November 9, 2015

Re: Letter of Recommendation for Zhe Yuan

I am pleased to write this letter of recommendation for Zhe Yuan. Zhe is a graduate student in the Department of Economics at the University of Toronto. I have known Zhe for about three years now and have had the pleasure of serving on his Dissertation Committee together with Victor Aguirregabiria (his primary supervisor), Andrew Ching and Yao Luo. Zhe also worked as a research assistant for me a number of years ago.

Over the three years that I have worked with Zhe, I have seen him develop into a careful, thoughtful and productive researcher. Zhe does work in Empirical Industrial Organization and Applied Econometrics. Broadly speaking, he builds and estimates structural models with the goal of uncovering structural parameters that can be used to understand and inform key economic and/or policy questions. He has a promising set of papers comprised of his job market paper, a second sole-authored paper and two other papers co-authored with faculty in the Economics Department. He has been very productive during his PhD and shows tremendous potential for developing and executing an independent program of research. A defining feature of his work is combining sophisticated econometric methodologies with important economic questions and a strong institutional knowledge of his empirical setting. **I think Zhe would be a great candidate for an Economics Department or research institution looking to hire in Empirical Industrial Organization or Applied Econometrics.**

Zhe has undertaken a very ambitious job market paper. His paper develops and estimates a structural model of network competition in the airline industry. A key feature of the airline industry is the organization of routes (or flights) into networks. It is now well recognized that networks confer a variety of benefits to airlines. First, networks enable airlines to transfer passengers between flights, thereby allowing them to operate larger fuller flights out of their hubs and exploit economies of scale at the flight level. Second, networks allow airlines to benefit from economies of scale and scope at the airport level, lowering the costs to an airline of entering a route from an endpoint at which it has existing service. Third, networks confer benefits on the demand side as airlines with a large network at an airport can provide a higher quality product through greater frequency as well as a more highly valued frequent flier program.

The existing empirical literature on the airline industry has recognized the important role of networks in this industry. Many papers in this literature – both structural and reduced-form - estimate how network considerations impact route-level decisions or outcomes. For example, Berry (1992, *Econometrica*) studies how endpoint airport presence impacts the profitability of serving a particular route. Berry and Jia (2010, *AEJ: Microeconomics*) build a structural model of airline demand and explicitly include the number of destinations served by an airline from an airport as a product characteristic in the utility function. Early work by Borenstein (1989, *Rand* and 1991, *Journal of Political Economy*) estimates how the size of an airline's network at an airport impacts its fares and market share on routes out of that airport. However, in all of these papers – as well as in numerous other papers in the literature – the airline's network structure is treated as *exogenous* and the goal is

to estimate how the existing network impacts behavior and/or equilibrium outcomes in particular markets.

Zhe takes a fundamentally different approach to studying airline networks. Zhe is interested in modelling and understanding how airlines form their networks, taking account of the various linkages that exist across the flight segments that comprise their network. Thus, in his paper, he endoegenizes airlines' network and capacity decisions. To my knowledge, it is the first paper in the literature to do this. This is a challenging undertaking and Zhe approaches it in a creative and novel way. He develops a three-stage game in which airlines first choose which segments to serve with non-stop service (this determines which routes they serve with direct and one-stop service), then choose what capacities to offer on each segment and, finally, compete in prices taking everyone's networks and capacities as given.

To estimate the model, he begins by estimating the marginal revenue of additional capacity on a route. While he does not estimate a BLP-style demand model, his reduced-form price and quantity equations allow him to capture the various positive and negative spillovers that occur when an airline adds capacity on a particular segment. For example, he shows that the marginal revenue of an additional seat on segment i-j can be decomposed into six different sources of revenue increases or decreases: the additional revenue of using that seat for non-stop service between i and j, the additional revenue of using that seat for connecting service via endpoint i (e.g.: k-i-j), the additional revenue of using that seat for connecting service via endpoint j (e.g.: i-j-m), the cannibalization of revenue from direct service between i and j, the cannibalization of revenue from direct service between k and j, and the cannibalization of revenue from direct service between i and m. This decomposition is simple and intuitive yet it highlights that additional capacity in a particular segment impacts numerous parts of an airline's network and that capacity decisions cannot be studied by considering segments in isolation. Zhe uses the estimates from his demand estimation to calculate the marginal revenue of adding capacity in each segment. He then backs out the marginal cost of capacity by assuming that capacity decisions are set optimally so that marginal revenue equals marginal cost. Finally, using equilibrium prices, quantities, marginal revenues, marginal costs and the observed network structure, he is able to back out bounds for the fixed costs of serving a segment based on revealed preference.

The overall goal of Zhe's paper is to estimate these structural parameters so that he can carry out counterfactual exercises. The particular counterfactual he considers in the paper is the entry of JetBlue Airways into the Atlanta-New York segment. He uses his model – and a clever way of carrying out the counterfactual without actually computing an equilibrium – to show that JetBlue's entry into that segment would generate capacity changes by both JetBlue and competing airlines in not only that segment but in other segments connecting to those endpoints. While the particular counterfactual that he currently includes in the paper is perhaps not the most illuminating one, I want to emphasize that there are many potential applications of his model. It is indeed the case that many shocks to the airline industry are likely to have a first-order impact on airlines' networks; yet, we don't currently have a framework for estimating how airlines will reorganize following a shock. Let me offer a few examples. First, consider the recent wave of mergers between U.S. airlines. One likely outcome of the mergers will be a reduction in the overall number of hubs in the U.S. For example, a combined United-Continental does not need as many hubs as the two airlines had separately, in particular if they have hubs in similar geographic regions. We have already seen the airline de-hub in Cleveland and there is speculation that Denver may be de-hubbed as well. Understanding (in

advance) how mergers may impact the size and existence of hubs is an important question which requires a model such as Zhe's to address. Second, there has been very little work studying innovation in aircraft technology. Over time, aircraft manufacturers have introduced new types of planes that have distinct capacity/range profiles from the existing planes in airlines' fleet - for example, consider the invention of the 50, 70 and 90 seat regional jet. As airlines adopt these new plane types, they will change the set of routes that are served with direct vs. connecting service. This, of course, will impact those routes that see service changes. But, as Zhe's model shows, this will also impact other segments in their network. Understanding the full impact of changes in aircraft technology thus requires a model like Zhe's to determine how changes in service on certain segments will impact fares, quantities, capacity and even possibly entry in others. Finally, I imagine that Zhe's model can be adapted to study linkages between airlines' domestic and international networks. Given that an airline's domestic network feeds its international network, a model like Zhe's could be used to shed light on how shocks to international markets will impact domestic networks and vice versa. I think this would be a very interesting extension of his work and, to my knowledge, there has been very little research on the interactions between airlines' domestic and international networks.

Overall, I think Zhe will be an interesting and productive Industrial Organization researcher. While his work is a little distant from my own in terms of methodologies (I myself do not do structural work), my impression is that he is a talented and careful econometrician and I know that his main supervisor, Victor, thinks very highly of his technical skills. Moreover, I believe that he is genuinely interested in applying those skills to important (and not yet answered) economic questions. I think the current draft of his paper perhaps focuses more on the technical aspects of the model than the economics of the research question but I suspect this is only because it is easier for him to communicate the former than the latter. It is clear from speaking with Zhe that he is passionate about both the methods and the economics in his papers. He has developed a keen enthusiasm for the airline industry and is always quick to ensure that his model and results reflect the unique institutional features of this setting.

Zhe is a pleasure to interact with. He listens carefully, works hard and is deeply motivated. He would be a generous colleague and department citizen. I encourage you to consider his application.

If you need any additional information, please do not hesitate to contact me.

Sincerely,

Mara Lederman
Associate Professor of Strategic Management