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University Licensing of Patents for Varietal Innovations in Agriculture

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Abstract

There has been a sharp increase in the number of patented agricultural products from public universities in the United States. We develop an experiment to examine the revenue stream to universities from licensing plant-based innovations. In the experiment we asked subjects to bid for access for a patented input that would be used to manufacture a differentiated product; treatments were employed to solicit bids that were financed by fees, royalties, and a combination of the two mechanisms under exclusive and non-exclusive contracts. The literature studying the economics of downstream duopoly competition in quantity suggests that revenues for the innovator would be greatest under a non-exclusive contract that uses fees and royalties. In our experiment we allow more than two firms to obtain access to the patent in the non-exclusive treatments, and our empirical results suggest that innovator revenues are greatest when royalties are used alone in a non-exclusive contract.

Keywords: Auctions, Horticulture, Licensing, Patents, Research and Development

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Introduction

Processed-food manufacturers have a ready source of research and development (R&D) financing through either internal or external sources. Moreover, they have the incentive to invest in R&D because downstream food industry product and process innovations are well-protected by existing patent and trademark law (Gopinath and Vasavada 1999). Incentives for investment in innovation in agricultural production are generally much weaker, primarily because of the atomistic nature of agricultural production, combined with the limited ability to extract rents from innovation in farm products or farming production processes (Alston et al. 2009; Alston et al. 2010). Consequently, the government has traditionally played a larger role in agricultural R&D than in food manufacturing R&D, conducted largely through agricultural experiment stations at land grant universities. Despite their prominent role in funding agricultural innovation, however, universities lack institutional mechanisms to ensure they get the greatest return on their research funding. In this paper, we develop an experimental approach that provides evidence in support of just such a mechanism.

Federal and state support for investments in agricultural R&D has been declining over the last few decades. Decreasing government support necessitates a reliance on new institutional arrangements to fill the gap (Alston, Babcock, and Pardey 2010). This trend spans all agricultural sectors, but is particularly acute in horticulture (Cahoon et al. 2007; Alston and Pardey 2008). Collective organizations funded by commodity levies with matching government support are one way to revitalize agricultural innovation in a public-private partnership. Another way is to use formal intellectual property rights embodied in government-sanctioned patents. Both of these alternatives, however, raise questions about the appropriate mechanism for funding research investments, and pricing research output. We address this issue in the context of the second alternative, and specifically examine the optimal use of fees and royalties in either an exclusive or non-exclusive contract for pricing patents on innovations created by university-based researchers. We frame our analysis using the specific example of research into new horticultural varieties.

The passage of the Bayh-Dole Act in 1980 gave universities the ability to claim intellectual property rights from the federal government for university-conducted research. Bayh-Dole gave universities additional incentives to undertake certain types of research, and in some cases an additional source of revenue (Jensen and Thursby 2001; Bhole 2006; Bulut and Moschini 2009). Questions remain, however, regarding the extent to which university research is transferred to industry stakeholders (Henderson, Jaffe, and Trajtenberg 1998), and the appropriate institutional arrangements for transferring technology to producers (Lach and Schankerman 2008). New institutional arrangements have arisen for the transfer of new plant varieties from research universities to consortia or cooperatives of growers willing to pay for licenses for new varieties (Cahoon et al. 2007), but pricing mechanisms in these markets have been inefficient and not conducive to the rapid growth of research and development in new fruit varieties. Specifically, the primary question is whether university technology transfer offices (TTOs) should use fixed fees, volume-based royalties, or a combination of fees and royalties in either exclusive or non-exclusive contracts in order to maximize licensing revenue. Our experiment provides empirical evidence on which of these arrangements is preferred from a TTO perspective.[1]

Our research is motivated by the rapid increase in the number of patented fruit varieties released by university breeding programs at the University of Arkansas, University of California, Cornell University, University of Florida, Michigan State University, University of Minnesota, and Washington State University, among others (Brown and Maloney 2009; Bareuther 2011; Gallardo et al. 2012), and consumer interest in better fruit varieties (Yue and Tong 2011; Rickard et al. 2013). Licensing schemes for patented fruit varieties have been determined through negotiations between a TTO and a grower-based licensee. These negotiations typically begin with a request for bids from potential licensees. The bids are evaluated based on financial and management considerations by the TTO with a focus on initial payments, annual payments, quality control issues, contracts with individual growers, and marketing plans. A successful bid for a new variety will often allow the licensee the first right of refusal on subsequent varietal introductions. In different instances in the United States, the licensees include growers or grower-packers, a grower-owned cooperative, or a management company acting on behalf of a group of growers.[2]

In practice, the varieties are licensed to individual growers and the licensing mechanisms involve some combination of upfront fixed fees, input royalties, and output royalties that require annual payments based on production. The upfront fixed fees are typically charged per grower. In the case of perennial fruit crops, input royalties are paid per unit of land or per tree, which does not force growers to adopt undesired, or unfamiliar, planting density patterns. *Ad valorem* output royalties have not been widely used for patented fruit varieties, but are becoming more common, especially for the most promising varieties (Lehnert 2010). The optimal structure of licensing payments for varietal innovations in agriculture has not been studied closely by economists. In practice it appears that such licensing has been done without a full understanding of how it affects the incentives for growers that acquire and manage the new varieties, or to the research institutions that develop the new and improved varieties. The question about exclusivity of the contract is particularly relevant to the case of patented apple varieties as plant breeding programs do consider licensing their varieties to growers in different states or, notably, to grower cooperatives in different countries. Our research provides a better understanding of how the design of the license for patented fruit varieties will influence revenues for the innovator using data from a laboratory experiment that mimicked conditions facing fruit growers considering an investment in patented varieties.

There is a large literature that studies innovator revenue when licenses are financed by fees or royalties. We contribute to this literature in a number of ways. First, we address a practical limitation in the way patents are licensed in the real world. License auctions are often conducted in *ad hoc* ways with little consideration given to optimizing university revenue; this includes the fee versus royalty consideration as well as the consideration concerning the degree of contract exclusivity. Second, despite the volume of theoretical analyses, there is no empirical research into the optimal contract design for patents covering demand-side innovations. Third, we address the lack of a comprehensive source of patent licensing data by designing an experiment that carefully replicates likely market outcomes for a new product, and the market for its patent. Our results indicate that university revenues from varietal innovations would be greatest with a non-exclusive, royalty-based licensing arrangement.

In the next section we provide an overview of literature that has studied innovation and the optimal use of fees and royalties for patents. In the section that follows, we provide a description of the laboratory experiment used to study university revenues for a vertical product innovation. The next section describes our theoretical framework, and motivation for the core hypotheses we test with the experimental data. We then present the results from our econometric analysis, and interpret how our findings inform the licensing process from a TTO perspective.

In the final section we provide the implications of our findings for university innovators more generally, and discuss avenues for additional research related to innovations generated by university breeding programs.

Fees Versus Royalties in Patent Licensing

Our formal understanding of the optimal mechanism for patent licensing has changed considerably in recent years. Based on Arrow (1962), it was initially thought that patent-licensed revenue is maximized if the innovator is perfectly competitive. With oligopolistic innovators, Kamien and Tauman (1986), Katz and Shapiro (1986) and Kamien, Oren, and Tauman (1992) found that licensing via a royalty system generates less revenue for an external (i.e., not an incumbent) innovator than if a fixed fee were used. However, the bulk of the empirical research finds that royalties, or combinations of fees and royalties, yield the highest returns for innovators (Sen and Taumann 2007).

Subsequent research sought to reconcile the predictions of theory with what was observed in industry. By including more realistic institutional attributes of an industry—such as contract exclusivity (Li and Wang 2010), product differentiation (Muto 1993; Fauli-Oller and Sandonis 2002), asymmetric information (Gallini and Wright 1990; Sen 2005), risk aversion (Bousquet et al. 1998), moral hazard (Choi 2001), incumbency (Shapiro 1985; Kamien and Tauman 2002; Wang 2002; Sen and Tauman 2007) or strategic delegation (Saracho 2002)—researchers were able to reconcile their findings with what appeared to be a paradox in the data. Wang and Yang (1999) show that royalties are preferred when rivals compete in a differentiated-products Bertrand environment, while Kamien and Tauman (2002) find the same result when the number of Bertrand-rival firms rises above a certain number. Fauli-Oller and Sandonis (2002) were the first to consider two-part tariffs (including a fee and royalties) with differentiated products as a potential explanation for the apparent superiority of royalties. Although their focus on differentiated products is relevant to the U.S. fruit market, and two-part contracts are apparently the dominant model, they nonetheless consider a cost-reducing innovation. Indeed, in all of theoretical work cited above, the innovation is cost-reducing, while the bulk of applied research in the horticultural industry aims to improve fruit quality.

More recent theoretical work considers innovations that operate on the demand-side (product innovation) and not the cost-side of the market (process innovation). Stamatopolous and Tauman (2008) consider the strategic rationale for pricing an innovation into a downstream duopoly market. Adopting the discrete choice modeling framework used by Anderson, de Palma and Thisse (1992) to study the behavior of oligopolies under product differentiation, demand is represented by an aggregate logit model. The innovator licenses its output using either fixed fees, royalties or a two-part tariff. When the market is covered (all consumers buy), they find that both firms purchase the innovation by paying a positive royalty and no fixed fee. However, if the value of the outside option is relatively high, then both firms will still license the innovation, but pay a two-part tariff. Their model, however, assumes downstream licensees compete in prices, which is not likely the case in any agricultural industry. Bousquet et al. (1998), on the other hand, find that a similar combination of fees and royalties is optimal if demand for the new product is uncertain. In their model, fees and royalties are a means by which a risk neutral innovator can provide insurance—and be compensated for it—to a risk averse licensee. While risk may be an important consideration, our focus is on more fundamental strategic behavior by downstream producers, and the optimal upstream response. A combination of fees and royalties also results if we assume the licensor possesses superior information to the licensees (Sen 2005). Given that the licensors in an agricultural context are likely to know more about the market than university scientists, this explanation is also untenable. In this study, we control for these other explanations in an experimental environment in order to test whether a licensee is able to induce the appropriate strategic responses among downstream licensors in order to maximize license revenue.

There is very little theoretical research that considers the strategic implications of licensing demand-side innovations to downstream competitors. In a notable exception, Li and Wang (2010) examine the profits an inventor can realize by using an exclusive or a non-exclusive contract (under different licensing schemes). They focus on a vertical product innovation, which describes the objective of plant breeders who seek varieties with better eating qualities relative to incumbent varieties. Li and Wang (2010) show that, in the case of a duopoly, licensing by means of a two-part tariff generates greater profits for the innovator compared to licenses that financed through royalties or fees alone. By setting the license price such that both downstream firms license an improved product, the licensee is able to raise industry profit, and then extract much of the resulting surplus via a fixed fee. Although the underlying mechanism is likely similar to what we observe in the horticultural industry, we relax the duopoly assumption to consider a more general, *N*-firm oligopoly, competing in quantities and purchasing licenses from a single innovator.

There is evidence of some degree of product differentiation, demand uncertainty, and asymmetric information in markets for horticultural products, and all of these considerations may influence the optimal licensing arrangement for new varieties. Because new patented apple varieties that are available to growers have been carefully vetted by apple breeders, growers, retailers, and panels of consumers over many years, we do not expect that demand uncertainty is a crucial consideration in the design of licenses for such varieties. Asymmetric information is also not likely to be a key factor due to the public nature of the research and the requirement to fully disclose all production-trial results. Anecdotal evidence from industry stakeholders suggests that the degree of contract exclusivity is a top consideration among growers contemplating the adoption of new varieties (Brown and Maloney 2009). Because there is no reliable secondary data available, we develop an experiment to test the predictions of Li and Wang (2010) and to better understand how the design of patent licenses for new apple varieties—including the use of fees and royalties and the degree of contract exclusivity—affects university revenue.

Experimental Design

Our experiment gave subjects an opportunity to produce and sell two products: A traditional product using an existing technology and a new product using a patented technology that was differentiated from the traditional product. The new product was described as a substitute for the traditional product, but was also considered to be a higher quality product. We asked subjects to bid for access to the new product and used the data to calculate revenues for the innovator of the patent. Treatments in the experiment were used to solicit bids that were financed by fees, royalties, and a two-part tariff under exclusive and non-exclusive contracts.

Subjects were randomly placed in one of six treatments differentiated by the payment mechanism for the patent (fees, royalty, or a two-part tariff) and by the number of potential patent holders (either exclusive or non-exclusive). Subjects in fee treatments were told that they would be required to pay an up-front, fixed fee before being able to produce the new product. We also explained that the royalty was defined as a per-unit amount, as opposed to an *ad valorem*, percentage royalty. We used an auction mechanism to determine which subjects were eligible to produce the new product. Only eligible bidders were given the opportunity to choose production levels for both products; subjects that were not eligible to produce the new product remained producers of the traditional product. For the eligible subjects, we charged the fee (in treatments that included a fee) regardless of production level, and subjects paid a royalty (in treatments that included a royalty) based on the number of new products they chose to produce.

In order to be able to form accurate profit expectations, all subjects were told how demand for each type of output, traditional or patented, would change once the new output was decided. Specifically, we provided expected prices for different quantity combinations of the two products. The new product, the one produced using the patented input, received a price-premium when its market share was 10% or less. Lower market shares for the new product generated larger premiums. Subjects eligible to produce the new product were allowed to sell any combination of the two products, knowing that the price of the new, differentiated product would fall as total production increased.

More specifically, we defined several parameters that provided a market structure for the subjects in the lab. First, the prices for the two products that the subjects produced and sold were defined in equations (1) and (2). For the quantities considered in our experiment, the implied elasticities in these equations fall within the range of values estimated for fruit in the literature (for a summary see Andreyeva, Long, and Brownell 2010). In addition, our demand framework was designed so that the profit-maximizing outcome for subjects was less than the total production capacity for one firm. The price for the non-licensed variety, p_n , and the price for the licensed variety, p_l, were defined in the following inverse demand equations:

(1) $$p_n = 3 - 0.001Q_n$$

(2) $$p_l = 2.5 - 0.001Q_l$$

Second, the conditions that describe the individual and collective production constraints in a given session (ω) were described. Equation (3) shows that total production of each product is the sum of production levels across all subjects, where subjects are denoted by subscript *j*. Collectively, there were 2000 units produced in every round in every session. Each subject was allocated 100 production units and their total production was split between the open and licensed products.

$$\text{(3)} \qquad \omega \equiv \begin{cases} Q_n = \sum_{j=1}^{20} q_{jn} \\ Q_l = \sum_{j=1}^{20} q_{jl} \\ Q_n + Q_l = 2000 \\ q_{jn} + q_{jl} = 100 \end{cases}$$

In the exclusive treatments we used a first price English auction to determine the price of the patented input, while in the non-exclusive treatments we used a random *n*th-price auction. The random *n*th-price auction determines both the price of the patented input and the number of subjects eligible to access the new technology[3]. In the non-exclusive fee and non-exclusive royalty treatments, we ranked all bids from highest to lowest, and the price of the patented input for all eligible bidders was equal to the last accepted bid. In the two-part tariff treatments, we ranked all bids by adding the fee revenue to the royalty revenue using a predetermined quantity of production to calculate the likely revenue from the royalty part of the bid.[4] In all treatments the eligible subjects then submitted their choice regarding how much of the new product they would like to produce and this information was used to clear the markets and to calculate profits for subjects and revenues to the innovator in each round. At the end of the experiment, we ranked the twenty subjects in a session by their earnings across the 13 rounds and they were paid between \$20 and \$39 (in one dollar increments) depending on their ranking.

In order to produce, subjects were required to own either traditional or patented inputs. All subjects were initially endowed with 100 traditional production units, and each traditional unit was used to produce a traditional product. In each round, subjects placed a bid that reflected their willingness to pay for access to a patented input required to produce a new and differentiated product. Winning bidders then chose the quantity of the patented input to purchase for that round. One input was used to produce one output for both products. That is, subjects were told that if they purchased patented production units, the patented units would replace traditional production units. Therefore, each subject always produced 100 units in every round. Further, because we always had 20 subjects per session, the total production across all subjects (traditional products and new products) remained constant at 2000 units. We did this to keep market conditions equal across the 12 experimental sessions.

We collected data from 240 non-student subjects, consisting of 12 sessions with 20 subjects per session (each treatment was replicated in two sessions). All subjects in all treatments went through three practice bidding rounds and 10 competitive bidding rounds. At the end of the 13 rounds all subjects completed a short computerized survey with questions related to various demographic and socio-economic variables (shown in the Appendix). Each round consisted of 10 periods and subjects' earnings were shown by period for each round. To minimize confusion among subjects in the lab, we did not use a discount rate to calculate present values of earnings across periods in a round.

Summary statistics for the data collected in the experiment are shown in Table 1. The top section of Table 1 reports information about subjects' bids by treatment, including all bids submitted in all treatments. The next section reports summary statistics for subjects' bids once all nonsensical bids were dropped. These are the bids used in the analysis. In most treatments there were subjects that clearly did not fully understand how the experiment worked and did not submit bids that made economic sense. There were clear thresholds for bidding activity that made economic sense[5], and bids submitted above these levels were dropped (Andersen et al. 2008). The summary statistics for this subset of bids show that the mean bid was $169.02 for the exclusive fee treatment, $20.92 for the non-exclusive fee treatment, $0.51 for the exclusive royalty treatment, and $0.21 for the non-exclusive royalty treatment. In the exclusive two-part tariff treatment the mean bid was $77.45 in fees and $0.20 in royalties; in the non-exclusive two-part tariff treatment the mean bid was $3.89 in fees and $0.18 in royalties. Because fees are paid regardless of output and royalties are paid based on output, and because the number of subjects that become market participants in the non-exclusive cases are not known, it is difficult to use the summary statistics to assess the relative preference for the various types of contracts. Therefore, next we develop a formal econometric model to estimate university profits, and with this model, we are also able to test our underlying hypothesis that contract choice depends on the level of contract exclusivity.

The lower portion of Table 1 highlights summary statistics for demographic variables for the subjects that participated in the experiment. The average age of subjects was 40.3 years, the average time spent working in the public sector was 7.2 years, and the average time spent working in the private sector was 11.8 years. The subject pool was 74% female, 83% held a degree, and approximately 55% had taken an accounting class and did their own taxes.[6]

Model

In our framework an agricultural innovation occurs in an environment in which there is a single, upstream innovator (the licensor, or the University), and multiple potential downstream licensees. The licensees, in turn, sell products either directly to retailers in the case of horticultural products, or to processors in the case of food-input commodities such as corn and soybeans. In this scenario, if the licensors are sufficiently large to possess some market power, such as if individual growers band together in a cooperative or trade association, then potential bidders plausibly interact in the output market as Cournot oligpololists (Li and Wang 2010). Therefore, our empirical model is designed to test the implications for innovator revenue of downstream competition among oligopolists competing in quantities. We define the innovation in our experiment as exogenous to the bidding process, and subject to fully-enforceable intellectual property protection.

Conceptual Model

In our experiment, we test the theoretical predictions of Li and Wang (2010), namely that an innovator licensing its patent on a new, economically-significant, demand-improving technology will prefer to license its technology using a non-exclusive, two-part tariff contract that consists of both a fixed fee and a per-unit royalty.[7] In this section, we summarize the context of their model, and their findings regarding the rank-ordering of profits to the university-innovator under each of six scenarios: (1) exclusive, fixed-fee licensing, (2) non-exclusive fixed-fee licensing, (3) exclusive royalty licensing, (4) non-exclusive royalty licensing, (5) exclusive two-part tariff, and (6) non-exclusive two-part tariff.

The innovation is vertical in the sense that licensees have the opportunity to produce a product that is generally regarded as being better than the old technology. In Li and Wang (2010) there are two firms downstream who compete in quantities and who must decide whether to compete for a license to the innovation that improves the quality of the product. Consumers have a Mussa-Rosen utility structure (Mussa and Rosen 1978) given in equation (4) by:

$$(4) \quad V = \begin{cases} \theta s_i - p_i, & \text{if they buy a good with quality } s_i, \\ 0, & \text{if they do not buy,} \end{cases}$$

where s_i indicates the level of quality of the product being considered, $i = n, l$ and $\theta \in [0,1]$ is a taste-for-quality parameter that is uniformly distributed over consumers. The level of quality for s_n is set equal to 1 and the level of quality for s_l is set equal to $1/\lambda$; the degree of innovation is represented by the parameter λ, where $\lambda \in (0,1)$, and a larger value of λ indicates a smaller quality improvement. Consumers are assumed to buy only one unit of output, and the population is normalized to 1.

The innovator and two downstream firms play the following game: In the first stage, the innovator decides to license to one firm, two firms, or both using a fixed fee, royalty, or a two-part tariff. In the second stage, each firm decides to accept or reject the offer from the innovator, and in the third stage, the firms compete downstream in quantities with full information whether the other accepted the offer or not.

The innovator's preference for fees, royalties, or two-part tariffs, and the exclusivity of the contract offered, are driven by the relative profitability of each strategy. Therefore, the rankings depend on how much the innovator is able to extract from both downstream firms in each case. The amount of surplus available, in turn, depends on the demand facing each firm, and the total amount of market demand. For the two-firm case, where j=1,2, the market demand without the innovation is:

(5) $Q_n = q_{1n} + q_{2n} = 1 - \left(p_n / s_n \right) = 1 - p_n$

so the market inverse demand equation is given by $p_n = 1 - q_{n1} - q_{n2}$. The profits for firm 1 are shown in equation (6) and profits for firm 2 are shown in equation (7).

(6) $\pi_1 = (1 - q_{n1} - q_{n2}) q_{n1}$

(7) $\pi_2 = (1 - q_{n1} - q_{n2}) q_{n2}$

The Cournot equilibrium quantities (in the case without access to the new innovation), q_{n1} and q_{n2}, are equal to 1/3, and equilibrium profits, π_1 and π_2, are equal to 1/9.

The resulting game is then solved for equilibrium output, prices, and profits for each of the firms and the innovator under the various combinations of licensing mechanisms (with and without exclusive contracts), and compare the welfare outcomes from each in a stylized duopoly model. In our case, however, we focus on the innovator's profit that derives from their optimal selection of the royalty rate, and setting the fixed fee so as to extract the full amount of surplus earned by the licensee(s). We write the innovator's profit under each scenario as π^{hk}, where h = F, R, and T, and k = O, B; F denotes a fixed fee, R denotes a royalty, T denotes a two-part tariff (including fees and royalties), O denotes an exclusive contract, and B denotes a non-exclusive contract. The innovator profits under each licensing scheme are shown in Table 2 across a range of parameters for λ. At the bottom of Table 2 we highlight the relative rankings across the licensing mechanisms for two levels of innovation, where λ=0.05 (a major vertical product innovation) and λ=0.40 (a moderate vertical product innovation). Here we see that a two-part tariff, non-exclusive contract generates the greatest level of revenue for the university across all levels of innovation considered in Table 2.

The intuition for the rankings in this table is straightforward. Under a fixed fee, licensing to one firm creates a monopoly, reducing the amount of competition among the downstream firms and raising potential profits to be absorbed by the licensor. Licensing to both firms in a duopoly simply improves the quality of the product, but because it does not change the state of competition downstream, generates no more profit to be extracted by the innovator. In the case of a royalty, if one firm buys a license it again enjoys a monopoly over the high-quality market, but the licensor is not able to extract all of the incremental downstream profits. If licenses are sold to both firms, then the state of competition is not affected, but both firms' output rises. Therefore, even though the licensor cannot extract all of the incremental profit from both firms, it is still better off with a non-exclusive license using a royalty. With a two-part tariff, the licensor is able to change the strategic balance between the two firms with a royalty, and is able to extract any remaining surplus with the fixed fee. Because of this ability to cause industry output to rise, and take full advantage of the resulting profit, the innovator always prefers to offer non-exclusive contracts through a two-part tariff in this duopoly setting.

However, in horticultural markets, non-exclusive licenses for varietal innovations are not typically limited to two firms in practice. In our experiment we do not restrict the number of firms that are given access to the innovation to reflect this real-world consideration. We used the data from our experiment to test whether the non-exclusive two-part tariff license is optimal for a university that licenses a varietal innovation. We expect that the optimal licensing scheme, in terms of revenue for the university, will change with a more competitive landscape downstream. In Li and Wang (2010) with two firms, the buyers know they are still a duopoly. With the possibility of more than two firms licensing the innovation in a non-exclusive scheme, the firms become more competitive and, therefore, the firms will produce more than the firms in the duopoly case would, and will generate more royalty revenue for the university. For these reasons, our hypothesis is that a non-exclusive license using only royalties will generate the greatest revenues for the university.

Empirical Model

The data collected in the laboratory experiment allow us to test two hypotheses on the rankings of the six licensing scenarios described above. The first hypothesis is related to the optimal licensing mechanism, and we expect that innovator revenues will be greatest when royalties are used alone, or used in combination with fixed fees in a two-part tariff scheme. The second hypothesis is related to the optimal degree of exclusivity of the contract; here we expect that a non-exclusive license will generate higher total revenues for the innovator relative to an exclusive license. Non-exclusive licenses that rely, in part or in full, on royalties have typically been used in the U.S. apple industry for the majority of patented varieties—the few varieties that have exclusive contracts have been licensed to very large grower-packer-shipper organizations.

Our model describes the potential revenue for the licensor of a vertical product innovation. Because the subjects in the experiment take the roles of firm managers, our experiment generates behavioral data indirectly on how much revenue, or licensing profit, can be earned by the innovator. Conceptually, the potential profit can be thought of as some combination of the alternative licensing schemes available to the innovator. Econometrically, we estimate the innovator profit in the following way:

$$\pi_r^{hk} = \gamma_r' \mathbf{Z}_r + \beta^{FO} X^{FO} + \beta^{FB} X^{FB} + \beta^{RO} X^{RO} + \beta^{RB} X^{RB} + \beta^{TO} X^{TO} + \beta^{TB} X^{TB} + \varepsilon_r^{hk} \quad (8)$$

In equation (8), π_r^{ht} describes the profit earned by the innovator in session r under the licensing mechanism h and with contract exclusivity k. The variables in $\mathbf{Z}_\mathbf{r}$ are included in the model to control for round- and session-specific effects. We also include six treatment variables, denoted as X^{hk}, to describe the six licensing schemes considered in the experiment, and β^{hk} are the coefficients for the six treatment effects.

We use the auction data from rounds four to 13 (the competitive, non-practice rounds), and the nonsensical bids were not used in the analysis. In the laboratory the markets were cleared by selecting a number of eligible bidders (one in the case of exclusive treatments and a random number between 2 and twenty in the case of the non-exclusive treatments) and setting the price of access to the patented input equal to the value of the last accepted bid. Eligible subjects then chose their production levels for the new product and this determined market prices and revenues for all subjects and the licensor.

Because of the design of our experiment, the observed outcomes in the lab represent only a small subset of the possible outcomes. In the empirical framework we wanted to consider a much wider spectrum of possible outcomes that would have happened under different draws on the number of eligible bidders. We develop this larger set of outcomes in three ways using actual bids from the lab and by simulating quantity choices under different combinations of eligible bidders (following the literature on inference with simulated data by Gregory and Smith 1991; Hansen and Heckman 1996; Dawkins, Srinivasan, and Whalley 2001). First, we considered the full range of the number of eligible bidders and the full range of quantities of the new product that the eligible bidders could choose in every round. Second, we determined the likely production quantity for each potential number of eligible bidders using information on quantities selected in the lab for specific numbers of eligible bidders. The mean quantities selected in the lab and the full range of eligible bidders were used in this case. Third, we examine the results using the mean quantities observed in the lab for a subset of eligible bidders that are expected to participate in the market for the varietal innovation. Therefore, in addition to reporting results from the observed outcomes in the lab, we also report results that consider this more complete spectrum of outcome possibilities. By imputing behavior in this way, we do not bias the econometric results because we continue to calculate innovator revenue using actual bids from the lab and following the *n*th-price auction method.

In the first case using simulated data we considered 126,000 possible outcomes.[8] This was done using the data from ten rounds in the twelve sessions. In each round we considered the outcome for 20 scenarios of eligible bidders (one to 20) and 100 quantity choices for those eligible bidders (from one to 100 in one-unit increments). In the second case, we use simulated data to describe 1200 possible outcomes using the mean quantities observed in the lab for each number of eligible bidders. In the third case, we focus on the 600 possible outcomes that use mean quantities observed in the lab and only consider a range of eligible bidders between one and 10.

Figure 1 provides an illustrative example of innovator revenues for the six treatments across the full range of eligible bidders (one to 20) when each eligible bidder chooses to produce 50 new products.[9] In Figure 1 the innovator revenues are the average values by treatment over the competitive rounds. It is instructive to observe the differences in innovator revenue across treatments, and then how these effects change as the number of eligible bidders changes. Although not shown in Figure 1, these differences are further influenced by the quantity of new products chosen by the eligible bidders. The empirical model uses the actual and simulated outcomes from combinations of eligible bidders and production quantities to estimate how the design of the license impacts innovator revenue and to test the hypotheses described above.

Results

In this section, we report the estimation results for the university-revenue model. The observed data from the laboratory experiment were used in the baseline model; additional results are then reported using actual bids and simulated quantities to provide a wider range of possible market outcomes. We report the impact of the pricing mechanisms and the role of exclusivity on innovator revenues through the six treatment effects. Next we present specific results that allow us to comment on our hypotheses concerning optimal pricing mechanisms for different levels of contract exclusivity, and to evaluate the impact of demand uncertainty on patent licensing.

Table 3 presents the baseline results using data from the 120 outcomes observed in the lab. Data from the 10 competitive rounds in the experiment (rounds four to 13) were used across the 12 sessions. The dependent variable is innovator revenue from fees and/or royalties collected from all eligible bidders. Innovator revenue is calculated following the *n*th-price auction method used in the laboratory experiment. More specifically, the price used to calculate innovator revenue is equal to the last accepted bid; quantities used to calculate innovator revenue are those submitted by the eligible bidders. We do not drop the nonsensical bids in the baseline analysis because it would substantially alter the amount of innovator revenue that was observed in the lab. For example, if the top observed bid in a round in an exclusive treatment is nonsensical and is dropped, we would not have a quantity observation (nor any revenue for the university) for that round. Furthermore, in the rounds in non-exclusive treatments, the eligible subjects selected quantities based on the posted number of eligible subjects. If we drop the nonsensical bids that were observed in the non-exclusive treatments, we would effectively be biasing total university revenue downwards.

Most of the results shown in Table 3 are not significant. We expect that the results are not significant due to the low number of observations per treatment, and, more importantly, because the observed outcomes in the lab contain some nonsensical choices by subjects. Therefore, next we present results that apply the auction data to generate a range of potential market outcomes as a way to circumvent both of the issues that plague the baseline results. Our approach uses the bids collected in the lab and applies them to a range of simulated quantity outcomes; these are outcomes (derived by the number of eligible bidders and production levels per eligible bidder) that had a probability of occurring in the lab, but that were not selected as part of the auction procedure. In addition, because we are simulating outcomes here, we are able to drop the nonsensical bids before we generate the data used in the analysis.

For each round in the lab, the markets were cleared once the number of eligible bidders was randomly drawn (between one and 20) and the total quantity of the new product was selected by the eligible bidders (between one and 2000). In Table 4 we show some summary statistics for the quantities that were selected by subjects in the lab for the different draws on the number of eligible bidders. Of the 60 rounds observed in the exclusive treatments, the mean quantity selected by eligible subjects was 28.2; the selected quantity spanned the entire range between one and 100 units across rounds. For the non-exclusive treatments, the frequency on the number of times each eligible bidder was randomly selected ranged between one and seven; we show the mean quantities selected by subjects across the range of numbers of eligible bidders.

Regression results using data from the simulated outcomes are reported in Table 5. The first column of results in Table 5 reports the results when all possible quantity and eligible bidder combinations are considered. The second and third columns of results are derived using outcomes that are based on the mean quantity choices made by subjects in our experiment, and therefore we consider these results to be more likely outcomes and to be more meaningful. In particular, the third column of results considers a subset of possible eligible bidders that reflects the range of market participation that is expected to occur in the real world. Overall, the results in Table 5 indicate that the non-exclusive licensing scheme that relies solely on royalties has the largest estimated coefficient and has the greatest impact on university revenue. In the second and third column we find that the non-exclusive two-part tariff scheme is also statistically significant and has the second highest estimated coefficient. These results provide strong support for our first hypothesis that royalties generate greater revenues than do fees, and for our second hypothesis that non-exclusive licenses outperform exclusive licenses.

In the context of the economics of downstream oligopoly competition in quantities, we find evidence that the number of potential buyers for a university innovation is an important consideration and affects the optimal scheme for the university that is licensing the patent. Research shows that the university would maximize revenue for a patent using a non-exclusive two-part tariff licensing scheme when selling an innovation to two potential buyers (Li and Wang 2010). However, our findings show that a non-exclusive license sold through a two-part tariff does not maintain the highest level of revenue for the university when the number of potential buyers is greater than two. As the number of potential buyers increases, the buyers will become more competitive and will produce more output under the patent than would the firms in the duopoly case. As a result, the university is able to generate more revenue through the use of royalties (without fees) in a non-exclusive licensing arrangement.

Given the large number of newly patented fruit varieties that are under development, it is important for university plant breeding programs and TTOs to understand the market potential for each new variety as well as the factors that influence that potential. It is equally important for TTOs to understand the key factors that influence the design of contracts with end users and the stream of revenues that accrue to the university. Our findings indicate that royalties will provide greater revenues to the innovator compared to a scheme that uses fees or a two-part tariff, and that a non-exclusive contract is the most appropriate path for TTOs to pursue for the licensing of new fruit varieties. This assumes that there exist a number of potential buyers interested in licensing the patent from the university. Despite the large volume of agronomic research into new plant varieties, the industry is proceeding without a commensurate amount of economic information. This research provides a better understanding of, and a commonly-shared platform for, establishing prices for licenses to agricultural innovations.

Conclusion and Industry Implications

This research is motivated by the sharp increase in the number of patented fruit varieties developed by breeding programs at public universities in the United States. Such varieties are licensed to growers as a way to generate revenue for universities through the use of fees and royalties. Although the optimal mix of fees and royalties for patents has been well discussed in the economic literature, there is very little empirical work that examines these questions for varietal innovations in agriculture. Horticultural variety innovations are particularly interesting as they typically involve a demand-enhancing innovation rather than a cost-inducing innovation, and because, in most cases, the new varieties are only intended to replace a small share of production dedicated to existing varieties. For these reasons we expect that the degree of exclusivity for licenses is an especially important consideration affecting the design of an optimal contract from the viewpoint of the TTO. Therefore, this research not only contributes to the fee versus royalty debate in the licensing of patents, but it also examines how contract exclusivity impacts innovator revenues and the optimal design of licensing contracts.

To address these questions we developed an experiment designed to examine which institutional mechanism generates the greatest revenue for a university-innovator: fees, revenues, or a two-part tariff and whether the contract should be offered to only one downstream producer, or several. In the experiment subjects were asked to bid for access for a patented input that would be used to manufacture a differentiated product. The empirical results suggest that innovator revenues are largest when royalties are used alone with a non-exclusive contract.

Our research serves as a starting point for additional work that explores two related issues concerning the licensing of new agricultural varieties. First, because patented apple varieties are being released from different land-grant universities, additional research might explore how the reputation of specific plant breeding programs influences the institution's pricing strategy for patents on varietal innovations. Previous research has shown that a university's prestige does influence their ability to license innovations (Sine, Shane, and Di Gregorio 2003). Second, given that the innovations are occurring at land-grant universities and that the technology is largely being distributed to U.S. growers, further work might consider the net societal impacts of the various licensing strategies; this would extend our analysis to consider the economic effects from licensing on the innovator as well as the effects on consumers and producers. Some growers, in particular (see Lehnert 2010) have expressed strong preferences for the type of licensing schemes that are employed for varietal innovations in the horticultural sector.

Our research also informs the patent-licensing process more generally. Regardless of whether the innovation involves an agricultural product or some other technology that is likely to increase downstream consumers' willingness-to-pay, the more competitive the industry structure, the more likely will non-exclusive, royalty contracts be the preferred licensing scheme for the TTO. Given the inherent complexity of two-part tariff contracts, both in design and administration, and the competitiveness of many technology-based industries, our findings suggest that non-exclusive, royalty-based contracts may be a more popular default-option than once considered desirable.

Endnotes

[1] We assume that the primary objective of the TTO is to maximize revenue from licenses on intellectual property rights on behalf of the university (which includes state taxpayers in the case of universities that are publically funded).

[2] In some cases patented varieties are released to one grower or a relatively small set of selected growers, and these varieties are often referred to as "club" varieties. In other cases the patented varieties are initially made available to a larger group of growers in a specified region and are referred to as "managed" varieties.

[3] In the non-exclusive treatments we used the random *n*th-price auction rather than the Vickrey auction or the Becker-DeGroot-Marschak auction because it uses a random and endogenously determined market-clearing price (Shogren et al. 2011). Because the market-clearing price is drawn from the pool of bids received in the auction, it retains some relation to bidders' valuation of the patented input in our experiment.

[4] The average level of production chosen by subjects in the exclusive royalty treatments was 30 units; it was 19 units in the non-exclusive royalty treatment. To rank bids in the two-part tariff treatments we applied these quantities to the royalty portion of the bid to determine potential revenues to the innovator.

[5] All subjects were given the aggregate demand conditions for the two products and a range of the relative prices that could be earned for various quantities of the two products. Based on this information, subjects could easily calculate the highest bid that would make economic sense, and if their bid was greater that this we interpreted this to mean that they did not fully understand the experiment. For example, the greatest difference in prices for the two products was $1.49 per unit, and if a royalty bid was submitted that exceeded $1.49 per unit, the bid was dropped from the analysis. A similar calculation was done to determine the set of economically sensible bids for the fixed fee.

[6] Our experiment took place in a laboratory on a university campus, however, none of our subjects were students (undergraduate or graduate students) and none were faculty. The subject pool consisted primarily of university staff members and residents of the local community.

[7] In summarizing the findings of Li and Wang (2010), we consider cases where the degree of innovation is relatively high (i.e., $0 < \lambda \leq 0.40$).

[8] Each of the 12 sessions included 10 competitive rounds. In the exclusive treatments we considered total output of the new product between one and 100 units; in the non-exclusive treatments we considered total output of the new product between one and 2000 units.

[9] In this particular case, the eligible bidders then produce 50 traditional products and the non-eligible bidders produce 100 traditional products each.

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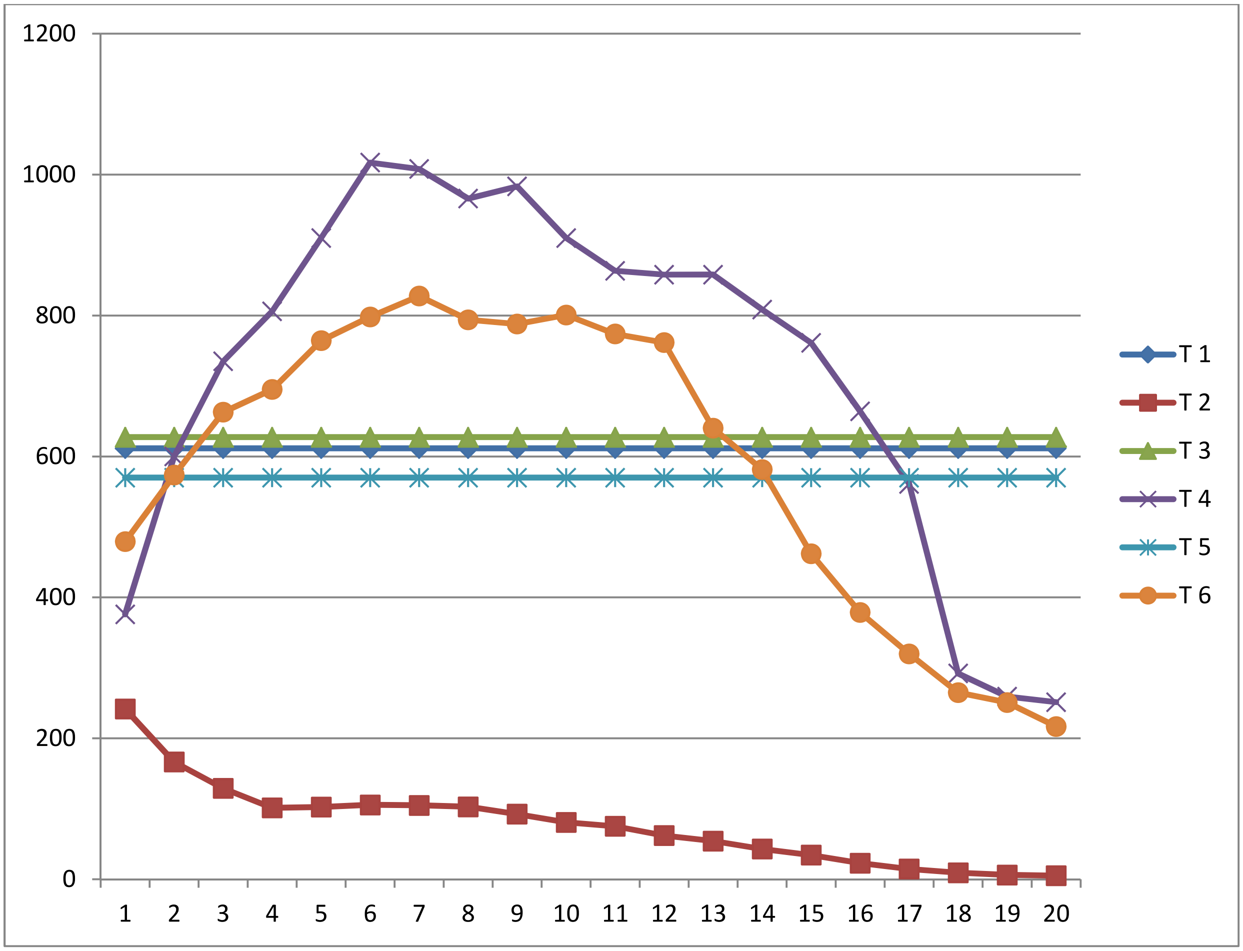
Figure 1. Simulated Innovator Revenue: Eligible Bidders Each Produce 50 New Products



Note: Average innovator revenues across rounds are shown along the vertical axis and the number of eligible bidders is shown along the horizontal axis. Treatments are defined as follows: T1 is the exclusive fee treatment, T2 is the non-exclusive fee treatment, T3 is the exclusive royalty treatment, T4 is the non-exclusive royalty treatment, T5 is the exclusive two-part tariff treatment, and T6 is the non-exclusive two-part tariff treatment.

Table 1. Summary Statistics From Auction Data

Treatment (all bids)		*Observations*	*Mean*	*Standard Deviation*	*Maximum*
Fee	Exclusive	480	468.18	712.39	10000
	Non-exclusive	480	20.92	61.42	500
Royalty	Exclusive	480	0.88	0.99	10
	Non-exclusive	480	0.65	4.74	100
Two-Part Tariff	Fee	480	104.01	415.34	6000
Exclusive	Royalty	480	1046.10	22821.61	500000
Two-Part Tariff	Fee	480	19.49	107.36	850
Non-exclusive	Royalty	480	1.53	8.93	70
Treatment (nonsensical bids dropped)		*Observations*	*Mean*	*Standard Deviation*	*Maximum*
Fee	Exclusive	353	169.02	216.32	700
	Non-exclusive	480	20.92	61.42	500
Royalty	Exclusive	382	0.50	0.46	1.49
	Non-exclusive	453	0.21	0.26	1.25
Two-Part Tariff	Fee	419	77.41	139.39	700
Exclusive	Royalty	419	0.20	0.29	1
Two-Part Tariff	Fee	459	3.89	8.22	100
Non-exclusive	Royalty	459	0.18	0.27	1.25
Age and professional variables (all subjects)		*Observations*	*Mean*	*Standard Deviation*	*Maximum*
Age		240	40.3	13.6	69
Years in Public Sector		240	7.2	9.5	35
Years in Private Sector		240	11.8	11.9	45
Years of Management Position		240	3.6	6.1	28
Other selected demographic variables (all subjects, n=240)				*Frequency*	*Percent*
Gender	Male			62	25.8
	Female			178	74.2
Education	High School			4	1.7
	College but no degree			37	15.4
	Associate Degree			31	12.9
	College Degree			89	37.1
	Master Degree			60	25.0
	Doctoral Degree			19	7.9
Accounting class taken	Yes			132	55.0
	No			108	45.0
Do-it-yourself taxes	Yes			133	55.4
	No			107	44.6

Table 2. Innovator Profit Under Alternative Licensing Scenarios for a Duopoly

	Calculation for Equilibrium Innovator Profit with:					
	Fixed Fee Exclusive	Fixed Fee Non-exclusive	Royalty Exclusive	Royalty Non-exclusive	Two-part Tariff Exclusive	Two-part Tariff Non-exclusive
	$\pi^{FO} = \frac{(2-\lambda)^2}{\lambda(4-\lambda)^2} - \frac{1}{9}$	$\pi^{FB} = \frac{2(1-\lambda)}{9\lambda}$	$\pi^{RO} = \frac{(2-\lambda)^2}{8\lambda(4-\lambda)}$	$\pi^{RB} = \frac{1}{6\lambda},\ 0<\lambda \le 0.25$ $\pi^{RB} = \frac{2}{3}\left(\frac{1}{\sqrt{\lambda}} - 1\right),\ \lambda > 0.25$	$\pi^{TO} = \frac{18-17\lambda}{72\lambda}$	$\pi^{TB} = \frac{1}{4\lambda} - \frac{2}{9}$
Degree of Innovation (λ)[a]	*Calculated Profits for the Innovator*					
0.05	4.763	0.011	2.407	3.333	4.764	4.778
0.10	2.262	0.020	1.157	1.667	2.264	2.278
0.15	1.428	0.028	0.741	1.11	1.431	1.44
0.20	1.011	0.036	0.533	0.833	1.014	1.028
0.25	0.760	0.042	0.408	0.667	0.764	0.778
0.30	0.593	0.047	0.326	0.551	0.597	0.611
0.35	0.473	0.051	0.266	0.460	0.478	0.492
0.40	0.383	0.053	0.222	0.387	0.389	0.403
Rankings						
At 0.05	3	6	5	4	2	1
At 0.40	4	6	5	3	2	1

[a] Note that a lower value of λ describes a greater level of vertical product innovation.

Table 3. Estimating University Revenue Using Auction Bid Data and Observed Quantities

Explanatory variables[a]	Using Laboratory Quantities and Eligible Bids (Rounds 4 to 13)
T1 (Exclusive fee only)	-0.7615
	(-0.20)
T2 (Non-exclusive fee only)	-0.8383
	(-0.22)
T3 (Exclusive royalty only)	-0.8381
	(-0.22)
T4 (Non-exclusive royalty only)	-0.8385
	(-0.22)
T5 (Exclusive two-part tariff)	-0.8262
	(-0.22)
T6 (Non-exclusive two-part tariff)	-0.8384
	(-0.22)
N	120

Note: The t-statistics are shown in parentheses. Innovator revenue is calculated following the structure of the random *n*th-price auction where the innovator charges all eligible bidders a price that is equal to the last accepted bid in that round.

[a] The model also includes dummy variables for the first session in each treatment and for rounds within the session; these results have been suppressed here but are available from the authors.

Table 4. Descriptive Statistics for the Quantities Observed in the Lab

Number of Eligible Bidders	**Session Frequency**	**Observed Quantity Produced by Eligible Bidder(s) (*excluding the nonsensical bids*)**				
		Mean	Median	Standard Deviation	Minimum	Maximum
Exclusive treatments						
1	60	28.2	20.0	29.6	1	100
Non-exclusive treatments						
2	3	29.0	39.0	22.7	3	45
3	4	143.5	142.0	25.2	120	170
4	3	110.3	113.0	37.1	72	146
5	5	102.4	115.0	25.7	57	118
6	1	202.0	202.0	0	202	202
7	1	156.0	156.0	0	156	156
8	2	190.0	190.0	9.9	183	197
9	2	170.5	170.5	36.1	145	196
10	4	208.0	207.0	74.8	135	283
11	6	194.7	180.0	82.7	120	354
12	2	189.5	189.5	24.7	172	207
13	7	207.3	191.0	71.5	119	315
14	4	235.5	238.5	56.5	178	287
15	2	207.5	207.5	14.8	197	218
16	4	338.5	349.0	58.3	259	397
17	4	332.0	278.5	167.8	202	569
18	2	244.5	244.5	43.1	214	275
19	2	528.5	528.5	323.1	300	757
20	2	356.5	356.5	173.2	234	479

Table 5. Estimating University Revenue Using Auction Bid Data and Simulated Quantities

Explanatory Variables[a]	Using Simulated Quantities and Eligible Bids (excluding nonsensical bids)		
	All possible output combinations[b]	*Output combinations using mean observed quantities*[c]	*Most likely output combinations*[d]
T1 (Exclusive fee only)	441.3***	-68.82	-29.73
	(25.68)	(-1.08)	(-0.49)
T2 (Non-exclusive fee only)	-75.51***	-12.79	63.41**
	(-13.05)	(-0.58)	(2.20)
T3 (Exclusive royalty only)	532.0***	-68.82	-29.73
	(30.95)	(-1.08)	(-0.49)
T4 (Non-exclusive royalty only)	930.0***	329.8***	466.7***
	(160.75)	(15.07)	(16.20)
T5 (Exclusive two-part tariff)	428.7***	-68.82	-29.73
	(24.95)	(-1.08)	(-0.49)
T6 (Non-exclusive two-part tariff)	153.0***	58.76***	106.3***
	(26.44)	(2.68)	(3.69)
N	126000	1200	600

Note: The t-statistics are shown in parentheses, and * denotes $p < 0.10$, ** denotes $p < 0.05$, and *** denotes $p < 0.01$. Innovator revenue is calculated following the structure of the random *n*th-price auction where the innovator charges all eligible bidders a price that is equal to the last accepted bid in that round.

[a] All models also includes dummy variables for the first session in each treatment and for rounds within the session; these results have been suppressed here but are available from the authors.

[b] In this regression we apply the auction bids to all possible output combinations for the new product (between 1 and 2000 units for the new product in each round).

[c] In this column of results we use the auction bids, the mean observed quantities for all possible random draws, and the full range of eligible bidders to simulate innovator revenues.

[d] In this column of results we use the auction bids, the mean observed quantities for random draws between 1 and 10, and consider a range of eligible bidders between 1 and 10 to simulate innovator revenues.

Appendix. Survey Questions Presented to Subjects Following the Auctions

1. What is your age? _____

2. Are you male ________ female _________?

3. What race are you? ____ Caucasian ____ African American ____ Asian ____ Hispanic ____ Native American ____ Other ____ Prefer not to answer

4. What is your household income level? ____ less than $40,000 ____ $40,000-$80,000 ____ $80,000 - $120,000 ____ $120,000-$160,000 ____ over $160,000

5. What is the highest education level that you have achieved? ____ High School ____ some college but no degree ____ Associates Degree ____ College Degree ____ Master's Degree ____ Doctoral Degree

6. Which one of the following categories best represents your employment status? ________ Full time employed ________ Part time employed ____ Stay at home to take care of my family ____ Unemployed ____ Retired

7. Are you married or living with someone in a long term relationship? ____ Yes ____ No

8. Do you have children under 18 years old living at home? ____ Yes ____ No

9. Have you ever taken classes in accounting or finance (at high school or college)? ____ Yes ____ No

10. Do you complete your own (or your family's) tax return each year? ____ Yes ____ No

11. How many years have you worked in the public sector? ____ Years

12. How many years have you worked in the private sector? ____ Years

13. How many years have you held a management position (in public or private sector)? ____ Years

14. Have you ever owned (or co-owned) your own business? ____ Yes ____ No

15. When you think about your investment portfolio, how would you describe the relative amounts in the following categories (expressed as a percentage of the total)? ____ Stocks ____ Mutual Funds ____ Bonds ____ CDs ____ Property

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