Research Statement

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My research draws on tools from operations research, machine learning, and economics to rigorously evaluate existing pricing strategies and guide the development and implementation of new ones. In my thesis, I produced actionable theory to assist practitioners working on the cutting edge of e-commerce. In particular my Ph.D. work yielded guidelines for when certain pricing strategies dominate or approximate others in information-rich environments.

With the deluge of big data, many retailers are experimenting with rich, data-driven pricing strategies. In practice these strategies can be complex and/or discriminatory (i.e. offering similar goods to customers at varying prices), thus making them hard to analyze or optimize. In response I study alternative pricing schema that sidestep particular issues of implementability or fairness, and prove these schema enjoy comparable performance guarantees. Often my results break down along simple vs. optimal lines, where simple pricing strategies perform comparably to more involved, optimal ones. Below, I provide an overview of my research direction by discussing my completed and working projects.

The Power of Opaque Products in Pricing *(joint w/ Adam N. Elmachtoub)*. Opaque selling is an exciting e-commerce technology where products or services have a feature (such as the color of an item or the departure hour of a flight) that is hidden from the customer until after purchase. Opaque selling has emerged as a powerful vehicle to increase revenue for many online retailers and service providers that offer horizontally differentiated goods. In my paper "The Power of Opaque Products in Pricing" (Major Revision at *Management Science*), we make a case for opaque selling strategies as a feasible alternative to *discriminatory pricing*, a practice where retailers offer different prices for horizontally differentiated goods (i.e. goods that vary superficially, for instance in color or style). Since the goods are substitutes, discriminatory pricing arbitrarily chooses some items to have high prices. By offering a menu of opaque products, a seller can create (vertical) differentiation between otherwise substitutable goods, and thus sidestep common drawbacks of pure discriminatory pricing. We show that in a very general model, and under minimal customer assumptions, opaque selling generates revenue rivaling the revenue produced under discriminatory pricing.

In particular we give a sharp characterization of when the revenue from opaque selling exceeds the revenue of an optimal discriminatory pricing strategy, and note this dominance occurs in cases of substantial business relevance. Furthermore, we show that even strategies offering a single opaque product can exhibit substantial gains for sellers. Along the way, we derived new theory for simple strategies that offer only a single price for all items. Taken together, these results

provide clear theoretical motivation for using opaque products as a vehicle for price discrimination. While these results are exciting, we note that traditionally opaque products have been studied as an inventory management tool. One promising future direction for work in this space would be synthesizing our paper with existing inventory models for opaque selling, giving a complete picture of opaque products as a revenue management device.

The Value of Personalized Pricing *(joint w/ Adam N. Elmachtoub and Vishal Gupta)*. Another emerging trend in e-commerce is personalization. Increased availability of high-quality customer information has fueled interest in personalized pricing strategies, i.e., strategies which predict an individual customer's valuation for a product and then offer them a customized price. While such strategies can improve a retailer's profits, personalization also comes at a cost; implementing sophisticated personalized pricing strategies requires investment in information technology and analytics expertise, and induces serious branding risks and potential for customer ill-will. In "The Value of Personalized Pricing" (submitted to *Management Science*) we study when personalized pricing is necessary, and characterize markets where a single price suffices. Furthermore, when personalized pricing is necessary, we study how complex and customized such strategies must be to achieve specific profit goals. Our answers to these questions yield a theoretical framework for practitioners to use when deciding whether or not to implement personalized pricing in a given market.

In particular, we derive tight, closed-form bounds on the ratio between the profits of an idealized personalized pricing strategy and an optimal single price strategy that depends on a few natural statistics of the market. These results provide precise conditions for when a simple, single price strategy is guaranteed to yield a desired level of revenue. For the cases when single pricing can not guarantee the desired level of revenue, we specify a general framework for analyzing personalized pricing strategies in terms of their capability to offer many prices, and their accuracy when predicting a customers valuations. Again, given some natural parameters of market, we show how to decompose the performance of a personalized pricing strategy into the performance of two conceptually simpler pricing strategies that isolate the loss from prediction inaccuracy, and the loss from operational restrictions (in terms of the number of distinct prices offered) respectively.

Work in Progress: Data-Driven Pricing for Service Requests (*with Adam N. Elmachtoub and Yunjie Sun*). Dassault Falcon Jet is a leading manufacturer of private aircraft with more than 2100 hundred jets currently in service around the globe. In addition to manufacturing, Dassault also maintains and operates a network of service centers that are available throughout the life of each jet sold. In these centers, Dassault performs the inspections, maintenance, upgrades, and repairs necessary to keep their customers in the air. However, Dassault does not have exclusive

service rights to its customers' aircraft. Their service centers operate in a competitive market where they compete with other centers for service requests. In particular, customers solicit *quotes* from Dassault, which are estimates of the cost and time required to perform *work orders* consisting of inspections, repairs, and/or refurbishments of a customer's aircraft. If the quote is accepted, the plane occupies a unit of space in their hanger while the work is performed.

In this project we tackle these challenges by creating an automated and data-enabled quotation system which accurately estimates the cost of completing the planned (and unplanned) work as well as the time this work will take. We then feed these estimates into a pricing model which treats each unit of space in the hanger as a reusable good, and develop new heuristics to approximate the optimal pricing strategy. As such, this projects merges theory with practice, utilizing analytic tools and new pricing insights to achieve good performance.

Future Directions. Moving forward, I intend to continue advancing the theory of pricing and revenue management. I plan to extend my theoretical work from static e-commerce environments to dynamic markets. I hope to broaden my research vision, expanding from pricing mechanisms to general mechanisms for coordinating the allocations of desirable goods and objectives not just of maximizing revenue, but of maximizing social welfare and societal gains.