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# FROM THE LAB

IN THIS ISSUE

**Credibility**
conference held November 2019

LAEF
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UC **Santa Barbara**

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# FROM THE LAB



## Credibility Conference



### Presentation Summaries

*Note: speakers are highlighted in author listings*

# Director's Message

## Finn Kydland

In this issue, because of the virus having forced us to cancel a conference in March (to have been titled *Social, Spatial, and Racial Inequality*), we have only one conference on which to report. Here's the invitation to that conference from the academic organizers:

> LAEF is pleased to host a conference on Credibility at the Upham Hotel Garden room, which is located at 1404 De La Vina Street in Santa Barbara. 42 years ago, Professors Kydland and Prescott identified the problem of time inconsistency—even well-meaning policymakers, when confronted with forward-looking agents whose choices depend on future policies, can end up delivering bad outcomes. The key is that the promise of future policies may not be credible; that is, market participants do not believe these future policies will actually be implemented. Time inconsistency raises several questions: Can policymakers "gain credibility"? Can they lose it? How valuable is credibility? How are discretion (the ability to react to current situations) and flexibility (how much agents can respond) connected to credibility? The goal of this conference is to develop tools that help us answer these questions. The academic organizers are Assistant Professor Zachary Bethune and Professor Eric Young, both at the University of Virginia.

It was a special delight for me to hear these papers from great researchers focusing on credibility in various ways. At some point before the conference dinner, Zach Bethune, saying he was inspired by Andy Levin, asked if I would give a dinner speech on how the Rules vs Discretion paper came about. To Norwegians, it's against nature to speak oneself about some accomplishment that people think is great (it might sound like bragging! see the Hagar strip at the end) but I agreed. Distracted at dinner, however, by our great Chancellor, Henry Yang, and his wife Dilling arriving part-way through the dinner and sitting down next to me, somehow I ran out of time. Having thought about this idea, however, it occurred to me that doing so in writing might provide a learning experience, especially for PhD students and beginning faculty. Before the final product, there were several hikes down blind (or at least dimly lit) alleys. But not to be deterred! At least at one instance at a conference, everyone present was looking for what they thought *had to be* an obvious error: How could the outcome of optimal control possibly be time inconsistent?! So one moral is, if you think you've discovered something important, everyone is convinced you're wrong, but you yourself know there's no error, you may be on to something *really* big! By the way, let me say at the outset that my wife Tonya often accuses me, when I tell a story, of including way too much detail. I love detail! As you'll see, I won't feel constrained here, as with only one conference covered in this issue of *From the Lab*, rather than

the usual two, we have plenty of room for a longer than usual Director's Message—certainly more room than I could have filled in a dinner speech! I may even touch on baseball—the ultimate in detail!

For me, the beginning has an additional aspect compared with Prescott's. In my second year as a Carnegie Mellon PhD student, I had become interested in a literature known as the assignment problem. The main idea was how to assign policy tools, say monetary and fiscal, to specific goals, say GDP and inflation, in such a way as to keep the economy from being unstable or, more generally, ensure it would approach the ultimate target in a timely fashion. In an international context, language such as internal versus external balance was used. Examples of articles that drew my attention included one by Marina von Neumann Whitman (yes, the famous von Neumann's daughter!) and by the future Nobel Laureates McFadden and Mundell.

After pursuing this idea for a few months, eventually I came to regard it as a dead end. It seemed dependent on adjustment coefficients that appeared unreliable and hard to measure. Models were not founded in optimization. I had accompanied my mentor, Sten Thore, from Norwegian School of Economics and Business Administration (NHH) to Carnegie Mellon, where he was to spend his sabbatical year. After graduation, I had already spent a year at NHH as his research assistant, an official full-time position in the Norwegian university system. The idea is to devote half the time on research with your assigned professor, and the rest to further your own development. In the latter vein, for example, during the year before following Sten to CMU, I had taken a one-semester course from NHH math professor Ole Martinussen, in which we covered the math underlying the Simplex method in linear programming. (This background had the by-product of making it quite easy for me to take in the autumn of my first year John Ledyard's second-year GE course, using Debreu's *Theory of Value* as the text.)

I first learnt to know Sten in the spring of my second year at NHH. I had signed up for an elective course in which we used as the main textbook Ronald Howard's *Dynamic Programming and Markov Processes*. In this course, for example, I coded up, in FORTRAN, a dynamic programming problem that appears in Howard's text. Thanks to Sten, dynamic programming was in my blood! I decided to model the assignment problem as a linear-quadratic dynamic game between monetary and fiscal policy makers. In their respective multi-period objective functions, they put different relative weights on the two targets, instead of being solely focused on one or the other target as in the standard assignment problem.

The obvious approach was to consider this a noncooperative game and to apply the dynamic version of Nash equilibrium. That's when I got my first surprise. For the linear-quadratic optimal control problem, Herb Simon had shown, as far back as in 1956, that whether one formulates the problem in policy space or in sequence space, the solution is identical. For my game, however, that was no longer the case, so I had to choose which one I considered more realistic. I argued for feedback rules in policy space. (To me, an important factor was the ease of dealing with uncertainty in the resulting policy rules.) By that time, Dave Cass had become my main PhD adviser. He knew about Simon's result, so when I told him what I had found, naturally he was dubious. I recall it took some doing to convince him.

Motivated by my impression of how policy decisions are made in Congress versus the Fed, I did consider an alternative version of the two-player game, one in which the fiscal policy maker moves first in every period, analogously to a Stackelberg game or, as I preferred to call it, dominant-player game. Here's where time inconsistency first reared its ugly head. This time, Dave bought it right away. It had been drilled into our heads by Dave, as well as by Bob Lucas, always to think in terms of *equilibrium*, and it seemed to me the recursive solution represented the superior candidate as an equilibrium. That's how I proceeded, while at the same time admitting that the dominant player would indeed perform better, according to his objective, if he could somehow commit to the optimal, but time-inconsistent, solution. In my dissertation, in addition to the policy-selection games, I had also an IO application. At the time, a literature existed on dominant-firm industries. In my framework, the dominant firm was the dominant player, with one or more followers who in every period would take as given that period's choice by the dominant firm, but behave noncooperatively among themselves. Again, the recursive dynamic solution was my choice of equilibrium concept.

CMU's Graduate School of Industrial Administration (GSIA), as the business school was called back then, was an inspirational place. It fit me like "foot in hose", as we say, translated from Norwegian: Its lack of focus on literature-oriented courses, but instead tools, and especially the requirement to write a first-year, and then second-year, summer research paper, preferably of publishable quality, I felt was ideal. Sten Thore had pushed me towards operations research topics. My first-year summer paper,

"Duality in Fractional Programming," was based on an idea I had worked on already in his course at NHH. I got it published in *Naval Research Logistics Quarterly*, at the time one of the top OR journals. My official summer-paper reader was Bob Kaplan, a junior OR professor with specialty in dynamic programming. My second-year summer paper, on hierarchical decomposition in linear programming, got published in *Management Science*. By my second year, however, I was committed to economics, and I regarded Dave Cass as my main adviser.

Before my third year at GSIA, we were told that a new professor had been hired from Penn: Ed Prescott. I had already been very much influenced by Bob Lucas, having taken his course on Growth and Fluctuations (also a second-year course that I took, this time spring of, my first year; it was unlike any other macro course in the world at the time!) and I had read Bob's and Ed's spectacularly important *Econometrica* article "Investment Under Uncertainty." When I happened to run into Ed for the first time, he asked in a friendly way what I was working on. Ed himself had recently published an application of dynamic game theory, in his case, as in one of my applications, in an industry context. So we hit it off very well (at least I thought so!) But when my thesis proposal was coming up, I still imagined my committee would be headed by Dave Cass, with Kaplan and Prescott as co-members. To my surprise, however, after my proposal Kaplan came to tell me that Prescott had insisted on being chairman.

As my fourth and last year is approaching its end, Ed one day shows me a brand new working paper by Bob Lucas: "Econometric Policy Evaluation: A Critique." We were still in the era in which, all over the world, macro basically consisted of versions of the IS-LM model (system-of-equations approach). We realized this paper was revolutionary. It clearly knocked the legs from underneath the IS-LM model!

In those days, once a year an economic dynamics and control conference would take place at which researchers with interest in optimal control, from economics as well as engineering perspectives, got together to exchange ideas, typically led by the control-theory guru Gregory Chow, and supported by economists such as David Kendrick and others. That year's conference was to take place in June in Chicago. Ed and I thought we could extend one of Bob Lucas's three great illustrating examples, his investment-tax-credit model (for our purpose, the model's clear and explicit dynamics, the capital stock being a state variable, was important; eventually, we added two-period time to build for some *extra* dynamics!), and append a reasonable objective function for the government to maximize within a stochastically fluctuating economy. Bob had shown how to do policy *evaluation* right (most explicitly how not to do it!) We thought we could show how to do optimal policy *selection* right.

Ed and Bob, in their *Econometrica* article, had demonstrated how to obtain the equilibrium of a competitive industry by maximizing a particular consumer-surplus problem. So we banged the investment-tax-credit economy into my dominant-player computer program, the government being the dominant player and the competitive industry the follower in a two-player game. Having seen Bob's paper only in April, we didn't have much time. Moreover, I was putting the finishing touches on my dissertation before my defense and had planned to return to Norway end of May. NHH had paid a generous stipend for my four years at GSIA, so I felt obliged to return to NHH (to Dave Cass's chagrin, as he wanted me to go on the market in the U.S.; my Norwegian wife may have had a say in our decision!) In the end, I was able to postpone my return by a month, so we could get a paper draft ready for the June 7–9 conference.

Our draft was rather rudimentary, so we spent the rest of June making modifications. A couple of months later, Ed submitted the resulting draft to a conference in Pittsburgh, from which proceedings, edited by W.G. Vogt and M.H. Mickle, were published. I suppose the paper in those proceedings was the first official draft of the paper. But, as we realized later, it was deficient in important ways!

Back at NHH, I was a bit frustrated as their small macro group didn't seem in tune with the kind of aggregate economics I was doing (or perhaps didn't fully understand it). I had entered a slight revision of Ed's and my paper, dated December 1973, in their Discussion Paper series, but it didn't generate much attention, except I got a generous comment letter from the great Norwegian economist Leif Johansen who, along with Ragnar Frisch and Trygve Haavelmo, was a professor at University of Oslo. Moreover, as Ed and I soon realized, in those days working from a distance was not easy. For example, we would send letters back and forth between Pittsburgh and Bergen! So I hatched a plan to invite Ed to visit NHH for the following academic year, 1974-75. With the help of Bank of Norway, who pitched in significant funding, I came up with a proposal for a visiting year. Ed accepted.

In the dominant-player game in my dissertation, my equilibrium concept corresponds to the recursive (feedback) solution. I had never calculated the optimal rule for the dominant player under full commitment. Of course I knew it would be superior for the dominant player, but I didn't anticipate it would beat it by that much. The mathematical problem to calculate that rule is not recursive and so standard

dynamic programming methods were inapplicable (more on that at the end).

In the autumn, at NHH, I taught macro to the undergraduate class about to graduate. I noticed one student, Nina Bjerkedal, who really was on top of things. By the end of the semester, I had talked her into becoming my research assistant, to start in the spring semester. She was great at math, knew how to program in FORTRAN, and so I proposed to her the following project: For the case of a dominant firm with one follower (the simplest problem I could think of in which time inconsistency is present), she would expand my dominant-player code so as to calculate the optimal policy rule with commitment. She would do so by "brute force," so to speak. With only two firms, the dominant firm's policy rule has two coefficients. She would search mechanically over those two coefficients, all the while adjusting the follower's rule accordingly, until the objective of the dominant firm reached its maximum. (I later used this numerical example in my 1977 *JET* paper.)

As mentioned, I had previously considered the recursive solution (by backward induction) to be the candidate to represent the dynamic equilibrium. When Nina showed me the comparison between this equilibrium and the optimum under full commitment, I was astounded at how much difference it made for the dominant firm. Ed and I had started our project with the aim of showing how to select optimal stabilization policy. So when Ed arrived in time for his year at NHH, it had become obvious to us that our "straw man," so to speak, would have to change drastically, to focus on how much better a policy maker could do under commitment than under our previously analyzed equilibrium. Also, it so happened that by that time we had heard from the *Review of Economic Studies* where we had submitted our paper months before. The paper was handled by Chris Sims, who suggested we pay more attention to the optimal solution. After Nina's spectacular numerical example, that was indeed the obvious thing to do. The time inconsistency of the optimal rule now loomed as the key issue. Ed and I decided to rewrite the paper completely (you could say we were lucky it wasn't accepted by the *RES*!) Nina's numerical example led us to conjecture that, in a dominant-player context, if the government policy maker behaves without commitment to the optimal policy, not only would the result be far from optimal, the outcome could be very bad for society, worse, say, even than doing nothing!

There was still one more issue we knew we had to deal with. The player acting as a follower, maximizing consumer surplus, was intended as a stand-in for a competitive economy, as in Lucas and Prescott's "Investment Under Uncertainty." But being a single player implied an inappropriate externality in the solution: That player would take into account the effect of its decision on the government's future decisions in a way that was unreasonable in a competitive economy of infinitesimal decision makers.

We pondered that issue for a while. Ed and I both were living in a suburb north of Bergen and would often take the same bus when going home. I still remember vividly, standing at the stop nearest to NHH waiting for the bus to Morvik, when it suddenly came to us how to do it. We had figured out what we came to refer to as the big-K-little-k problem (methodology all described in the appendix to the published article).

During Ed's year at NHH we were making steady progress. For example, we were looking for a numerical example or two of the feedback solution—discretion—doing poorly. Also, I was busy preparing chapters of my dissertation for submission and, in the case of the *IER* paper, revision. Ed spent much of his time doing his part of what was to become the Lucas-Stokey-Prescott volume. I can't resist mentioning that on January 12 an important event was coming up, an event that Ed and I absolutely did not want to ignore: the Super Bowl featuring the Pittsburgh Steelers against the Minnesota Vikings. When I discovered that the game was to be broadcast on the radio by Voice of America, I invited Ed to our apartment. We had stocked up on plenty to drink, and were delighted to find out that the two announcers for Voice of America were the decades-long Pittsburgh institution in sports radio, Myron Cope, along with Jack Fleming doing play-by-play. What an exciting night: Hansa Beer and a scratchy broadcast of the Steelers in the first of their six Super Bowl victories!

I was keeping an eye out for the next stochastic control conference, analogous to that in Chicago at which we presented our initial draft. When I found out it was to be held in May in Boston, I submitted my dissertation paper on the assignment problem and it got on the program. In the spirit of too much detail (according to Tonya), I can talk here about two things. My son, Eirik, was due to be born early-to-mid May. To catch the conference I would have to depart from Bergen no later than May 19. My then mother-in-law, Martha Kjellevold, generously agreed to travel from Aurland to Bergen to stay with us that May (doing a much better job than I could have and resulting in my wife's blessing to go!) Eirik obliged by arriving on May 13. So off I went.

I arrived in Boston middle of the day before the conference. I knew the Red Sox would be playing the Oakland A's. Scheduled to start for the A's that night was one of the greatest pitchers at the time, Vida Blue. So in early evening I headed for Fenway Park. You may wonder, why would a Norwegian be interested in baseball? When I arrived as a student to Carnegie Mellon, the Pirates were still playing at Forbes Field, a pure baseball stadium located only a quarter mile from CMU. Often, say

between 8 and 9, I would head over to the ball park where, if you arrived in the 3rd or 4th inning, they would let you in for free. I learnt to pick my seat in the bleachers so I could watch the great Roberto Clemente in right field. I learnt to appreciate Willie Stargell and his frequent home runs, and the great double-play duo, Gene Alley and Bill Mazeroski (famous for his 1960 World Series 7th-game 9th-inning home run against the Yankees to win that series for the Pirates).

Moreover, I was in Pittsburgh during the 1971 World Series. For the past 30 or 40 years, I imagine I've been about the only person in the world who could answer the following baseball trivia question: In that World Series, the Pirates used six *different* starting pitchers (rather unusual)—who were they? Dear reader, how many did you get right? The answer is: Dock Ellis, Bob Johnson, Steve Blass, Luke Walker, Nelson Briles, and Bob Moose. (Steve Blass pitched also the 7th game, became a hero, was expected to be a star pitcher the following season, but simply could not find the strike zone, and eventually retired, to become the Pirates color announcer, which I believe he still is). So, in Boston, I was really looking forward to Vida Blue, who by that time in May already was 8–1 for the season. But he lost—just didn't have it that night. Still great to be at Fenway Park! (Over a beer or two, I'd be glad to tell you about the game, a decade or two later, that Tim Kehoe and I attended at Fenway Park. Disaster! But limits to how much detail one can include in a Director's Message!)

On the first day of the conference, Gregory Chow announced an extra session the following day. Attendees were invited to sign up to present work in progress. I did and got to go first. The audience consisted of the usual groups from engineering (including Mike Athans) and economics (in addition to Chow, David Kendrick, Stanley Fischer, and others). Admittedly, Ed and I had chosen a rather incendiary title for the draft of the revised paper: "On the Inapplicability of Optimal Control for Policy Making." I barely got past the title and all hell broke loose. Everyone was convinced there had to be an error somewhere and kept looking for that mistake. Of course I knew there was no error and did my best to stand my ground. So this experience is the basis for my motto for PhDs in the introduction: If everyone thinks you're wrong but you know you're right, you may be on to something really important!

To understand how even a title could generate such a reaction, one has to remember how excited the profession was at the time about optimal control. In May 1973, a major magazine, Business Week, had run a two-page article entitled "Optimal control: A mathematical supertool." Some of those in attendance at the conference, including Gregory Chow and Mike Athans, were cited in that article. The models they used basically were elaborate versions of the IS-LM model. Ed and I were among the few at that time who even knew about the Lucas critique. Among those who *had* heard about it, most simply brushed it aside as unimportant.

The kind of disbelief experienced in Bosten did persist for a while. One factor may have been that the model relied heavily on capital accumulation, including explicit production function, which of course was important in growth theory, but virtually unheard of in a business cycle context. We did realize it could be important to include an example that hit home more easily, considering the focus of macro literature at the time. So the last thing we did before submitting the final draft was add an inflation-unemployment example. This example demonstrated clearly the tendency, under discretion, towards excessive inflation without corresponding benefits in terms of unemployment outcomes. Moreover, evidently this example provided the inspiration for the famous paper by Barro and Gordon!

After the 1977 *JPE* paper, Ed and I did write one more paper on time inconsistency, published in the *JEDC* in 1980. Except for the duopoly example Nina Bjerkedal had helped produce for me, we didn't yet have a worked-out example of the optimal policy with full commitment—call it the optimal policy. Being time inconsistent, we imagined it unlikely ever to be implemented. But, importantly, it does represent a benchmark for what can potentially be achieved. As part of the motivation for the *JEDC* paper, we suggested that possibly a constitutional amendment requiring the budget to be balanced in peacetime, or an institutional arrangement that results in the process of policy change being long and protracted (an idea formalized years later by Krusell and Ríos-Rull), could result in policy being much closer to optimal. If so, being able to compare quantitatively with the benchmark of the fully optimal policy would provide strong justification for society to establish such an arrangement.

But the optimal policy needed to be calculated. The main issue in "recursivizing" the problem was to ensure that the effect of future policy on agents' behavior in earlier periods is properly taken into account. We accomplished that task by introducing as a "pseudo-state" variable a Lagrangean multiplier—a shadow price—whose movement over time is an important element in our solution. Variants of this method have been used since by many researchers, including some present at the Credibility conference. Beyond the papers at this conference, especially illuminating is the recent article on recursive contracts by Marcet and Marimon, in which they

include also analysis of a Ramsey problem as an example.

I've written one more paper related to time inconsistency. In Scandinavia, it's not uncommon that as an admired and long-serving professor nears retirement, someone takes the initiative to a festschrift of chapters in his or her honor. For the past several decades, a much admired Norwegian finance professor—number of students, attention in media, etc.—has been Thore Johnsen at NHH. I've known Thore since we overlapped as PhD students at CMU, and over the decades since. So when asked to contribute a chapter in what the editors call an anthology, in Thore's honor, of course I agreed. I'm not enamored with festschrift-like volumes, but in this case the editors suggested an extra reason to be positive. They asked each of us to write our chapter in such a way that it would be accessible not only to professors and graduate students, but also to undergraduates. As I'm sometimes asked to give keynote speeches at conferences, often in China for example, at which few in the audience have a PhD in economics—they're simply interested in economics for whatever reason, some of them perhaps employed in business—it was natural for me to write up, illustrated with plenty of graphs, what I talk about in such speeches. Since 2008, my main theme indeed has been related to time inconsistency. In many countries, institutions are such that it's virtually impossible to carry out good, long-run, growth-promoting policy. On the other end of the spectrum there's Ireland, for example, who in the 1990s and 2000s managed credibly to remove uncertainty about tax policy, with spectacular success.

This anthology chapter, entitled "Policy Consistency and Economic Growth," is available on my home page: finnkydland.com. If you decide it may be beneficial to your class, no need to ask my permission to distribute it (although I'd enjoy hearing about it if you do!)


Hägar the Horrible
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## Director's Message References


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# Credibility

## November 15–16, 2019

**Agustin Samano Penaloza** – University of Minnesota
**Ana Moreno-Maldonado** – European University Institute
**Marco Bassetto** – Federal Reserve Bank of Minneapolis
**Zach Bethune** – University of Virginia
**Javier Birchenall** – UC Santa Barbara
**Henning Bohn** – UC Santa Barbara
**Thomas Cooley** – New York University
**Alessandro Dovis** – University of Pennsylvania
**Finn Kydland** – UC Santa Barbara
**Andy Levin** – Dartmouth College
**Yang Lu** – Hong Kong University of Science and Technology (HKUST)
**Tai Nakata** – Federal Reserve Board of Governors
**Chris Phelan** – University of Minnesota
**Myroslav Pidkuyko** – Manchester & Bank of Spain
**Vincenzo Quadrini** – University of Southern California
**Peter Rupert** – UC Santa Barbara
**Arunima Sinha** – Fordham University
**Kieran Walsh** – UC Santa Barbara
**Juan Pablo Xandri** – Princeton University
**Pierre Yared** – Columbia University
**Eric Young** – University of Virginia

# Reputation and Sovereign Default

Manuel Amador and **Christopher Phelan**

Countries employ a variety of strategies when facing financial crises. Some nations are committed to repaying their debt, while others choose to sacrifice their reputation and default. Motivated by debt-handling strategies one observes in the real world, Manuel Amador and Christopher Phelan investigate the relationship between a sovereign state's reputation and defaulting behavior on its debt.

The authors introduce a framework that is consistent with the reputational theory in sovereign repayment of debt. Reputation is characterized by a set of market beliefs. A sovereign government can be either a commitment type if it doesn't default or an optimizing type if it defaults randomly. For a borrower state, there are three categories of defaulters: "serial defaulters" who have had a history of defaulting in the past; "debt-intolerants," who recently defaulted but maintain a low debt-to-GDP ratio compared with countries that have not recently defaulted; and "graduates," who become trustworthy after years of good behavior.

Chris and Manuel find that in the Markov equilibrium, it is optimal for a country to switch back and forth to imitate committed countries when borrowing, only to reveal its hidden type upon defaulting. A switch is unobservable, but when defaulting takes place, the borrower clears its debt at the cost of its reputation. Nevertheless, if a government has tended to default but decides not to, there will be a big jump in this borrower country's reputation. To derive Markov equilibrium under reasonable assumptions and conditions, the model requires a race between the growth rates of the bond price and the reputation of a state. Consequently, equilibrium in this model exhibits both debt-intolerant and serial default behaviors.

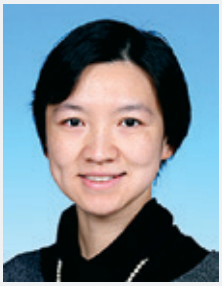
To better understand and illustrate the nature of the constructed Markov equilibrium in the model, Chris presented a numerical example in which the equilibrium path initiates from zero debt and no reputation. Under particular parameter values, the authors estimate that it takes a country 31 years of not defaulting at all to "graduate." On the other hand, had a nation defaulted at any given time, it would take a much longer time (an estimated 200 years) to restore its reputation and be considered a relatively trusted country again.

The presenter also discussed defaulting behavior under initial conditions other than debt-free and zero reputation. In particular, Chris fed random aggregate shocks into the model and showed how this would affect the equilibrium manifold and change the corresponding default and no-default regions.

The audience members raised several questions during the discussion. One asked whether the initial bond price, when a country has no reputation, is unique since the construction of a Markov equilibrium path heavily depends on initial states. Chris replied that he had proved the existence of equilibrium, but the uniqueness is a work in progress. Another participant raised the question of the possibility of speeding up the "graduation" rate. The presenter responded that given a specific set of borrowing rules, this would certainly be possible.

# Managing Expectations in the New Keynesian Model

Robert King and **Yang Lu**



In many macro-economic models, ex ante optimal policies are often not optimal ex post, a phenomenon we call time inconsistency. The typical way of solving for the optimal policy includes an implicit assumption that the ability or the inability of policymakers to commit is observable to private participants. But this is seldom true, and sometimes the commitment ability has to be signalled in a way that has costs. Developing a new Keynesian dynamic model, the authors explore the question of optimal policy when policymakers can commit but are not fully trusted.

The authors study optimal monetary policy in a setting where the private sector is forward-looking, and where learning occurs about the central bank's commitment type. The model considers two types of central banks, a patient type that can commit and a myopic type that cannot. These two types are both rational and choose optimal policies by taking into account the learning and rational expectations of the private sector. New features of this model are that the private sector has forward-looking expectations and that learning is incomplete because inflation outcomes are stochastic given the central bank's policy choices.

To solve the model, the authors adopt a mechanism design approach so that the equilibrium of the model can be obtained as the solution to a recursive optimization problem of the committed central bank. They conclude that a committed central bank with a good initial reputation adopts policies similar to the standard solution under full commitment, which features an initial interval of high but declining inflation ("start-up inflation") to temporarily sustain positive levels of output gap. The committed central bank with poor initial reputation aims at building reputation with anti-inflation policies that involve real costs.

On the other hand, if the central bank is not of the commitment type and has a good initial reputation, there will be lengthy real stimulations with gradually rising actual and expected inflation, followed by stagflation when the history of positive inflation surprises depletes the bank's reputation. The authors also show that equilibrium dynamics under a discretionary type is consistent with the inflation experience of the United States in the 1960s and 1970s.

The biggest concern during the discussion came from using the Phillips curve to pin down current period inflation. The amount of information needed to know the outcome of the policy was not clear. The Phillips curve says that inflation is the linear combination of expected future inflation, the output target, and the cost-push shock. If expected future inflation is exogenous, then after setting the policy goal, everything is fine. But if the expectation is endogenous, and depends on the goal, then the determinant of current inflation is more complicated.

# Expectation Formation, Imperfect Credibility, and the Performance of Forward Guidance Strategies at the Effective Lower Bound

**Andrew Levin** and Arunima Sinha

The authors explore how to deal with problems caused by being near the effective lower bound of interest rates, and in particular what are known as make-up strategies. The authors claim that these strategies, which involve keeping policy accommodative for longer, are not effective because of limited credibility and potential policy errors under uncertainty.

According to minutes from a Federal Reserve meeting, the effectiveness of a make-up strategy "depends on the private sector's understanding of the strategy and on their confidence that future policymakers would follow through on promises to keep policy accommodative." But, according to the authors, model uncertainty and imperfect credibility are impediments to that understanding and confidence. First, the private sector may not believe promises from policymakers about actions in the future, particularly if the policy committees experience turnover. Second, the ability of policymakers to make promises may be hampered by their own limited understanding of the economy.

The authors compare results from a standard Fed Board macro model that has been used extensively to analyze the open market committee's strategies, a model that incorporates limited credibility, and a model that uses a somewhat flattened Phillips Curve. They conclude that the effectiveness of make-up strategies depends on credibility.

In both the limited and full credibility models, the authors increase interest rates from the effective lower bound one to two years after an economic shock. But in the limited credibility model, the authors find that output and inflation are lower than with full credibility. Given an assumption of a flattened Phillips Curve, a shift in the output gap has muted effects on inflation. The authors argue that if the central bank incorrectly formulates its strategy on the premise of a steeper Phillips Curve, then the misperception delays the timing to lift from the lower bound, resulting in inflation remaining elevated for a decade.

Because of these shortcomings of make-up strategies, the authors propose that digital cash can resolve the problem. They claim it can promote financial stability, while serving as an efficient medium of exchange.

Audience members wondered why quantitative easing was not the easiest way to push inflation higher. Some suggested that while freely distributing money might solve a short-term policy objective, it could be very difficult to control excessive levels of inflation subsequently. Before proposing an alternative, some participants felt the authors needed to explain why quantitative easing would not work. There was also discussion about the validity of the Phillips Curve model.

# Credible Forward Guidance

**Tai Nakata** and Takeki Sunakawa

Developing strategies to deal with the effective lower bound constraint on nominal interest rates is an important task for economists and central bankers. In forward-looking models with an effective lower bound, the commitment to keeping the policy rate at the bound for an extended period is thought to be effective in stimulating economic activity during a deep recession, as anticipation of an overheated economy could lead forward-looking households and firms to increase consumption and to set higher prices.

Despite the theoretical value of such overheating commitments or lower-for-longer policies, central banks that have recently faced the effective lower bound have not adopted this type of policy, with the exception of the Bank of Japan. An important argument against overheating commitment policy is its potential time-inconsistency.

The authors study credible policies in a sticky-price model with an effective lower bound, focusing on understanding what the central bank can credibly achieve when optimal commitment policy is not time-consistent. Specifically, the authors formulate and solve a series of optimal sustainable policy problems, in which the central bank chooses state-contingent allocations to maximize welfare that are subject to equilibrium conditions and an incentive-compatibility constraint. The incentive-compatibility constraint requires that the continuation value associated with the chosen state-contingent allocation be at least as large as the continuation value associated with deviating from that allocation.

The authors show that in their model even when optimal commitment policy is not credible, the central bank can still credibly keep the policy rate at the lower bound for an extended period in the aftermath of a crisis. The model suggests that the policy would generate a temporary post-crisis overheating of the economy and mitigate the declines in output and inflation through expectations. The welfare cost of the effective lower bound would be substantially lower under an optimal sustainable policy than under optimal discretionary policy.

Optimal sustainable policies are of interest to central banks for two reasons. First, by construction, the policies are time-consistent, making them immune to criticisms that the promised overshoot of inflation and output associated with any lower-for-longer strategies lack credibility. Second, the authors argue, when the duration of reputational loss is sufficiently short, the policies are not history-dependent, or at least not as history-dependent as optimal commitment policy. If so, the approach would address criticism that the complex policy rate path under a lower-for-longer strategy would be difficult for the central banks to clearly explain to the public.

# Lending Relationships and Optimal Monetary Policy

**Zachary Bethune**, Guillaume Rocheteau, Tsz-Nga Wong, and Cathy Zhang

Many small businesses, in order to finance investments, rely on secure access to credit through stable relationships with banks. Small businesses with access to a credit line or revolving credit arrangement hold 20% less cash relative to firms that are not in a lending relationship, and their demand for cash is more elastic. Insofar as monetary policy affects the cost of cash, it will impact firms differently depending on their access to lending relationships, thereby affecting the value of these relationships and, ultimately, banks' incentives to form them.

Monetary policy is especially critical to relationship lending in times of financial crisis, when banking ties are severed due to bank failures, stricter application of loan covenants, or tighter lending standards. The goal of the paper is to understand the mechanism through which monetary policy affects the creation of lending relationships and its role during financial crises to mitigate the adverse effects of severed credit ties.

The authors develop a general equilibrium model of lending relationships and corporate finance in the tradition of the New Monetarist approach. They use the framework to study the optimal monetary policy in the aftermath of a crisis when the measure of lending relationships is an endogenous state variable. In the model economy, entrepreneurs receive idiosyncratic investment opportunities, which can be financed with bank credit or retained earnings in liquid assets. The interest rate spread between liquid and illiquid assets is controlled by the monetary authority.

Entrepreneurs cannot perfectly self-insure against idiosyncratic investment opportunities, creating a role for banks. Banked entrepreneurs use their liquid assets and bank credit. The model provides a theory of firms' precautionary demand for liquid assets conditional on their access to credit. Firms in a lending relationship hold fewer liquid assets than unbanked firms, and the gap widens as the interest spread between liquid and illiquid assets increases. Moreover, the demand for liquid assets by firms with access to relationship lending is more elastic to the interest rate spread. These findings imply that monetary policy impacts firms differently depending on their access to credit, with banked firms being more negatively affected by an increase in the user cost of liquid assets than unbanked firms.

The authors study optimal monetary policy responses to banking shocks under different assumptions concerning the policymaker's power to commit. If the policymaker can commit, optimal policy entails setting low spreads close to the zero lower bound at the outset of the crisis to promote internal finance by newly unbanked firms. To maintain incentives for banks to participate in the credit market despite lower interest spreads, the policymaker uses forward guidance by promising high spreads in the future. If the policymaker cannot commit, the interest spread falls over time but by a small amount and is typically lower than under commitment. The recovery is considerably slower with no commitment than under commitment, resulting in consumption levels that are lower by 0.036% to 0.057%.

# Commitment and Competition

Thomas Cooley, Ramon Marimon, and **Vincenzo Quadrini**

The paper explores how contractual relationships within different organizational structures affect economic outcomes. It is widely accepted that commitment and competition enhance welfare. However, when there are matching frictions, commitment to individual arrangements could deter entry in equilibrium. Organizational forms like partnerships may be characterized by weaker agency frictions than public companies. The weaker agency frictions allow partnerships to use more efficient arrangements than public companies. But because partnerships are internally more efficient, it will be more difficult for firms to attract someone belonging to an active partnership. In equilibrium this may result in less competition for managers. Less competition implies lower reallocation of human resources if some of the partners could be more productive elsewhere. The equilibrium with partnerships could then be less efficient than with public companies.

The authors propose a model in which investors compete for managers. There are matching frictions. Managers and firms are matched through directed search. Firms could be organized in the form of partnerships or public companies. In both organizations managers have limited commitment, meaning that they can leave the firm and repudiate the contract at any time. The commitment of the firm differs in the two organizations. While in a partnership the firm can commit to the optimal contract, this is not the case in a public company. In particular, a public company will repudiate the contract if the firm's value becomes negative.

If firms commit to long-term contracts, they will fulfill their obligations even if this implies negative profits. Commitment would then make the promise of high continuation utilities credible. Instead, if firms do not commit, they would repudiate the contract if their value becomes negative. This implies that the promises of high continuation utilities are not credible. As a result, firms are unable to match external offers, allowing external firms to profit from matching with employed managers. The prospect of positive profits will then encourage external firms to search for employed managers, reducing the overall mismatch.

In the partnership equilibrium, there is lower turnover of managers and a higher likelihood of mismatch. By changing the organizational structure, equilibrium turnover and matching efficiency can increase, as low quality matches are separated with higher probability. Thus, there are equilibrium benefits to being organized as public companies, and this could offset the costs of lower contractual efficiency. Using a parameterized version of the model, the authors show that with public companies the benefits from greater matching efficiency could be bigger than the contractual inefficiencies. The organizational change generates greater risk-taking, larger size of the financial sector, with higher value added per employee, and higher compensation and greater income inequality within the financial sector. These predictions are consistent with the empirical patterns.

One audience member asked how the result would change if the partnership could choose to not commit. The speaker noted that the answer would depend on the market structure.

# Instrument-based vs. Target-based Rules

Marina Halac and **Pierre Yared**

A familiar debate in monetary policy concerns whether central bank incentives should be based on instruments or targets. The existing theoretical literature has mainly focused on one side or the other. Marina Halac and Pierre Yared develop a model with binary signals and symmetric punishments under a canonical delegation framework to compare the pros and cons of both instrument-based and target-based rules.

Their paper has a wide array of applications, including, but not limited to, monetary policy, fiscal rules, and environmental policy. In this model, a principal makes use of joint punishments as incentives for a better informed but biased agent. In the context of monetary policy, the government relies on such punishments to incentivize the central bank. Rules are either instrument-based or target-based. Instrument-based rules depend on the central bank's observable actions. Target-based rules condition incentives on outcomes, which rely on the agent's actions and private information.

Using mechanism design, Pierre derived the conditions required for both instrument-based and target-based rules to be optimal. In particular, he showed that monetary policies based on targets dominate instrument-based rules if and only if the central bank's private information is sufficiently precise. To prove this, he considered two extreme cases: one with an agent who has perfect information and one with an agent who is uninformed. Target-based rules dominate instrument-based ones given perfect information, and vice versa given no information. An optimal rule for each class takes a threshold form, and an agent will face the worst punishment upon violation. In addition, Pierre introduced another class of optimal unconstrained hybrid rules that can easily be implemented.

An audience member asked if the model could be extended into a continuum of types, and whether this would produce different results. Pierre responded that in a setting with a continuum of signals, the main results of the paper would still apply. However, one caveat is that the hybrid rule would not exist for a continuum of types. Another participant raised a question concerning implementation problems due to unknown IS curves. Pierre responded that it was implicitly assumed in the model that an agent knows the shock at the end of every period and can then make informed decisions.

# Rules Without Commitment: Reputation and Incentives

**Alessandro Dovis** and Rishabh Kirpalani

How should we design rules if there is uncertainty as to whether the rules will be followed by policy makers? Rules are often proposed as a solution to a decision maker's time inconsistency problem. But, as Alessandro Dovis explained, there is tension between what is good in the short run and in the long run. As a result, there is uncertainty as to whether, in the moment of truth, policy makers would adhere to such rules.

The primary example used to motivate this question addressed policy for regulators that could intervene to save failing firms. There is a natural tension between leniency and willingness to give aid to avoid welfare reduction in the short run versus the negative welfare effect this would have in the future. A history of aid from policy makers would incentivise firms to apply less effort toward the costly task of ensuring risks taken were responsible.

The authors modeled policy makers as either a commitment type (implying perfect obedience to a policy rule) or an optimizing type that can choose whether or not to follow the rule. We can imagine the rule designer to be another policy maker, politicians, or voters that have society's best interests in mind. The policy maker's type is unknown to firms or to the rule designer. However, firms will make their choices on the basis of the announced policy rule and on the basis of the policy maker's reputation, which the authors define as the probability that the policy maker is the commitment type.

In solving his model, which makes several general assumptions, Alessandro explained that when a policy maker's reputation is low, lenient policy rules are optimal because maintaining or increasing reputation is critical. In particular the leniency of the rule would be such that it would be followed by the optimizing type as well as the commitment type. This creates uncertainty among firms as to the policy maker's type, which Alessandro showed was actually beneficial in this setting, providing incentive for firms to avoid taking excessive risks.

When a policy maker's reputation is high, Alessandro explained, the rule designer wants to choose a rule that induces separation, meaning that the optimizing type would not follow the rule. This preserves the high reputation and also a continuation of high efforts on the part of firms, which contributes to social welfare.

On the nature of the rule itself, we would normally assume that clear rules were better, and Alessandro said that this was true when a policy maker's type was known. However, he said, if policy maker's type was uncertain, but reputation was high, opaque rules helped to maintain the desired uncertainty without the negative welfare effects of leniency.

The authors also used this model to describe monetary policy, where individuals' actions manifested in wage inflation rates. On this example, a conference participant thought that the benefits of uncertainty seemed counterintuitive. Alessandro responded that if an individual knew they were dealing with the optimizing type, their actions would result in excessively high inflation. However, with some uncertainty, policy makers could optimally exert some control on inflation, but with some wiggle room.

Several audience members raised questions as to whether this model of policy setting and response would be valid in more realistic settings. First, a question was raised on the benefits of uncertainty: would an individual or firm prefer the state of uncertainty and not wish to learn the policy maker's type with certainty? The individual would want to learn in order to maximize his own payoffs, Alessandro said, but the individual also would prefer social welfare benefits of uncertainty among peers, and as a result should ideally prefer the state of uncertainty to be maintained. The rule designer, as a representative of people but not any one individual, clearly would wish to preserve uncertainty when uncertainty improved welfare.

# Robust Predictions in Dynamic Policy Games

Juan Passadore and **Juan Pablo Xandri**

A common problem when game theory is used to make predictions about real-world phenomena is evaluating among multiple equilibria without a clear sense of which is most likely. It may be possible, Juan Xandri explained, to find common properties across these equilibria, and thus make predictions that are robust to the multiple equilibria problem.

A motivating example in Juan's presentation involved the decision by a government whether to pay its debts or instead to default. Juan also discussed some preliminary work on extending this approach to another, related example, involving monetary policy under a New Keynesian framework.

The author used a model where the market determines the bond's price at issuance, in essence determining the interest rate that a government pays. A country experiences unpredictable fluctuations in income, and a government would choose pay its debts only if it is optimal from a finances standpoint in this model. It is assumed that the worst-case response of the market to a government choosing to default is autarky (the government will never again be allowed to auction off debt), but there are no other negative consequences. But this does not imply that the market is required to impose autarky and reject future bond offerings from a government that had ever defaulted. We would not expect, in this model, for the choice to default to affect a country's income.

Juan showed that, after viewing all the observable actions taken so far, it was possible to identify the potential equilibria that generated those past actions. Then, it was possible to add detail to potential future developments in the game. Juan produced, for instance, a maximum and minimum continuation value for the prices of bond issues by a government that had chosen not to default, given any history. The minimum continuation value, Juan showed, was increasing in the opportunity cost of not defaulting. The maximum amount of the borrowing-to-income ratio was identifiable, as well. Furthermore, many of the same details held in expectation under a framework that included correlated equilibria.

Juan provided some intuition on what factors influence the price of issued debt in this framework. On the one hand, higher debt issuance choice implied opportunities existed for the government to obtain a better return than the interest rate on the bonds, which in turn implied healthier income. This would likely cause the market to price bonds higher. However, this effect was limited because as the quantity of debt rises, so too does the utility of default. In some ways, this resembles reputation, Juan said. If the opportunity cost of continuing to pay debts is high (in other words the utility of default is high), and the choice to default is rejected, it should mean that expectation for the future is positive. Juan noted that though this wasn't precisely the idea of reputation, it worked very similarly.

An audience member raised a question about the usefulness of the model when government issues debt with multiple maturities, as opposed to the single-period bonds assumed here. Juan said that this was a topic that he had not yet pursued, but that it seemed including an additional state variable could address this nuance.

# Organizational Equilibrium with Capital

**Marco Bassetto**, Zhen Huo and José-Victor Ríos-Rull

The authors look for an equilibrium concept that addresses shortcomings of Markov and best sequential equilibria, while capturing the fact that good institutions and social norms take time to build. They propose organizational equilibrium. This new equilibrium concept is especially suitable for the study of macroeconomic policy in models with state variables and time-inconsistency problems.

Like Markov equilibrium, payoffs in the organizational equilibrium depend only on state variables (not on history), but unlike Markov, actions can (and will) depend on history. Unlike sequential equilibrium, organizational equilibrium does not rely on self-punishment. Finally, organizational equilibrium relies on two subgame perfect equilibrium refinement criteria: first, same continuation value on and off the equilibrium path; and second, no one is made better off by deviating and counting on others to restart the game. In essence, this makes it renegotiation-proof.

The authors apply the organizational equilibrium concept to a quasi-geometric discounting growth model and to a problem of optimal dynamic fiscal policy. The presentation focused on the first application. The quantitative findings indicate that the allocation starts close to that implied by a Markov equilibrium, and it gradually converges to an allocation close to the Ramsey outcome. Ultimately, the steady state allocation is preferable to that of the Markov equilibrium, but stops short of the Ramsey outcome. A member of the audience asked about the possibility of gradual erosion of collaboration across cohorts of decision makers, and Marco replied that it would require shocks.

In the quasi-geometric discounting growth model, the organizational equilibrium corresponds to the optimal organizationally admissible sequence of saving rates. This sequence satisfies "no restarting": the subutility is weakly increasing over time; and "no delay": the first agent has no incentive to delay the proposal. An audience member asked if the weakly increasing condition implied that the decision makers coming after the current one must be at least as well off as the current one, to which Marco responded that indeed this was the case.

Another audience member suggested that if someone deviates, a way to restore the equilibrium is that the next agent starts from the initial saving rate. The authors show that the saving rate of the Ramsey outcome, as well as a sequence of constant saving rates, cannot be an organizational equilibrium. Instead, they show that the transition implied by this new equilibrium concept is such that the initial saving rate will be close to that of the Markov equilibrium, and it will converge to a saving rate close to the Ramsey outcome, as credibility gradually builds. An audience member asked what would happen if agents were incredibly impatient, and Marco responded that, in such a case, the savings rate converges to the Markov equilibrium.

An audience member asked about the relationship between the organizational equilibrium and the timeless perspective. Marco replied that, in this framework, the timeless perspective would correspond to the Ramsey outcome, and, as he showed, organizational equilibrium never converges to this outcome. Another member of the audience asked about the role of population growth, and Marco said that the model could easily be adapted to incorporate population growth.

## One Size Fits All? Estimating Tax Elasticities Across Time

Patrick Macnamara, **Myroslav Pidkuyko**, and Raffaele Rossi

The team's research explores long-run effects of tax policy. The existing empirical literature has primarily estimated short-run effects at a given point in time, or estimated long-run effects over many years. In this paper, the authors provide complementary evidence by estimating a life-cycle model and quantifying the tax policy transmission mechanism. This allows them to compare the long-run effects of tax changes in 1983 with 2016 in the United States, which they find to be substantially different.

The authors use a life-cycle model with labor and capital income risk. Labor supply is endogenous, where labor productivity features ex-ante heterogeneity across households, changes over the life-cycle, and idiosyncratic shocks. Return on wealth is also risky, where households face stochastic entrepreneurial productivity and can either become entrepreneurs or lend their savings to other households. In order to create baseline models for 1983 and 2016, the authors combine directly estimated parameters (e.g., tax function, labor productivity age-profile) and time-invariant calibrated parameters (e.g., risk aversion, discount factor), and estimate the remaining parameters to match observed wealth and earnings distributions.

Participants had several questions about the model, and the presenter clarified that entrepreneurship is undertaken alongside (not instead of) labor income, and that, upon death, wealth is redistributed to other households by the government. Multiple participants were also curious as to why the top marginal tax rate in the model didn't match the statutory top marginal income tax rate, with one participant suggesting that this may be due to the Alternative Minimum Tax. The presenter indicated that the estimated tax rate was an average across capital and labor income, and the model backs out marginal tax rates from average tax rates because marginal rates are not available at the household level. Furthermore, he emphasized that what is important in this setting is not the level of the tax function, but the change from 1983 to 2016. Finally, several participants questioned the choice to model Social Security as a flat-rate balanced-budget government program separate from income taxes, given that Social Security is not currently solvent and that self-employed individuals pay a higher rate.

Given the estimated models at two points in time, the authors then conduct a policy exercise of cutting the top marginal tax rate by five percentage points and compare the new steady-state outcomes to identify long-run effects. They find that a $1 decrease in tax revenue increases GDP by $2.38 in 1983, but only by $1.17 in 2016. Furthermore, the long-run elasticity of taxable income to the net of average marginal tax rate is around 0.68 in 1983, and 0.47 in 2016. Tax policies have a smaller effect in 2016 along the whole distribution of income, though the difference is more pronounced for the top 1%. The presenter acknowledged certain assumptions made in the model, but that it allowed the authors to compare the effects of tax policy across time and across income groups in a way that existing empirical evidence has not.

The study then disentangles these results by closing off various channels in the model. They find that most of the differences between 1983 and 2016 result from the decline in the progressivity of taxes, increased dispersion of labor productivity, and increased concentration of wealth. A participant expressed a desire for more discussion of the evidence from this disentangling exercise and the key takeaways. Several participants agreed with the authors on the importance of generating a right tail of earnings and wealth distributions, but wondered whether alternative methods to the one chosen here based on entrepreneurship, would give similar results.

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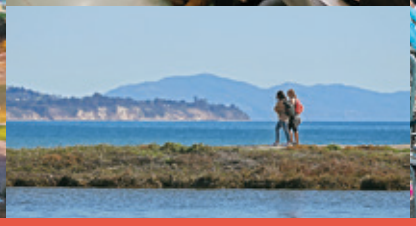

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