Price, Wage and Fixed Commission in On-Demand Matching

Motivation. Sharing economy platforms, which are essentially intermediary firms that connect the supply side with the demand side, often employ crowdsourced supply (physical goods or intangible services) to meet customer demand. For example, ride-hailing platforms such as Uber and Lyft rely on free-lance drivers who decide when and how long to work. Short-term rental platforms such as Airbnb crowdsource property listings from hosts who manage the availability of their properties on their own. Just like price-sensitive customers on the demand side, crowdsourced suppliers are also sensitive to their rewards for providing services. Thus price for customers and wage for suppliers are the two key controls by which the platform such as Uber and Lyft coordinates demand and supply. It can be a non-trivial task to set both price and wage optimally. On the one hand, the platform needs to offer a decent wage to attract suppliers and a reasonable price to attract customers. On the other hand, the platform needs an adequate profit margin (i.e., the gap between the price and wage) is to ensure its own profitability. In addition, time-varying demand and supply conditions often add to the complexity of the platform’s problem of deciding the optimal price and wage, which need to be adjusted according to the current market conditions. For example, Uber implements so-called “surge pricing” to contingently match supply with demand for a given short time period in each designated region. In the Uber setting, the “surge multiplier” multiplied by the base fare (as a whole, corresponding to the price in our model), together with the travel time and distance, determines the trip fare. For simplicity, our model assumes away the spatial dimension.

In practice, platforms often charge the suppliers a flat, across-the-board commission that applies to all market conditions. For example, Uber started its business taking a 20% commission on all rides, and now it raises and lowers that rate in different cities depending on the supply of drivers and demand by riders. In a fixed-commission contract, all parties agree on a specific rate, according to which the platform takes a portion of the total revenue generated through the sharing transactions. (The platform may adjust the fixed rate but keeps it for a relatively long time.) However, such a pre-committed crowdsourcing contract does not seem optimal at the operational level. Since demand and supply conditions change, the platform would ideally want to freely update both price and wage to match supply with demand. With the platform’s hands tied by the flat commission contract, the pricing decision and its associated wage determined by the preset affine commission contract are most likely suboptimal for a given market condition. In this paper, we focus on the following research question. If the fixed-commission contract is not optimal for the platform, how good is this contract?

Settings of our model. Depending on time and day, the platform may be faced with many different market conditions. For instance, see Figure 1 that is generated from a Uber data set
requested and obtained by fivethirtyeight.com from New York’s Taxi & Limousine Commission under the Freedom of Information Act. On Tuesday, February 16, 2016, because there was a heavy rain in the early afternoon, a peak occurred in the number of Uber trips in Manhattan in addition to the two normal daily peaks during the morning and evening rush hours. On Tuesday, February 23, 2016, it began to drizzle at noon and that continued for the rest of the day, and we see that the normal demand pattern for Tuesdays with no rain (e.g., February 9, 2016) was amplified. Demand can also be driven by special occasions. On Valentine’s Day of 2016, which was a Sunday, demand surged proportionally during the day compared to a normal Sunday, such as February 21, 2016. The late-night peak in demand on Sunday February 7, 2016, is due to the Super Bowl.

In our model, we focus on a market with demand and supply uncertainty by associating each possible market condition with some probability. Under each market condition, there is a pool of potential customers with heterogeneous valuations and suppliers with heterogeneous opportunity costs. For a given pair of price and wage, there are a certain number of customers who are willing to make a purchase and a certain number of suppliers who are willing to provide the service. In other words, there exist a demand curve and a supply curve for each market condition. Both the customers and suppliers enter the market after assessing their likelihood of being matched. For a given price and wage, the platform matches the demand and supply after they enter the market.

The benchmark model. To study the performance of a fixed-commission contract, we start with a benchmark model in which the firm is free to choose the price and wage for each market condition. That is, in the benchmark model, depending on the realization of a market condition, the platform sets both the price and wage to maximize its profit. We show that the platform’s optimal price has a $U$-shaped relationship with the wage. This implies that campaigns to improve wages and benefits, such as by imposing a higher minimum wage for the independent agents in a two-sided market, likely also benefit customers on the demand side. The intuition is that with the wage increases, more suppliers would like to provide the service, and as a result, the platform is compelled to squeeze its own margin by lowering the price to use the larger amount of supply, resulting in an increase in customer surplus. Moreover, we show that the benchmark model as a
two-dimensional price and wage optimization problem can be reduced to a one-dimensional problem of solving the most desirable matching quantity for profit maximization.

**Performance of the fixed commission rate contract.** We compare the performance of the optimal commission contract, which specifies a linear relationship between the price and wage, with the benchmark where there is full freedom for the platform to contingently choose the price and wage, under uncertain market conditions. We show that if both demand and supply curves are affine functions with common price and wage sensitivity across market conditions, a commission contract is indeed optimal. In particular, if the independent suppliers’ willingness-to-sell and the customers’ willingness-to-pay are uniformly distributed and the uncertainty comes from the market size of customers and suppliers, a fixed-commission contract is optimal. In general, the fixed-commission contract is not optimal. However, as long as supply curves are concave, we show that by using the optimal fixed-commission contract, the platform obtains at least 75% of the optimal profit of the benchmark for any market condition. For the case where supply curves are not concave but have bounded growth, we provide a primitive-dependent performance bound of the optimal commission contract. For instance, if supply curves have an increasing rate slower than a cubic function, we show that the optimal commission contract achieves for the platform at least 52.75% of the optimal profit of the benchmark for any market condition. Numerical results further show that the actual performance is better than the provable worst-case performance bounds.

**Extensions.** We study several extensions, which include objectives other than profit maximization, piecewise commission contracts and price-setting suppliers.

**Main contributions.** First, we show that there is a fundamental difference between the two-sided market with crowdsourced supply and the traditional supply chain setting and two-sided market literature in economics. By pointing out the difference, we provide a theoretical justification for studying the two-sided matching models from the operational perspective where the matching quantity is naturally taken as the minimum of the demand and supply (analogous to sales volume being the minimum of the demand and capacity in the operations literature). Second, we show that the two-dimensional price and wage optimization problem can be reduced to a one-dimensional problem that solves for the most desirable matching quantity, thereby making the problem significantly less complex. This insight is robust under different platform goals. It may serve as a guide to more complicated two-sided pricing problems. For example, we expect that the same insight would hold for a dynamic two-sided pricing problem where unmatched demand and supply can be carried from one period to another. Third, we contribute to the supply chain contract literature by studying the commonly practiced fixed-commission contract as a type of crowdsourcing supply contract. More specifically, we provide constant or easily computed performance bounds for a fixed-commission contract under demand and supply uncertainty.