I am an applied macroeconomist, and my research contributes to the microfoundations of information-constrained macroeconomic theory. I use a blend of applied theory, empirical, and experimental methods to study how limited attention and imperfect information shape individual choices and aggregate outcomes. My work is grounded in macroeconomics in terms of research questions and basic methodology, but pursues an interdisciplinary approach, drawing on research in behavioral economics, psychology, and cognitive neuroscience.

A. Background

The macroeconomic modeling framework that has flourished since the Rational Expectations Revolution of the 1970s assumes that economic agents make decisions based on rational forward-looking beliefs about the evolution of the economy and the choices made by all other agents. In most workhorse models, these beliefs are furthermore based on perfect information about the economy. This framework has been tremendously fruitful and has generated a breadth of influential predictions and policy recommendations. Nevertheless, to match the evidence of smooth, gradual adjustment of aggregate economic variables over the business cycle, this framework has been extended to incorporate a range of adjustment costs and time-varying frictions. But real world evidence of such features has been mixed. At the same time, a large literature in psychology, behavioral economics and finance has documented that individuals systematically deviate from the benchmark of fully informed rational behavior that is assumed in these models.

In a series of influential papers, Nobel Laureate Christopher A. Sims (1998, 2003) challenged the plausibility of the many adjustment costs and frictions used to improve the empirical fit of modern macroeconomic models; instead, he proposed that aggregate sluggishness arises from decision-makers’ limited capacity to process information about their environment. Macroeconomic models of imperfect information had been considered before, going back to Edmund Phelps (1970) and Robert Lucas (1972), but these earlier models had a relatively modest impact on macroeconomic analysis. Sims’s innovation was to propose using an information theoretic measure to quantify the average amount of information economic agents need to make the fully informed choice in a given context. This measure is entropy, the building block of Claude Shannon’s (1948) theory of communication, and a quantity with solid axiomatic foundations as a measure of uncertainty. Having such a measure enables the modeler to define a
cost function for information, which in turn means that information choice can be modeled just like any other choice: to maximize benefits net of costs. In this framework, agents are “rationally inattentive”: they make optimal choices about how to allocate their attention given their objective, the uncertainty in their environment, and the cost of obtaining information to reduce this uncertainty. My research applies the rational inattention framework to key questions in the areas of monetary economics and income inequality, and also tests its predictions using controlled laboratory experiments.

B. My Agenda

My research agenda includes two complementary programs of work that develop and test the rational inattention paradigm: (1) building models to assess how information choice impacts economic outcomes---with specific applications to price rigidity, the effectiveness of monetary policy, and inequality; and (2) designing controlled laboratory experiments to measure the information processing costs and attention limitations that affect decision-making---with a focus on how they generate discrete adjustments, affect strategic considerations, and yield persistent heterogeneity in beliefs.

The two programs reinforce each other: open questions in macroeconomics motivate the design of controlled laboratory experiments that seek to identify certain frictions or biases in decision-making, and the results from laboratory experiments then serve as motivation to improve theories of decision-making and to draw out implications for macroeconomic outcomes. The proposed models of decision-making are then tested against large data sets of field data on economic decisions. I expect this process to be a recurring theme in my future research.

1. Implications of Information Frictions

My work in this area shows that incorporating the information acquisition problem into economic models can have surprising consequences for aggregate outcomes and policy, challenging the predictions of full-information models. My research uses micro-level data sets to develop statistics that discipline quantitative macroeconomic models, in order to generate counterfactual analyses and to infer policy implications.

“Coarse Pricing Policies” (Review of Economic Studies, Accepted) contributes to the literature on inflation determination and monetary policy effectiveness. It demonstrates how a theory of information-constrained price setting connects and addresses three central questions in the literature: (i) what explains the muted dynamics of inflation during the Great Recession and its aftermath, (ii) how effective is expansionary monetary policy in times of high volatility in real economic activity, and (iii) how can the large transitory volatility of prices at the product level be reconciled with the slow-moving dynamics of aggregate inflation. In recent years, these questions have challenged the workhorse models of price setting and our conventional measures of price rigidities and monetary policy effectiveness.
First, I show that modeling price-setting firms as rationally inattentive generates both volatile prices at the product level and sluggish adjustment in the aggregate. Firms use a menu of noisy, coarse prices to roughly track the optimal price while saving on information costs. This pricing generates both volatility and mistakes, which aggregate to a slow response of inflation to shocks.

The consensus that has recently emerged in the monetary literature is that much of the volatility of prices at the product level does not matter for macroeconomic dynamics, and can be filtered out by the researcher. However, I argue that filtering out this volatility risks misstating the nature of pricing rigidities and biasing estimates of how inflation responds to shocks. Empirically, I show that firms whose pricing policies feature more transitory price changes also adjusted prices more aggressively in response to the big disturbances that occurred during the Great Recession. The proposed theory then quantifies the importance of transitory price changes for this result. Counterfactual simulations show that ignoring transitory price changes would affect both the impact response to shocks and the persistence of the aggregate inflation rate.

The model also predicts that in periods of heightened uncertainty, such as during the Great Recession, firms that are information-constrained choose to keep prices elevated, to protect themselves against the losses from underpricing in a more volatile environment. This precautionary overpricing can help rationalize in part why prices did not fall more during the last recession.

Lastly, the paper challenges the notion that monetary policy becomes less effective in periods of high volatility, such as the Great Recession. The endogenous information mechanism is key: When volatility increases, information-constrained firms respond by acquiring more information. But they do not overshoot in their acquisition of information, because information is costly. As a result, the degree of price rigidity remains high and monetary policy remains highly effective. This contrasts existing theoretical results from alternative sticky price models, which predict less monetary policy effectiveness when volatility rises.

“Price Rigidity during the Great Recession” (with Camilo Morales-Jimenez; Working Paper) further contributes to the monetary economics literature on price rigidities. The central question we ask is: Did the informational rigidities that prevent prices from adjusting flexibly to shocks become more severe during the Great Recession? We study the dynamics of prices in a large data set and develop a quantitative model to address this question in three steps.

First, we document that underneath the relatively muted inflation dynamics, the Great Recession featured significant cyclical changes in the distribution of price changes. We document that the frequency, skewness and kurtosis of price changes increased during the crisis, while the absolute size and standard deviation declined.

Next, we show that these patterns can be rationalized with a model of price setting with costly information, but are inconsistent with models of rigid prices based on perfect information. We develop a model of information-constrained price setting in which both the decision of whether or not to update prices and the decision of what price to charge once the price is updated are based
on noisy signals about market conditions. We modify the model to allow firms to be partially myopic in their information choice, rather than fully optimizing their information choices.

Finally, we estimate our model to match the dynamics of both macroeconomic aggregates and pricing moments. Matching the dynamic pattern of the pricing moments helps us estimate the degree of nominal rigidities, informational frictions, and myopia in information choice. We find that most of the rigidities in price setting come not from infrequent but from inaccurate adjustment. Moreover, the data suggest that these frictions became more severe in the depth of the recession. We estimate that large shocks to risk premia and inflation expectations drove both volatility in real economic activity and the worsening of informational rigidities. In isolation, these findings would imply a high degree of monetary policy effectiveness. However, in practice, we estimate that while extremely expansionary, monetary policy was thwarted by other economic shocks throughout the crisis.

The theoretical in this paper setup is motivated by the evidence documented in Khaw, Stevens and Woodford (2017), discussed below. It illustrates how evidence accumulated using controlled laboratory experiments can be successfully used to provide microfoundations for frictions in macroeconomic models.

“Price Dispersion and the Border Effect” (with Ryan Chahrour, Journal of Monetary Economics, Revise and Resubmit) moves to the open economy setting and contributes to the literature on trade frictions and differences in prices across countries. A large literature in international macroeconomics has concluded that the large and volatile differences in the prices of even identical goods across countries imply a high degree of cross-country segmentation.

In this paper, we challenge this conclusion by demonstrating an identification problem in distinguishing between segmentation between countries and segmentation that exists at the regional level, within countries. Using a model of price dispersion in which retailers have imperfect information about the prices of different producers who are active in their market, we show that cross-country price and trade data are not sufficient for resolving this identification challenge. However, incorporating data on regional trade flows identifies segmentation at both the national and the regional level.

We take our model to the data using evidence from the United States and Canada. Our central finding is that the evidence of product-level price dispersion combined with information on regional trade flows indicate that much of the measured market segmentation occurs at the subnational regional level. Splitting the United States in two equal-sized regions, we estimate that on average producers are three times more likely to sell to retailers in their own region than to retailers in the “away” U.S. region. Crossing the national border further reduces access, but the additional reduction in access is an order of magnitude smaller.

We also uncover asymmetry across countries in the severity of these frictions. Canadian producers are seven times more likely to sell in their own region than in the “away” Canadian region, and 11 times more likely to sell in their own region than in an American region. Overall,
regional bias is a major component of the national home bias, and it appears more severe for Canadian producers. In a counterfactual exercise, we show that the data are not far from a parameterization in which all segmentation comes from regional, rather than national frictions.

“Investor Sophistication and Capital Income Inequality” (with Marcin Kacperczyk and Jaromir Nosal, *Journal of Monetary Economics, 2018*) contributes to the literature on income inequality. A large body of work has sought to identify the factors that can account for the rapid growth in capital income in the United States in the last thirty years. This literature studies random growth models, which feature exogenous returns on investments, akin to the outcomes of entrepreneurial activity. Instead, we consider an equilibrium model of the financial market in which returns are determined endogenously, as a function of investors’ demand for different financial assets. This provides a powerful source of amplification in the growth of inequality. We show that the availability of information in the economy can have large distributional consequences. In the presence of informational asymmetries across individual investors, technological progress that improves access to information can disproportionately benefit the relatively more informed group, resulting in an acceleration of inequality in the medium run, followed by plateauing in the long run.

The paper shows this mechanism in the context of a portfolio choice model in which information-constrained investors make decisions about how much to invest in different risky assets. When investors differ in their capacity to process news about risky asset payoffs, both the size and the composition of the risky portfolios differ across investors. Not surprisingly, this generates inequality. More interestingly, progress in the aggregate information processing technology can exacerbate this inequality, and this effect can be economically large, as less sophisticated investors get priced out of high-return assets. This pecuniary externality is amplified in an economy with heterogeneous assets because the shifts in ownership shares occur asymmetrically across assets. Allowing investors to choose how to learn about different assets is critical here: With endogenous information choice, the sophisticated ownership share grows most for the most volatile assets, which are precisely the assets that generate the largest capital income gains.

2. **Evidence of Information Frictions and Limits to Attention**

This part of my research agenda uses controlled laboratory experiments to measure the attentional and cognitive limitations that people face in the process of decision-making. Experimental work is not very common in macroeconomics, but it is particularly suitable for testing theories of information frictions. Not only do we know the subjects’ objective (since we incentivize them to do a particular task or to solve a particular problem), but we also control the data generating process, and the information that the subjects receive. Therefore, we can test to what extent the subjects are using this information optimally, and what aspects of the environment affect their information use. I use the results of these experiments to inform theories of decision-making in economic contexts, as described above. Therefore, the experimental designs seek to capture the essential aspects of decision-making in a macroeconomic context, by featuring tasks that require
the tracking of random variables, forward-looking, incentivized decisions, and, in some cases, payoffs that depend on other subjects’ behavior, to emulate the strategic considerations that are present in macroeconomic models.

Discrete Adjustment to a Changing Environment: Experimental Evidence (with Mel W. Khaw and Michael Woodford, Journal of Monetary Economics, 2017) is motivated by the pervasive evidence of lumpy adjustment in economics. Many economic decision variables change infrequently, even though the relevant market conditions evolve continuously. This behavior is often attributed to fixed costs of adjustment, even though there is little direct evidence about the magnitude of such costs. Here we present evidence for an alternative view, under which such discrete adjustment economizes on the cognitive resources of decision-makers.

In the first part of the paper, we report results from a controlled laboratory experiment in which participants were incentivized to forecast the outcome of a simple random variable. The experiment is designed to minimize the costs of adjusting. Nevertheless, we find that our subjects adjust their forecasts infrequently, and moreover, they exhibit patterns of behavior similar to those documented in the product-level price setting literature. Furthermore, since we control the information that the subjects observe at each point in time, we can test if participants incorporate information optimally in real time. We find this is not the case: subjects’ forecasts deviate significantly from the Bayesian forecasts.

To rationalize these deviations, we develop a model of decision making under cognitive limitations, in which both the decision of whether to update one's forecast and the decision of what forecast to make are subject to cognitive limitations. This model generalizes existing models of cognitive limitations by allowing mistakes to occur along both dimensions.

Quantitatively, we show that our experimental data allow us to reject many familiar models of discrete adjustment in favor of the model of cognitive limitations. We conclude that much of the evidence of discrete adjustment in choices at the individual level may in fact reflect such limitations rather than fixed costs of adjustment. Distinguishing between cognitive limitations and fixed costs has important implications for policy. For example, if cognitive limitations are malleable and respond to incentives or to changes in the environment, the severity of the friction may not be independent of economic conditions. Ozbay and Stevens (2019, in progress, discussed below) is part of a wider research area that has documented using controlled laboratory experiments that cognition is flexible and responds to incentives.

We also extend the model to allow decision-makers to have intrinsic preferences for certain actions over others. These intrinsic preferences allow the decision-maker to deviate from the optimal information-constrained behavior predicted by the pure model. Our data support the existence of these deviations from the baseline model. In particular, we estimate that our subjects adjust too often, given the mistakes that they make when adjusting. The baseline model without intrinsic preferences would predict an even lower rate of adjustment than that observed in the data.
The results from this experiment have already informed my macroeconomic models – specifically, the price setting model I use with my co-author Camilo Morales Jimenez, described above).

“Adjustment Dynamics during a Strategic Estimation Task” (with Mel W. Khaw and Michael Woodford, Working Paper) contributes to the literature on how beliefs are formed in strategic settings. The dominant paradigm for how we model expectations in macroeconomics is the rational expectations (RE) hypothesis. This paradigm assumes that agents use all the information they have optimally and, furthermore, also understand and take into account the fact that all other agents in the economy behave in this way. In short, agents are not only Bayesian, but also strategically sophisticated. An extensive experimental literature in game theory has documented that subjects are, by and large, strategic, in that they think about how others might behave, but they are limited in their strategic thinking. This work has mostly used static, one-shot experiments.

We contribute to this literature by designing a controlled laboratory experiment that is more suited to testing the type of decision-making relevant to macroeconomic models. Our subjects face a simple strategic estimation task that requires them to make many repeated forecasts. They observe in real time how well they are doing, and are given all the information they need to form the RE forecast.

In the experiment, we consider a probability estimation task in which payoffs depend on both individual forecasts and the group average. Subjects have the information to compute the RE forecast, and moreover, this forecast is simple to compute. Nevertheless, forecasts differ considerably from the RE predictions. Average forecasts are noisy, biased, and respond incompletely to news about the fundamental. Moreover, strategic considerations affect adjustment dynamics, with complementarity resulting in large deviations from equilibrium predictions, while substitutability results in fast convergence.

We evaluate the extent to which our subjects conform to the predictions of game theoretic Level-k literature, the bounded rationality strategic alternative to RE. However, given the evidence of noisy adjustment, we consider a stochastic Level-k model. Roughly one third of our subjects employ limited strategic thinking. This finding contrasts results from static experiments, which typically find that 10% or less of subjects are non-strategic. This divergence underscores the importance of including dynamic considerations in experiments. Moreover, we show that these non-strategic participants are very influential in driving the aggregate (group level) dynamics: Their noisy, heterogeneous responsiveness to new information contributes significantly to the gradual adjustment of the aggregated forecast. Our findings suggest that strategic contexts may make forecasting random variables even more difficult than our previous experiment found.
“Costly Cognition” (with Erkut Ozbay, in progress) designs a laboratory experiment to test the flexibility of cognition. We ask subjects to perform a simple visual matching task that requires varying degrees of attention. We limit subjects’ response times and find that even in this constrained setting, attention is malleable: it responds to incentives and to task difficulty. Nevertheless, accuracy declines with task difficulty, which implies that the attention reallocation does not fully compensate for task difficulty. We consider a model of cognition that endows agents with a total level of capacity, but allows agents to adjust how much capacity to allocate to a particular task within this overall limit. We then use experimental data to test how flexibly the allocation of capacity responds to incentives. We find evidence that attention allocation is somewhat lumpy and can generate both weak and sharp adjustments in response to small changes in task difficulty. We conclude that a model with fully flexible allocation of attention may overstate the degree to which subjects optimize information choice.

“Individual Differences in the Perception of Probability” (with Mel W. Khaw and Michael Woodford, Working Paper) contributes to the literature on probability estimation biases in psychology. Prior work in psychology has documented significant distortions of subjects’ forecasts relative to objective probabilities. However, the nature of the distortion differs across studies, with some studies documenting conservatism in subjects’ revisions of forecasts, while others find overconfidence. These seemingly conflicting reports reflect differences in the tasks analyzed and in the statistical methods employed to identify the bias. Thus far, no dominant reconciliation of the conflicting results has emerged.

In this paper, we study the subject-level data from the experiment of Khaw, Stevens and Woodford (2017, described above). We fit to the data a family of computational models that describe the subjective encoding of probabilities reported by our subjects as a noisy function of the optimal Bayesian estimate. In our estimation, we allow for heterogeneity in three dimensions: momentum, over-reaction, and variance. The first is a level effect, allowing subjects to systematically over- or under-estimate; the second captures the spectrum of conservatism to over-reaction; and the third determines the level of random noise in the estimates.

When the data from all subjects are pooled, estimates of momentum and over-reaction are statistically insignificant, and the variance of the aggregated forecast is small. However, at the individual level, we document the coexistence of both conservative and overconfident subjects for the same task. These individual differences are correlated with the subjects’ adjustment patterns and decision times, with more conservative subjects adjusting less frequently and also taking a longer time to decide. Moreover, the biases are persistent at the individual level, despite ample opportunities to learn from systematic mistakes.

**Ongoing Work**

My ongoing research agenda includes a set of projects that continue to focus on the information acquisition problem at the individual level and its implications for the aggregate economy, using
a diversified set of methods. First, I am currently developing a model in which imperfect memory and attention provide a microfoundation for the sluggish adjustment of expectations that has been documented in macroeconomic surveys. This project is a continuation of the set of papers that address sluggish adjustment in macroeconomic data as a result of information frictions. Second, motivated by the evidence in Ozbay and Stevens (in progress) that attention seems to be re-optimized infrequently rather than continuously, I am developing a model that asks to what extent infrequent reallocation of attention can generate the coexistence of both over-reaction and under-reaction to new information that has been documented in the macroeconomics and finance data. This model will also connect to the evidence of systematic biases documented in Khaw, Stevens, and Woodford (2019, working paper) on individual differences. I also plan to continue conducting laboratory experiments to test the nature of information frictions and the shape of the information cost function. In particular, my co-authors and I are currently planning a larger scale experiment testing for heterogeneity in biases, with the goal of identifying if subjects cluster at the extremes of the conservatism-overconfidence spectrum, or if they align themselves on a continuum.

A subset of the research described above is part of a joint research agenda with Mel Khaw (Duke Center for Cognitive Neuroscience) and Michael Woodford (Columbia Department of Economics), as part of the “Attentional and Perceptual Foundations of Economic Behavior Program,” an interdisciplinary research program that seeks to bring together economists, psychologists, and cognitive neuroscientists to advance our understanding of limits to perception, attention and cognition, and their roles in shaping economic decision-making.

References


