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**There's an App (Update) For That: A Structural Model of Product Updating Under Digitization**  
(Job Market Paper)

The digitization of consumer goods gives firms the ability to monetize and update already purchased products. This changes firms' incentives to innovate by shifting their focus from pushing consumers toward buying replacement products to maintaining continued engagement through incremental product updates. I study how these technological changes have affected firms' product innovation decisions, both in terms of the frequency and the content of product updates in smartphone application (app) markets.

I develop and estimate a structural model of the demand for and supply of apps. To estimate this model, I employ natural language processing and machine learning techniques in order to classify app updates and to define markets using unstructured text data. Noting a distinction between extensive- (purchase) and intensive-margin (use) demand behavior, I estimate a model of extensive-margin demand and find that consumers are more likely to purchase an app following an update, but that consumers are generally not responsive to the content of an update.

I next use a dynamic model of app updating to estimate the fixed costs associated with different types of updates, and find that major, feature-adding updates are approximately 22% costlier to produce than those that only make minor adjustments to the product. Finally, I conduct a counterfactual analysis to understand how digitization has affected firms' updating behavior. In this exercise, I "turn off" the digital aspects of these products by removing developers' ability to both monetize app use and to update an app past the point-of-sale. I find that digitization results in both more frequent and more substantial product updating.

JEL Classifications: D12, L13, L15, L86

Keywords: Endogenous product characteristics, Dynamic oligopoly, Software, Digitization

**Public Communication and Tacit Collusion in the Airline Industry**  
with Gaurab Aryal (UVa) and Federico Ciliberto (UVa)

We provide evidence that airlines can, and do, use public communication to coordinate in reducing the number of seats they supply in a market. To measure communication, we use natural language processing techniques to analyze airlines' quarterly earnings calls, and quantify instances where top airline management uses keywords such as "capacity discipline" in those reports. We find that whenever airlines "talk" about capacity discipline, the supply of seats in the following quarter decreases substantially, by as much as 6.4%. To test the validity of our results, we develop a new method for conducting placebo tests for research that uses text as a primary source of information. This approach allows us to account for the fact that estimating a model using seemingly unrelated words may result in a false-positive result if the contextual meaning of that word is sufficiently "similar" to the economically relevant words or phrases.

JEL Classifications: L13, L40, L44, L93

Keywords: Tacit collusion, Cheap talk, Airline industry