncertain prospect, two examples of which are maximum expected utility (MEU) and variational utility (VU).

To proceed, Ingor presented a costly ambiguity model as a new functional form to accommodate ambiguity aversion. In particular, subjective probabilities are treated as a weighted average between the agent's least favorable scenario in the information set and their unique subjective belief. The weights in the mixture are unique and reveal the agent's confidence in their belief systems. To characterize the model, Ingor illustrated a proof that the model satisfies uniqueness and produced list of axioms, including Weak Order, Continuity, Monotonicity and a suitable relaxation of independence. Finally, Ingor described the implementation of Bayesian updating in ambiguity models, and claimed that Bayesian updating for the subjective probabilities requires much weaker dynamic consistency than that of standard models. By relaxing the dynamic consistency principal, he showed that the Bayesian updating rule for the subjective belief system is conditional on any non-null event of the state space. To illustrate, Ingor applied an example of the Ellsberg Setting. In the end, Ingor pointed out that the recursive structure can exist within the variational functional form. As with the mean-variance model, the costly ambiguity form does not survive the recursive process, although the variational structure remains.

During the presentation, a participant asked about the relationship between the costly ambiguity model setup, MEU and VU. Ingor made it clear that while MEU is a special case of cost ambiguity model when the cost function is a linear function in ambiguity, cost ambiguity model is in fact a special case of VU. Another participant inquired about whether the subjective probability framework can also be applied to non-Bayesian updating. Ingor responded that the model allows for the combination of the Bayesian updating of subjective beliefs and non-Bayesian procedures for some information sets and events; in other words, non-Bayesian updating can be introduced separately for objective and subjective rationality components. ◆

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