My research interest includes dynamic structural models in oligopolistic competition, biased belief in dynamic games, finite mixture models and consumers' preferences. In my future research career, I will focus on finite mixture models and dynamic decision models and empirical consumer/firm strategic actions.

In empirical studies using the dynamic game framework, one commonly used technique assumes rationality in the estimation. However, under many circumstances assuming the rationality of the firms is restrictive. One of the cases is how firms coordinate through multiple equilibria in dynamic oligopolistic competition. My job market paper, *"Trust in a Dynamic Game: A study on Collusive Price-fixing in the Chilean Pharmaceutical Retail"*, discusses firms' coordination issues when initiating collusion using the facilitating strategy of price leadership. Literature in collusion focuses on the *implementation* but overlooks the *initiation* of collusion. By understanding the economics behind collusion initiation, the government can tailor policies to prevent collusion from emerging. The paper is the first to model the firms' initiation problem using a structural model that accounts for both *incentive problems* and *coordination problems*. The *incentive problems* refers to whether there exists a sustainable collusive equilibrium. The *coordination problems* relates to firms' uncertainty about multiple sub-game perfect equilibria. The work contributes to understanding the firms' learning-to-coordination process during the initiation of a collusive episode. This paper proposes a model to account for the firms' uncertainty regarding which equilibria they are in during collusion initiation by imposing firms to hold biased beliefs towards a competitive equilibrium. Firms' firm-specific "belief parameters" capture the biasness in the beliefs: the "belief parameters" take the value from 0 to 1, where 0 represents firms holding beliefs they are in the competitive equilibrium, and 1 represents firms are rational in the dynamic pricing of price leadership. Firms gradually build up the trust and learn other firms' "true" probability to cooperate in the price leadership mechanism, and the "belief parameters" will converge to the unbiased beliefs. Identifying the belief parameters relies on two exclusion restrictions: (1) one firm's lagged pricing decision affects his payoff through adjustment costs while other firms' lagged pricing decisions do not. (2) The profits on a given market are not affected by the market outcomes in other markets. The framework with nonequilibrium belief represents the data observed better than the rational expectation model. This model provides a framework that allows players to deviate from equilibrium strategies and model their convergence to a coordinated equilibrium. This model account for firms' non-rational beliefs in a parsimonious way. Furthermore, this framework allows the researchers to test whether the players' beliefs are in equilibrium.

Another issue in the dynamic decision models that remain unsolved is how to incorporate unobserved heterogeneity. The technique requires iterations in computation and henceforth is daunting in combination with dynamic choice problems. In joint work with Hiro Kasahara, *"Using Euler Equation to Estimate Non-Finite-Dependent Dynamic Discrete Choice Model with Unobserved Heterogeneity"*, we propose an estimator for dynamic discrete choice models with unobserved heterogeneity employing the Euler equation technique. In the dynamic discrete choice analysis, controlling for unobserved heterogeneity is an important issue, and finite mixture models provide flexible ways to account for it. The previous discussion of incorporating the finite mixture model in the dynamic discrete choice model focuses on a class of models where the difference in future value terms depends on a few conditional choice probabilities(finite dependence property). In models that do not exhibit finite dependence property, it is computationally costly to estimate finite mixture models with the expectation-maximization(EM) algorithm. Arcidiacono and Ellickson (2011) discusses the finite mixture in dynamic discrete choice with finite dependence property. My joint work with Hiro Kasahara adopts the EM algorithm to incorporate unobserved heterogeneity for a broader range of the dynamic discrete choice model that does not require the finite dependence property. Following the Euler Equation(EE) representation of dynamic discrete decision problems, we provide an alternative conditional choice probability (CCP) value function representation. This representation relies only on the CCP of one action. Our contributions, contrasting to the Hotz-Miller CCP representation that relies on all the conditional choice probabilities, is that we propose a characterization that avoids the matrix inversion in each EM iteration. The matrix inversion can be computed outside the EM iterations, and therefore this characterization

is computationally attractive. The characterization provides an unbiased estimator for models with and without finite dependence property. We illustrate the computational gains with Monte Carlo simulations.

I am interested in extending the Euler-Equation representation of the dynamic discrete choice models to more generalized questions. One work in progress, *"Dynamic Decision Models with Continuous-Discrete Mix Choices"*, generalizes the Euler equation expression to estimate the dynamic choice problems where agents make both discrete and continuous choices. In dynamic decision problems, agents can make both discrete and continuous choices at the same time. The existence of both types of choices is natural under some circumstances. For example, empirical industrial organization literature examines firms' entry and investment decisions. The decision of entry is discrete, and the decision of investment is continuous. Blevins (2010) provides identification results of the class of dynamic discrete-and-continuous-choice models. We show the discrete-and-continuous model is equivalent to the agents' decisions that simultaneously map every possible state to an outcome. We can represent the agent's future value with the discounted payoff from repeatedly taking an arbitrary action with the property. The estimation technique is the first to account for the Dynamic decision models with discrete-continuous-mix choices.

The project, *"Dynamic Discrete Choice Model with Many Choices"*, apply the Euler Equation approach to dynamic discrete choice problems with large control spaces. Researchers compute the value function from the probability-weighted average of the continuation value in a model where an agent faces many choices. The estimator requires the conditional choice probabilities(CCPs) of many choices to be correctly estimated. The result derived in the Euler equation shows that value function admits the expression that is a function of the CCPs of an arbitrary function. The characterization requires a consistent estimation of a single CCP instead of all the CCPs.

My other interest lies in the finite mixture models. In joint work with Hiro Kasahara, *"Testing the Number of Components in Finite Mixture Normal Regression Model with Panel Data"*, we develop a test for the number of components in the finite mixture normal panel regression model. We implement the test by considering the sequential likelihood-ratio test of the null hypothesis of a m_0-component model against an alternative of $(m_0 + 1)$-component model. The finite normal mixture models suffer from three major issues, the infinite Fisher Information matrix, the unbounded likelihood ratio and the loss of strong identifiability. We reparameterize the parameters in the direction orthogonal to the zeros under the null hypothesis following Kasahara and Shimotsu (2012). The likelihood ratio test statistic can be approximated by a local quadratic expansion of squares and products of the reparameterized parameters. We show mathematically the finite mixture normal panel regression models suffer from unbounded likelihood and singular Fisher Information matrix. To account for the infinite information matrix and the unbounded likelihood issue, we obtain the data-driven penalty function via computational experiments to attend to the unbounded likelihood ratio. We apply the test to random coefficient Cobb-Douglas production function estimation following the framework of Gandhi et al. (2016) and Kasahara and Shimotsu (2015). The empirical findings suggest evidence of heterogeneous production technology beyond the Hicks-neutral technology factor.

I am also interested in consumer choices of durable goods and how consumer preferences can be shaped over time. Another work in progress, *"Does the EV rebate program raise awareness on the environment: evidence based on China automobile market"*, identifies consumer preference change based on individual choice data. This project uses administrative vehicle registration data from one of China's major cities to identify consumers' preference over household vehicles' gas-efficient attributes over time. We propose to evaluate the long-run effect of electric vehicles(EV) adoption policy on the consumer's preference using administrative data from one major city in China. The data contains registration, transfer and disposal record from January 2010 to the present. The administrative data include the Vehicle Identification Number(VIN) of the registered vehicle, the household district information, the gender, and the consumer's date of birth. The identification relies on the relative preference of high displacement vehicles and low displacement vehicles. The Chinese tax structure creates a discontinuity in demand for the displacement attribute. The Chinese government imposes a

7.5% consumption tax for a vehicle with engine displacement below 1.6 litres and a 10% tax for those above 1.6 litres(Xiao (2011), Xiao and Ju (2014)). The level of the difference between vehicle above 1.6-litre displacement compared to those below 1.6 litres conditional on rebate program for electric cars over time can explain whether the consumers' preference for environmentally friendly vehicles has changed.

My current research projects are in the areas of econometrics of dynamic decisions and consumer/firm strategic actions. In econometrics of dynamic decisions, I am developing an Euler-equation-derived algorithm that can be applied to more generalized models such as models with the discrete-continuous mixed decision or models with a large choice set. In the topics of consumer/firm choice, I am working on topics on durable goods consumptions.

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