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Letter of Recommendation for Yichen (Christy) Zhou

I am writing to enthusiastically recommend Yichen (Christy) Zhou to a department looking for someone who works at the intersection of Energy, Environment and Industrial Organization. Christy is one of the brightest and most energetic students whom I have supervised at the University of Maryland. I would put her on a par with my co-author Ron Chan, who is an Assistant Professor at the University of Manchester. Christy's job market paper "Knowledge Capital, Technology Adoption, and Environmental Policies: Evidence from the US Automobile Industry" will, I believe, advance the Economics literature in two important areas: the literature on innovation in clean (v. dirty) products (Acemoglu et al., 2012; 2014; Aghion et al., 2014); and the literature on improvements in fuel economy (Knittel, 2012; Klier and Linn, 2012; 2014).

The first literature points out that, if innovation in clean products is path dependent, environmental policies (such as a carbon tax) which increase investments in clean technologies will have benefits beyond the immediate period. A fuel tax that promotes investment in energy efficiency will increase the productivity of future investments in energy efficient technologies. This idea has been implemented empirically by Aghion et al. (2014) who look at the impact of fuel taxes on patents to promote fuel economy in the automobile industry. Aghion et al. (2014) do not, however, link patents to fuel economy per se. The second literature, which estimates fuel economy technical frontiers (MPG, holding weight and power constant), has measured shifts in the fuel economy frontier over time (Knittel, 2012; Klier and Linn 2014), but does not link these to investment in innovation or to the adoption of fuel efficient technologies.

Christy's job market paper estimates the impact of environmental policy (as proxied by fuel taxes) on investment in fuel-efficient patents (knowledge capital) and on the adoption of specific fuel-saving technologies in the US automobile sector. She estimates a structural model of the new car market in which automobile manufacturers choose not only vehicle characteristics and price, but how much to invest in fuel-efficient patents (knowledge capital) and whether to adopt specific technologies (e.g., variable valve timing) that will improve fuel economy. New car demand is estimated using a nested logit model, with fuel efficiency affecting demand through vehicle operating cost. Knowledge capital reduces the cost of vehicle production, while the adoption of specific technologies raises production cost, but improves fuel economy.

Christy estimates the model using panel data for the US car market from 1986-2006. She finds that the specific technologies that she examines explain about 92% of the shift in the fuel economy frontier over this period. She then simulates the model to examine the impact of imposing a \$1 per gallon gas tax in 2006, as well as a policy that would have reduced by 25% the costs to automakers of augmenting knowledge capital. She finds that the gas tax would have increased average fuel economy by about 0.5 miles per gallon in 2006. The reduction in R&D

costs, by increasing the stock of patents, would have had a much more modest effect on fuel economy but would have reduced production costs.

This is an impressive, carefully done paper. In addition to complementing the work of Aghion et al. (2014) and Knittel (2012), it extends the environmental economics literature (Bento et al. 2009; Jacobsen 2013) which has modeled the welfare impacts of a gasoline tax, taking into account automakers' responses only through price adjustments. Christy models welfare effects allowing firm adjustments in technology adoption and investment in patents. She also examines the impact of market competition on incentives to adopt fuel efficient technologies by simulating a counterfactual in which Chrysler and GM merge: this provides incentives to increase investment in knowledge capital, which applies to all models produced by the firm, but less incentive to adopt fuel-efficient technologies.

Christy is a self-starter. She has done a great job in choosing an important research topic, in modeling firm behavior and in choosing an estimation strategy. She has been meticulous in executing the research. I would like to emphasize that the dissertation is 100% her work. It demonstrates her ability to identify an important research topic and carry out the research.

In addition to her job market paper, Christy is writing two more papers on technology adoption—one with Tom Klier and Josh Linn and the other with Carolyn Fischer and co-authors. The paper with Klier and Linn looks at the impact of market demographics as well as fuel price on the adoption of fuel-efficient technologies by automakers over the 1997-2013 period in the US. The paper with Carolyn Fischer and co-authors examines the impact of fuel economy regulations in one country on the fuel efficiency of vehicles sold in other countries.

Christy is also a great teacher. She recently worked as a TA in our Applied Master's in Economics program, teaching students Stata and helping them with assignments in a variety of courses. She received extremely high marks in this, and also for teaching Computer Methods in Economics to our undergraduates.

To conclude, Christy is one of the brightest and most energetic graduate students with whom I have worked in my 35 years at the University of Maryland. She is also very effective at presenting her work. I predict that she will continue to produce high quality research on policy-relevant topics at the intersection of Industrial Organization, Energy and Environmental Economics. I strongly urge that you hire her.

Sincerely yours,

A handwritten signature in black ink that reads "Maureen L. Cropper". The signature is written in a cursive, flowing style.

Maureen L. Cropper
Distinguished University Professor of Economics