Research Statement

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My research focuses on finance and macroeconomics and their interface with decision theory, industrial organization, and public finance. I have pursued two basic themes. First, actual economies feature a variety of frictions such as adjustment costs, uninsurable idiosyncratic risks, liquidity constraints, asymmetric information, and agency conflicts. The bulk of my research is to develop models to explore how these frictions influence firms' or entrepreneurs' investment and financing decisions, and market equilibrium. I also study their implications for asset prices, and for fiscal policy such as dividend tax reform.

Second, individual choices may be inconsistent with the standard expected utility model and rational expectations, as documented by many experimental and empirical studies. In addition, many asset pricing puzzles such as the equity premium puzzle provide a serious challenge to the standard risk-based models. A part of my research is to develop models to investigate how nonstandard preferences and departure from the rational expectations hypothesis affect individual decision making and asset market equilibrium.

The rest of my statement is organized according to my past, present, and future research topics along the preceding two themes. I review my work on investment and financial policies in Section 1, on dynamic general equilibrium models with incomplete markets in Section 2, on asset pricing and market microstructure in Section 3, and on applications of nonstandard preferences in Section 4.

1. Investment and financial policies, and firm dynamics

By the celebrated Modigliani and Miller Theorem, in a world without any market frictions such as taxes, transactions costs, market incompleteness, information asymmetry, and agency conflicts, a firm's capital structure and dividend policies are irrelevant, and financial and investment policies are independent. One of my main research topics is to study how market frictions influence investment and financial policies at both the micro and macro levels.

I begin by reviewing my research on investment. Real investment often incurs adjustment costs, and thus may be partially or completely irreversible. Making an irreversible investment decision is analogous to exercising an American call option. This real options approach to investment has been widely used to study capital budgeting and other corporate decisions. Some of my research is to extend this approach and apply it to a variety of economic questions.

a. Irreversible investment with regime shifts

Business cycles are often associated with regime shifts. Regime shifts in demand conditions may influence a firm's cash flows or growth opportunities, and hence its investment policy and capital accumulation. In "**Irreversible investment with regime shifts**," (*Journal of Economic Theory, 2005*), Xin Guo, Erwan Morellec and I provide an irreversible investment model, in which the demand shocks are modeled as a regime switching process. For this process, the growth rate and volatility of cash flows shift between different states at random times. We derive a closed-form solution to the value-maximizing investment policy. We make a technical contribution to characterize this optimal policy by partitioning the state space into three regions, rather than two regions in the case of a geometric Brownian motion process. If the state variables (capital and shock) lie in the inaction region, no investment occurs. Outside of this region, investment can be infinitesimal or lumpy. It is infinitesimal at the investment threshold, but lumpy in the transient region or at the initial date when the state variables lie in the action region. Lumpiness of investment has been widely documented in empirical studies. The usual interpretation relies on the presence of non-convex adjustment costs. Our analysis suggests that regime shifts alone may generate lumpy investment behavior. We also show that marginal q and the user cost of capital are regime dependent.

b. Investment under uninsurable idiosyncratic risk

The standard real options approach to investment typically assumes that markets are complete or the decision maker is risk neutral. This assumption is often violated in many investment and financing problems in reality. For example, risk-averse entrepreneurs are often exposed to uninsurable or undiversifiable idiosyncratic risks, and thus they face incomplete markets. Because of information asymmetry and moral hazard, an entrepreneur's investment options are often non-tradable, and there may not exist complete assets to span the payoffs of the investment projects. In a series of papers with Neng Wang, we take market incompleteness as given and explore the implications of uninsurable idiosyncratic risk for an entrepreneur's investment, financing, consumption/savings, and portfolio choice decisions.

In "**Investment, consumption and hedging under incomplete markets**," (*Journal of Financial Economics, 2007*), we develop a real options model of investment for an entrepreneur who faces uninsurable idiosyncratic risks from his investment project. The entrepreneur also makes consumption/savings and portfolio choice decisions to smooth consumption and to partially diversify risks. In this case, the key insight that volatility raises the option value of waiting in the real options literature may not be valid. In our model, there are two opposing effects. First, volatility has a positive effect on the entrepreneur's investment option value because of the convex payoff structure of options, as in the standard real options analysis. Second, idiosyncratic volatility lowers the certainty equivalent value of the investment option for the risk-averse entrepreneur, because of his precautionary saving motive. The net impact of volatility on the option exercising decision is ambiguous, depending on

whether the convexity effect or the precautionary saving effect dominates. We use both an analytical asymptotic approximation method and a numerical projection method to analyze the net effect of an increase in volatility. Our results and intuition can be best understood in the special case where the entrepreneur can trade a risk-free asset only.

In reality, investment payoffs may be given as a lump-sum value or as a stream of stochastic cash flows. We show that, in the lump-sum payoff case, when the entrepreneur has a sufficiently strong precautionary saving motive or the idiosyncratic volatility is sufficiently large, the precautionary saving effect may dominate the convexity effect. As a result, idiosyncratic volatility encourages the entrepreneur to invest earlier, opposite to the prediction of the standard real options analysis. In the flow payoff case, due to the precautionary saving motive, uninsurable idiosyncratic risk lowers the certainty equivalent values of both the investment project and the investment option by the same magnitude to the first-order approximation. As a result, an increase in volatility delays option exercising due to the convexity effect, as in the standard real options analysis. Intuitively, in the lump-sum payoff case, after exercising the investment option, the entrepreneur does not expose himself to the idiosyncratic risk from the investment project. By contrast, in the flow payoff case, after exercising the investment option, the entrepreneur still exposes himself to the idiosyncratic risk from the stream of investment cash flows.

In our work in progress with Hui Chen, "**Entrepreneurial investment and financing decisions under uninsurable idiosyncratic risk**," we develop a model of an entrepreneur's joint investment and financing decisions. This work is motivated by the puzzling empirical evidence documented by Graham and Harvey (2001). They find that small firms and firms with high managerial ownership are less likely to apply the standard capital asset pricing theory and the net present value rule. To explain this puzzling evidence, we argue that in contrast to shareholders of public corporations, entrepreneurs or managers in small firms are exposed to undiversifiable idiosyncratic risk because they have limited access to the financial markets due to asymmetric information, or because they are restricted from selling the shares of their firm due to regulations or compensation contracts. Our key insight is that uninsurable idiosyncratic risk lowers the entrepreneur's subjective valuation of equity, and issuing risky debt has a risk sharing benefit. Thus, an undiversified entrepreneur may choose higher leverage than a fully diversified entrepreneur.

Uninsurable idiosyncratic risk is important not only for investment and financing decisions, but also for firm dynamics. Some empirical evidence shows that entrepreneurs on average do not earn more than paid employees in terms of present value. One may ask why individuals want to stay in business and take entrepreneurial activities. Neng and I address this question in "**Experimentation under uninsurable idiosyncratic risk: An application to entrepreneurial survival**." In this paper, we propose an analytically tractable real-options model in which an entrepreneur does not know his investment quality and learns about it over time. We show that due to the option value of learning, an entrepreneur may stay in business

even though the net present value (NPV) is negative. We also show that risk aversion erodes option value and lowers private firm value so that a highly risk-averse entrepreneur may exit even when the NPV is positive. We also show that a more risk-averse or a more pessimistic entrepreneur exits earlier. Finally, the model can generate the positive relation between wealth and survival duration without liquidity constraints. In ongoing research, we plan to extend this model to analyze strategic experimentation with multiple risk-averse agents.

c. Capital structure, credit risk, and industry dynamics

Many studies have documented empirical evidence on the relation between capital structure and firm entry, exit, investment, and production decisions. However, simply taking leverage ratio as an exogenous regressor may be misleading. This is because rational firms may anticipate the effect of leverage on product/input market behavior so that the latter may influence capital structure choices. This endogeneity problem makes the interpretation of the empirical evidence controversial. The extant models in the literature typically either hold investment policy fixed and study capital structure decision, or hold capital structure decision fixed and study the effect of capital structure on investment policy.

To study the interaction between investment and financial policies, I embed the Leland (1994) single-firm capital structure model in a continuous-time competitive industry equilibrium framework in my paper "**Optimal capital structure and industry dynamics**," (*Journal of Finance, 2005*). In the model, there is a continuum of heterogeneous firms subject to idiosyncratic productivity shocks. These firms make investment, financing, entry, and exit decisions. The capital structure choice reflects the tradeoff between tax advantages of debt and the associated bankruptcy costs and agency costs. After debt is in place, shareholders make investment and default/exit decisions to maximize equity value, instead of firm value, reflecting the conflict of interests between shareholders and debtholders. The interaction between financing and investment/production decisions influences the stationary distribution of firms and their survival probabilities. I solve the model in closed form. I show that the equilibrium output price has an important feedback effect on the capital structure decision. The intuition is that a change in an exogenous variable may influence firm value and hence firms' entry and exit decisions. This changes industry competition and output price. The changes in industry price in turn affect a firm's investment and financing decisions.

This mechanism generates a number of novel testable implications: First, industries with high technology growth or good starting distributions of technology have relatively lower average leverage, lower turnover rates, and higher output. Second, industries with risky technology have relatively lower average leverage, higher turnover rates, and higher output. Third, industries with high bankruptcy costs have relatively lower average leverage, lower turnover rates, and lower output. Fourth, industries with high fixed operating costs have relatively lower average leverage, higher turnover rates, and lower output. Finally, industries with high entry costs have relatively higher average leverage, lower turnover rates, and lower output.

In the preceding paper, I assume that firms are subject to idiosyncratic productivity shocks only. Many empirical studies have documented that leverage is countercyclical and moves with business cycles. Motivated by this observation, in the paper joint with Dirk Hackbarth and Erwan Morellec, "**Capital structure, credit Risk, and macroeconomic conditions**" (*Journal of Financial Economics 2006*), we incorporate both macroeconomic aggregate shocks and firm-specific idiosyncratic shocks into a continuous-time partial equilibrium Leland-type capital structure model. We consider finite maturity debt and the firm can adjust capital structure dynamically over time. We model the aggregate shock as a regime switching process reflecting cyclical macroeconomic conditions, and the idiosyncratic shock as the usual geometric Brownian motion process. This modeling is important because the extant diffusion (structural) models of capital structure and credit risk typically overpredict leverage ratios and underpredict both credit spread and default probabilities. Our model overcomes this problem. Our model can replicate the observed debt levels and the countercyclicality of leverage ratios. It can reproduce the observed term structure of credit spreads, and can generate strictly positive credit spreads for debt contracts with very short maturities. The model also provides a novel testable prediction: Firms adjust their capital structures more often and by smaller amounts in booms than in recessions. We also make a technical contribution in that we provide a closed-form solution for a default problem and a dynamic capital structure problem with regime switching processes. We show that default can be triggered either when the idiosyncratic shock reaches a threshold in a given regime or when there is a regime shift of macroeconomic conditions. The latter may explain the default and exit clustering observed in practice.

d. Mergers and acquisitions in oligopolistic industries

Making a merger decision is analogous to exercising an exchange option. That is, management decides whether and when to exchange the existing firm value for another value derived from the merged entity. This decision is costly and may be irreversible. Management can determine the timing of a merger. To analyze the timing, returns, and terms of mergers and acquisitions, a recent literature applies the real options approach. This literature, however, typically ignores the equilibrium interaction among firms in an industry. Intuition suggests that product market competition should influence firm value and hence merger decisions. On the other hand, mergers change industry structure and hence industry competition. In "**The timing and returns of mergers and acquisitions in oligopolistic industries**," Dirk Hackbarth and I develop a real-options model of mergers and acquisitions in an industry equilibrium framework. We study the interaction between industry structure and takeovers by extending Perry and Porter's (1985) static model to a dynamic continuous-time environment. We also introduce bidder competition and study bid premium. In a Cournot-Nash industry equilibrium, firms have an endogenous incentive to merge when restructuring decisions are motivated by operating and strategic benefits. We derive a closed-form solution to the industry equilibrium. Our model predicts that: (i) merger activities are more likely in more concentrated industries or in industries that are more exposed to industry-wide shocks; (ii) returns to merger and rival

firms arising from restructuring are higher in more concentrated industries; (iii) increased industry competition delays the timing of mergers; and (iv) in sufficiently concentrated industries, bidder competition induces a bid premium that declines with product market competition. These novel testable predictions are useful for empirical studies.

e. Investment and tax policy

Capital market imperfections affect not only individual investment and financial decisions, but also aggregate behavior and economic policy. In a series of papers joint with Francois Gourio, we explore the implications for dividend tax policy. Under the U.S. tax system, dividends are taxed at both the corporate and personal levels. In addition, the tax rate on dividends was higher than that that on capital gains before the 2003 tax reform. This tax wedge makes external equity finance more costly than internal finance, and thus distorts investment efficiency. Partly motivated by this consideration, the Bush government enacted the Jobs and Growth Tax Relief Reconciliation Act (JGTRRA) in 2003. This act reduced the tax rates on dividends and capital gains and eliminated the wedge between these two tax rates through 2008. Because one primary goal of JGTRRA is to promote long-run capital formation, these tax cuts could be made permanent. An important question is: What is the quantitative long-run effect of dividend taxation on aggregate capital accumulation?

Economists disagree about the economic effects of dividend taxation on investment. Two views are prevalent. The key consideration is the marginal source of investment finance. Under the "new view," firms use internal funds and do not raise new equity. Thus, dividend taxation does not influence the user cost of capital and investment. Under the "traditional view," the marginal source is new equity and the return to investment is used to pay dividends. A dividend tax cut reduces the user cost of capital and hence raises investment. Empirical evidence on these two views is inconclusive.

In "**Firm heterogeneity and the long-run effects of dividend tax reform**," Francois and I build on the existing literature on dividend taxation in two distinct ways. First, we embed the traditional single-firm model used in empirical studies in a computable dynamic general equilibrium framework. Second, we incorporate a continuum of heterogeneous firms in the model. These firms are subject to idiosyncratic productivity shocks. This firm heterogeneity generates a cross-sectional distribution of firms across three different finance regimes, with some firms behaving according to the traditional view of dividend taxation and other firms behaving according to the new view of dividend taxation. We document empirical evidence that firms' investment and financing patterns are different in different finance regimes, and that the distribution of firms across finance regimes changed after the 2003 tax reform. This evidence supports our model mechanism.

We use our calibrated model to provide a quantitative evaluation of the 2003 dividend tax cut. Our simulations suggest that a permanent cut of the dividend tax rate alone raises the long-run capital stock by a small magnitude. In addition, it raises total factor productivity and labor

productivity by a small magnitude. This result is primarily generated by the reallocation effect in our model with tax frictions and decreasing returns to scale in production. When both dividend and capital gains tax rates are cut down to the same level permanently, aggregate effects are much larger. The reason is that the user costs of capital for all firms are reduced and this reduction has a larger effect on capital formation. We also show that when shutting down the price feedback effect in a partial equilibrium model, the increase in capital is much larger, suggesting that a partial equilibrium model for policy analysis may be misleading.

Dividend taxation has not only a long-run effect on aggregate capital accumulation, but also a temporary effect. In addition, tax changes are often temporary. In work in progress with Francois, "**Transitional dynamics of dividend tax reform in General Equilibrium**," we develop a dynamic general equilibrium model with firm heterogeneity and entry and exit to study the permanent and temporary effects of dividend tax reform. Because of computational complexity, we start with a single firm partial equilibrium model to understand the key intuition in the paper, "**Dynamic effects of permanent and temporary dividend tax policies on corporate investment and financial policies**.**"** In this paper, we study a firm's behavioral responses to dividend tax changes. In the model, the firm decides how much to invest and how to finance investment subject to collateral constraints and capital adjustment costs. When making financing decisions, the firm decides whether to use internal funds, debt, or external equity. The firm can borrow or save and may be in one of three finance regimes: dividend distribution, equity issuance, and liquidity constrained. The firm is forward-looking and has perfect foresight about the future course of tax policies. We find some interesting results: First, an anticipated temporary dividend tax cut has a short-run effect of lowering investment, similar to an anticipated permanent dividend tax increase. Second, a firm responds asymmetrically to an anticipated permanent dividend tax increase versus an anticipated permanent dividend tax cut due to the collateral constraint. Finally, in anticipation of future tax changes, the firm engages in tax arbitrage by borrowing or saving in order to transfer corporate earnings across time so as to reduce shareholder's tax burden.

I now turn to corporate income tax policy. In work in progress, "**Corporate tax policy and long-Run capital formation: the Role of irreversibility and fixed costs**," I build an analytically tractable continuous-time general equilibrium model of investment with firm heterogeneity. I plan to analyze the role of irreversibility and non-convex adjustment costs in the effects of corporate tax policy on long-run capital formation and welfare. A key insight is that a change in the corporate tax rate changes both the size of capital adjustment and the number of adjusting firms. In addition, this change not only affects cost of capital, but also has a reallocation effect that affects average labor productivity.

2. Dynamic General equilibrium models with incomplete markets

I have reviewed my work on the implications of uninsurable idiosyncratic risk for individual investment and financing decisions. I now turn to my work on aggregate behavior and market

equilibrium. When households are heterogeneous in their uninsurable idiosyncratic employment risks, market interactions among these agents determine aggregate savings and wealth distribution. This issue is often studied in an important workhorse model, called the Bewley model. Although many researchers provide numerical solutions to this model, there are two open theoretical questions in the presence of both aggregate and idiosyncratic shocks. The first question is the existence of a sequential competitive equilibrium and the second is the existence of a recursive competitive equilibrium. These two questions are of fundamental importance for numerical work. I address these questions in "**Competitive equilibria of economies with a continuum of consumers and aggregate shocks**" (*Journal of Economic Theory, 2006*). I give a novel existence proof. The key insight is to describe the economy in terms of sequences of aggregate distributions. I begin with a detailed analysis of an individual's decision problem. After aggregating individual optimal behavior and deriving the law of motion for aggregate distributions, I establish the existence of a sequential competitive equilibrium by applying a fixed-point theorem to a compact space of sequences of aggregate distributions. This result is established under standard assumptions on preferences and technology and for fairly general individual and aggregate shock processes.

After imposing the additional assumption that individual and aggregate shocks are time-homogenous Markov processes, I turn to recursive characterizations of sequential competitive equilibria. I define recursive equilibrium with the state variables consisting of individual asset holdings, individual shocks, aggregate shocks, the aggregate distribution, and the continuation utility value. Including continuation value as a state variable to make certain decision problems recursive is a technique widely adopted in the literature on sequential games and on dynamic contracts. Here this state variable serves as a device for selecting continuation equilibria when the economy unfolds over time.

Computation of competitive equilibrium is important in macroeconomics, but is difficult for economies with heterogeneous agents and market frictions. Equilibrium allocations in economies with frictions are typically not Pareto optimal. In this case, a recursive equilibrium with the natural state space may not exist. Manuel Santos and I tackle this issue in work in progress, "**Existence and computation of Markov equilibria for dynamic non-optimal economies**." Our key insight is to include marginal utility as an additional state variable. In this case, a suitably defined Markov equilibrium exists. We develop numerical methods to solve such equilibria for financial economies and production economies with finitely many heterogeneous agents and with a variety of frictions.

3. Asset pricing and market microstructure

A variety of frictions exist in financial markets. In this section, I review my work which focuses on the implications of two types of frictions, asymmetric information and search, for asset prices and trading.

a. Asymmetric information

In financial markets, some investors are informed and some are not. This information asymmetry is useful for understanding asset prices and trading volume as shown in the dynamic rational expectations equilibrium literature (e.g., Wang (1993, 1994)). This literature typically assumes that agents have information about current and past data such as prices and dividends. In the paper joint with Rui Albuquerque, "**Advance information and asset prices**," we introduce a novel assumption that informed agents have private information about a firm's future earnings or growth opportunities. The presence of advance information makes the model solution difficult because both informed and uninformed agents solve complicated forecasting problems. By suitably defining state variables, we derive a closed-form solution to equilibrium under the assumption of exponential utility and normal random variables. We find that the equilibrium stock price incorporates advance information and may move irregardless of fundamentals. Thus, the model helps explain the stock excess volatility puzzle. We also find that stock returns may exhibit the phenomena of short-run momentum and long-run reversals. The momentum and reversal effects provide a serious challenge to the efficient markets hypothesis and standard risk-based models. Many researchers have shifted attention to behavioral models, where investors are boundedly rational and arbitrage is limited. A common behavioral interpretation is that investors underreact to current news and overreact to consistent patterns of news pointing in the same direction. Our model provides a rational account of the underreaction and overreaction effects. In ongoing research, Rui and I plan to analyze the case where advance information is public to all investors. We also plan to conduct both theoretical and empirical studies of the implications of advance information for trading volume.

The above paper assumes competitive markets. In the paper joint with Dan Bernhardt, "**Informed trading when information becomes stale,"** (*Journal of Finance, 2004*), we study strategic interactions among heterogeneously informed agents. In this paper, we address one of the most important open questions in theoretical market microstructure finance: How do informed speculators trade in a dynamic environment when different speculators receive distinct signals at different dates? What has made this problem so difficult is that each informed agent's trading problem is intrinsically different because the nature of each agent's information is different. One must simultaneously solve each informed agent's trading problem and solve for the consistent equilibrium pricing at each date. To do so, one must solve the forecasting and information extraction problems of these agents, and address how they trade over time.

We solve this challenging problem. We consider an environment in which new, normally-distributed innovations to the asset's value arrive in each period. The key step in our analysis is to first conjecture and then verify that: (i) an equilibrium pricing rule is a linear function of net order flow; (ii) the optimal trading strategy of an informed agent is a linear function of each piece of his unrevealed private information, i.e., the difference between each signal and the expectation of that signal given public information; and, (iii) an informed agent's expected

future trading profits are a quadratic function of this private information. Our main finding is the following: The price impact of order flow crucially depends on both how information is divided among informed agents and the timing of information acquisition. For the price impact of order flow to rise with time, the sequential arrival of sufficiently heterogeneous information is necessary. Moreover, such information arrival can generate the U-shaped intra-daily volume found in the data, and the increasing spreads, volume, and price volatility that arise as an event window approaches.

b. Search

In the modern economy, some commodities and assets are traded in both centralized and decentralized markets. In centralized markets, trades are intermediated by market makers at publicly posted bid-ask prices. In decentralized markets, traders search counterparties and face search frictions. Prices are negotiated and transactions are conducted in private meetings among traders. Traders can choose which market to enter. This observation raises the following questions: How does the market fragmentation influence liquidity and the bid-ask spread? What is the social consequence of the market fragmentation?

In the paper "**A search model of centralized and decentralized trade**" (*Review of Economic Dynamics, 2006*), I provide a simple search model to shed light on these questions. I carefully set up the model so that I can derive a closed-form solution. The key mechanism in the model is the externality effects generated by one market on the other market, and by one trader on the other traders. I show that the bid-ask spread reflects the transaction cost in the centralized market and the search frictions in the decentralized market. Surprisingly, I show that compared to the competitive market-making, monopolistic market-making may improve social welfare, because it partially internalizes the externalities of bid-ask prices on the decentralized market. This might explain why the monopolistic specialists system on the New York Stock Exchange could be socially useful.

4. Applications of nonstandard preferences

Many experimental and empirical studies have documented the failure of the standard expected utility model. Thus, researchers have developed many new utility models in decision theory. These new utility models may be useful in addressing some empirical puzzles in macroeconomics and finance. One line of my research is to apply some of these new utility models to the study of some puzzling economic phenomena.

a. Ambiguity and model uncertainty

Under the rational expectations hypothesis, there exists an objective probability law governing the state process, and economic agents know this law which coincides with their subjective

beliefs. This rational expectations hypothesis has become the workhorse in macroeconomics and finance. However, it faces serious difficulties when confronting with asset markets data, e.g., the equity premium puzzle. The Ellsberg Paradox and related experimental evidence demonstrate that the distinction between risk and ambiguity is behaviorally meaningful. Roughly speaking, risk refers to the situation where there is a probability measure to guide choice, while ambiguity refers to the situation where the decision maker is uncertain about this probability measure due to cognitive or informational constraints. Knight (1921) and Keynes (1936) emphasize that ambiguity may be important for economic decision-making.

In "**A two-person dynamic equilibrium under ambiguity,**" (*Journal of Economic Dynamics and Control, 2003*), Larry Epstein and I try to understand the home bias puzzle in international finance based on ambiguity. This puzzle describes the behavior that (i) domestic investors invest more in domestic assets than in foreign assets, and (ii) country-specific consumption growth is highly correlated with country-specific output growth. This behavior apparently violates risk sharing and cannot be explained by the standard risk-based complete markets models. In the paper, we provide a novel explanation for the home bias puzzle. Our key hypothesis is that domestic investors are more ambiguous about foreign shocks. It is intuitive that investors may not be familiar with foreign markets, institutions, and firms. There are some empirical studies that document the widespread fact that investors tend to invest in the familiar, with the home bias being just one instance. We formalize this intuition and set up a novel two-agent pure-exchange economy model with recursive multiple-priors preferences. We solve the model in closed-form and show that our model can explain the home bias puzzle qualitatively.

In the paper joint with Nengjiu Ju, "**Ambiguity, learning, and asset returns**," we apply the recursive smooth ambiguity utility model of Klibanoff et al. (2005, 2006) to the study of aggregate stock returns. This utility model is analytically more tractable than the recursive multiple-priors model. In addition, it permits a separation between ambiguity and ambiguity attitude. In the multiple-priors model, the set of priors represents both ambiguity and ambiguity aversion, which makes the interpretation of comparative statics and calibration difficult. Note that the multiple-priors model is a special case of the smooth ambiguity model with extreme ambiguity aversion.

We provide the first quantitative asset pricing application of the smooth ambiguity preferences. Our model has two main ingredients. First, we assume that aggregate consumption follows a hidden Markov regime-switching process. The representative agent learns about the hidden state based on past consumption data. The posterior state beliefs capture fluctuating economic uncertainty and drive asset return dynamics. Second, we assume that the representative agent is ambiguous about the hidden state and his preferences are represented by the smooth ambiguity model. Unlike the standard Bayesian theory, this utility model implies that the posterior of the hidden state and the conditional distribution of the consumption process given a state cannot be reduced to a predictive distribution. We derive the pricing kernel for the smooth ambiguity utility. In order to derive quantitative implications, we propose two tractable utility

specifications: log-exponential and power-power. We obtain both analytical results and numerical results (using the projection method). By calibrating the model, we show that it can match the first moments of the equity premium and the risk-free rate in the data. In addition, our model can generate a variety of dynamic asset pricing phenomena, including the procyclical variation of price-dividend ratios, the countercyclical variation of equity premia and equity volatility, and the mean reversion and long-horizon predictability of excess returns.

In ongoing research, I plan to explore further applications of the smooth ambiguity preferences and the quantitative implications of learning under ambiguity. Examples include portfolio choice, credit spread, monetary policy, and heterogeneity. I also plan to extend this utility model to permit a three-way separation among risk aversion, ambiguity aversion, and intertemporal substitution.

b. Temptation and self-control

One key insight of the standard real options analysis is that there is positive option value of waiting. However, if the decision maker is tempted by immediate gratification and suffers from self-control problems, then he may procrastinate or preproperate. The procrastination and preprorperation behavior cannot be explained by the standard expected utility model and the standard real options analysis. This behavior is usually explained by time inconsistency using the hyperbolic discounting model. This model has two undesirable predictions in the presence of uncertainty in an infinite-horizon discrete-time setting: (i) there is no generally agreed welfare criterion; (ii) there may be multiple equilibria, including equilibria with cycles. For an investment problem, a cyclic equilibrium implies that the odd numbered selves never invest and even ones always invest.

Motivated by this consideration, I adopt the Gul and Pesendorfer (2001, 2004) self-control utility model to analyze an agent's option exercise decision under uncertainty over an infinite horizon in the paper "**Option exercise with temptation**" (*Economic Theory*, *2008*). This utility is time consistent, but can be used to explain time inconsistent behavior. I show that the cost of self-control lowers the benefit from continuation or stopping and may erode the option value of waiting. When applied to the investment and exit problems, the model can generate the behavior of procrastination and preproperation. In addition, unlike the hyperbolic discounting model, the model provides a unique prediction for the option exercise timing, which is characterized in a closed-form solution.