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 fruit varieties developed by breeding programs at public universities in the United States. We developed an experiment to examine the revenue stream to universities from the licensing of these varietal 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. All treatments also considered the impact of demand uncertainty for the product that used the patented input. Our empirical results suggest that innovator revenues are greatest when royalties are used alone. In the absence of demand uncertainty, innovator revenues are greatest with an exclusive contract, but with demand uncertainty innovator revenues are greatest with non-exclusive contracts.

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Introduction

Processed-food manufacturers have a ready source of research and development (R&D) financing through either debt or equity markets and have generally good incentives to invest in R&D because food industry product and process innovations are relatively well protected by patents and trademarks (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 limited ability to extract returns to innovations in farm products or farming production processes (Alston et al. 2009; Alston et al. 2010). Consequently, the government has traditionally played a bigger role in agricultural R&D than in food manufacturing R&D, much of which has been conducted with a mix of federal and state government funding in the state agricultural experiment stations at land grant universities, sometimes with private funding support.

Over the past few decades we have witnessed fading federal and state government support for investments in agricultural R&D oriented to farm production, and an increasing reliance on the development of new institutional arrangements to fill the gap (Alston, Babcock, and Pardey 2010). Such trends are common across many sectors in agriculture, including horticulture (Cahoon et al. 2007; Alston and Pardey 2008). The creation of collective action organizations funded by commodity levies with matching government support is one way to revitalize agricultural innovation in a public-private partnership. Another way is to use formal intellectual property rights such as patents. Both of these alternatives brings with it questions about the appropriate mechanisms for funding the investment in research and for pricing the products of that investment.

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The passage of the Bayh-Dole Act in 1980 ceded the intellectual property rights for university-conducted research from the federal government to universities. This institutional innovation gave universities additional incentives to undertake certain types of research, and in some cases an additional source of revenue as a result (Jensen and Thursby 2001; Bhole 2006; Bulut and Moschini 2009). It also has created questions about the extent to which university research is transferred to industry stakeholders (Henderson, Jaffe, and Trajtenberg 1998), and the appropriate institutional arrangements for universities to transfer technology to producers (Lach and Schankerman 2008). Intellectual property rights for new plant varieties offer some incentives for investment in this area and new institutional arrangements have arisen for the transfer of new plant varietal technology from research universities to consortia or cooperatives of growers willing to pay for licenses for new varieties. Pricing mechanisms in these markets to date, however, have been inefficient and not conducive to the rapid growth of research and development in new fruit varieties.

Motivation for our research that considers optimal licensing arrangements stems from the increase in the number of patented fruit varieties that have been released in recent years by university breeding programs at the University of California, Cornell University, Michigan State University, the University of Minnesota, and Washington State University (see Brown and Maloney 2009 and Bareuther 2011 for further details), and consumer interest in such varieties (Yue and Tong 2011; Rickard et al. 2013). Licensing schemes for patented fruit varieties have been determined through negotiations between a Technology Transfer Office (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 licensee has been an individual grower-packer, a grower-owned

cooperative, or a management company acting on behalf of a group of growers.

 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, the input royalties are paid per unit of land or per tree; this

condition 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).

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), we 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, are far more common (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

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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 contracts (including fees 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 and not quality-improving while the bulk of applied research in the horticultural industry is quality-improving.

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 combination of the two. 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 combination of fee and royalty. 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

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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. Sen (2005) generates a similar combination of tools under asymmetric information. If the licensee has private information regarding its cost of producing the new product, then the licensor will benefit from using a combination of fees and royalties.

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 there are several new patented apple varieties available to growers, and since the returns for perennial fruit crops do not accrue for many years after the initial investment is made, we expect that demand uncertainty is a key factor in the design of licenses for such varieties. Anecdotal evidence from industry stakeholders also suggests that the anticipated demand conditions are a top consideration among growers contemplating the adoption of new varieties (Brown and Maloney 2009). More specifically, we expect that the presence of demand uncertainty for patented apple varieties will impact the optimal use of fees versus royalties, and the optimal use of exclusive versus non-exclusive licensing arrangements. For these reasons, we extend the work by Bousquet et al. (1998) and use experimental data to better understand how demand uncertainty might influence the optimal design of patent licenses for new apple varieties.

Overall, for varietal innovations in horticulture, the optimal structure of licensing payments has not been studied closely by economists. In practice it appears that it has been done in an ad hoc way with little consideration given to whether the payments provide the appropriate incentives to growers that acquire and manage the new varieties, or to the research institutions that develop the new and improved varieties. The objective of our research is to better

understand how the design of the license for patented fruit varieties influences revenues for the innovator (the university). Our study developed a laboratory experiment that mimicked conditions facing fruit growers considering an investment in patented varieties. The central component of our experiment focused on how licensing arrangements (fixed fees, royalties, or a combination of fees and royalties), either as part of an exclusive or non-exclusive contract, would influence innovator revenues in the presence of demand uncertainty.

Experimental Design

We developed a laboratory experiment that 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. We asked subjects to bid for access to the new product and used the data to estimate revenues for the innovator of the patent. Treatments in the experiment were used to solicit bids that were financed by fees, royalties, and a combination of the two pricing mechanisms under exclusive contracts and under non-exclusive contracts. All treatments also considered the impact of demand uncertainty for the new product over time.

Subjects were randomly placed in one of six treatments differentiated by the payment mechanism for the patent (fees, royalty, or a fee-royalty combination) and by the number of potential patent holders (either exclusive or non-exclusive). It was explained to subjects in fee treatments that it was an upfront fixed fee that was paid to become eligible to produce the new product. It was also explained to subjects that the royalty was paid per unit produced. Bids in all treatments were submitted before eligible subjects decided on production levels for the two products; for the eligible subjects the fee was charged regardless of production levels and the royalty was paid based on the number of new products that the subjects chose to manufacture.

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We collected data from 240 non-student subjects; this consisted 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. In rounds without demand uncertainty (via price erosion), prices were held constant across periods within a round. However, in rounds with price erosion, subjects experienced a declining price for the new product across time periods within a round. In these rounds the price for the new product was subject to a random decrease (between 0% and 3%) per time period within a round.

All subjects were initially endowed with 100 traditional production units; each traditional unit produced a traditional product. In each round subjects placed a bid that reflected their willingness to pay for access to a patented input that was needed to manufacture the new and differentiated product. The bidders that were given access to the patented input would then chose the quantity of the patented input that they would like to purchase for that round; in our experiment one input was used to produce one output for both products. Subjects were told that if patented production units were purchased, the patented units would replace traditional production units and would be used to manufacture the new product. Therefore, each subject always produced 100 units in every round. Furthermore, because we always had 20 subjects per session, the total production across all subjects (traditional products and new products) remained constant at 2000 units. Information describing prices for the two products was provided to

subjects before they began bidding; prices were given for different quantity combinations of the two products. The new product manufactured using the patented input received a price premium when its production level comprised 10% market share or less; lower market shares for the new product would generate larger premiums for the new product. Subjects that were eligible to manufacture the new product were allowed to produce any combination of the two products knowing that the price of the differentiated product would fall as total production increased.

In the exclusive treatments we used a first price English auction to determine the cost for the patented input; in the non-exclusive treatments we used an Nth price auction to determine the cost of the patented input and the number of subjects that became eligible to access the patented input (and then to produce the new products). In the non-exclusive fee and non-exclusive royalty treatments, we ranked all bids from highest to lowest, and the cost of the patented input for all eligible bidders was equal to the last accepted bid. In the fee-royalty 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.[2] In all treatments the eligible subjects then submitted their choice regarding their production level of new products (that use the patented input), and this information was used to clear the product markets and 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.

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; here we include all bids that were submitted in all treatments. The next section reports summary statistics for subjects' bids once all nonsensical bids were dropped, and these are the bids used in the analysis. In most

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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[3], and bids submitted above these levels were dropped. 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 combination treatment the mean bid was $77.45 in fees and $0.20 in royalties; in the non-exclusive combination treatment the mean bid was $3.89 in fees and $0.18 in royalties. 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.[4] Next a conceptual model of financing innovation for the case of patented fruit varieties is presented, and then an empirical model is developed to estimate the impact of factors that influence innovator revenues using the auction data.

Model

The model is designed to consider an exogenous innovation (i.e., we do not model the prior stage of the decision of how much to invest in agricultural research and development, which is a natural extension of the work here, contingent on the optimal pricing structure), which is subject to fully enforceable intellectual property protection. Extending the model in Bousquet et al. (1998), it is assumed the innovator sells to a competitive downstream market with many potential licensees rather than just one potential licensee. The framework in Bousquet et al.

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(1998) is extended to allow licensees to produce two products—one using an existing technology and another that uses a new (patented) technology in production. The innovator is external to the industry and licenses the innovation using either fixed fees per licensee, per-unit royalties, or a non-linear pricing system that combines fixed fees and per-unit royalties.

Bousquet et al. (1998), find that a combination of fees and royalties is optimal if demand for the patented product is uncertain. Following Bousquet et al. (1998) our conceptual model also considers a licensor that is risk neutral and maximizes total licensing revenues, while the licensee is risk averse and maximizes the expected utility of profits. It is assumed that there is no cost uncertainty, but we do pay special attention to the role of demand uncertainty (modeled as price erosion) in the empirical model presented next. The empirical model is developed to test the implications of our conceptual model using data from the experiment. More importantly, for the theoretical component of our research, the solution to the conceptual model provides valuable intuition as to why royalties are observed for patented varieties in the U.S. apple industry.

Conceptual model

In the model outlined below the licensees are able to produce open varieties (denoted with subscript o) and/or licensed varieties (denoted with subscript l). Prices and unit costs for the two varieties are differentiated; in the experiment we set c_o and c_l equal to zero as a way to simplify the decisions for our subjects. The innovator (or licensor) charges for access to the innovation (in the input market) that consist of either i) a fixed fee per licensee (denoted as φ), ii) a per-unit of output royalty rate (denoted as ρ), or iii) a combination of a fixed fee and a per-unit royalty. The objective for licensee i is to maximize their utility by choosing production levels for the two varieties as shown in equation (1) below. Because output levels are chosen ex-post, maximization of net profits corresponds to maximization of utility. Prices for each variety

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depend on the total quantity produced for each variety (where $Q_o = \sum_i q_o^i$ and $Q_l = \sum_i q_l^i$) and

the state of nature (ω) which defines the production constraints for individual licensees and the

industry.

$$\max_{q_o^i, q_l^i} \pi^i = p_o(Q_o, Q_l; \omega) q_o^i(\omega) - c_o q_o^i(\omega) + p_l(Q_l, Q_o; \omega) q_l^i(\rho, \omega) - (c_l + \rho) q_l^i(\rho, \omega) - \varphi$$

(1)

$$\text{where } q_o^i, q_l^i \geq 0$$

The licensor earns revenue (Ψ) from fixed fees and from per unit royalties, and the optimization

problem for the innovator is outlined in equation (2). Here the innovator chooses levels for the

fixed fee and per unit royalty to maximize expected revenues from all licensees subject to the

acceptance constraint for each licensee (where $i \in I$). Following Bousquet et al. (1998) we

assume that licensee i places a value on the right to have access to the new innovation by

comparing the potential utility of profit to their reservation utility (denoted as $\bar{\upsilon}^i$ in the model

below).

$$\max_{\rho, \varphi} E[\Psi(\rho, \varphi; \omega)] = E[\rho Q_l(\rho, \omega) + \varphi],$$

(2)

$$\text{subject to } E(\upsilon^i[\pi^i(\rho, \varphi; \omega)]) \geq \bar{\upsilon}^i, \forall i \in I,$$

$$\rho, \varphi \geq 0$$

Next we let L_U be the Lagrangian expression associated with the innovator's optimization

problem in equation (3). The multiplier associated with the licensee participation constraint is

denoted as λ. The first-order conditions are shown in equations (4) and (5).

(3)

$$L_U = E[\rho Q_l + \varphi] + \lambda \sum_i (E(\upsilon^i[\pi^i]) - \bar{\upsilon}^i)$$

(4)

$$\frac{\partial L_U}{\partial \rho} = E(Q_l) + E(\rho \frac{\partial Q_l}{\partial \rho}) - \lambda \sum_i E(\upsilon^{i\prime} q_l^i) = 0$$

(5)

$$\frac{\partial L_U}{\partial \varphi} = 1 - \lambda \sum_i E(\upsilon^{i\prime}) = 0$$

Solving equations (4) and (5) simultaneously to eliminate λ provides the optimal royalty level, which can be used, in turn, to calculate the optimal value for the equilibrium fixed fee in equation (6).

$$(6) \qquad E(\upsilon^{i''})E[\rho\frac{\partial Q_l}{\partial \rho}] - (\sum_i E(\upsilon^{i''}q_l^i) - E(\upsilon^{i''})E(Q_l)) = 0$$

If we assume that all licensees face the same constraints and therefore make identical production decisions, we can define $E(\upsilon'Q_l) = \sum_i E(\upsilon^{i''}q_l^i)$ and $E(\upsilon') = \sum_i E(\upsilon^{i''})$, where υ' is the aggregate utility for all licensees. The expression $\sum_i E(\upsilon^{i''}q_l^i) - E(\upsilon^{i''})E(Q_l)$ can then be rewritten as $E(\upsilon'Q_l) - E(\upsilon')E(Q_l)$ which is the covariance (over ω) between the growers' marginal utility of net profits and their total output of the licensed variety. The covariance term is included in equation (7).

$$(7) \qquad E(\upsilon^{i''})E[\rho\frac{\partial Q_l}{\partial \rho}] - \text{cov}(\upsilon',Q_l) = 0$$

The first term in equation (7) captures the output-distortion effect of a royalty. Increasing the royalty causes the licensee to reduce output in the expected way. The second term (the covariance term) is more complicated as it embodies the insurance-effect offered by the licensor. The covariance term is negative as output is an increasing function of the fixed fee, so an increase in the royalty increases royalty revenue by an amount that is greater than the compensation required by the licensee through a reduction in the fixed fee to meet the participation constraint. The difference between the increase in royalty revenue and the change in fixed fee is interpreted as an insurance premium paid by the risk averse party to the risk neutral party. Essentially, the fixed fee provides a way for the licensor to be compensated for sharing the risk that the new product will fail with the licensee.

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Empirical Model

Here we outline the empirical model used to investigate how the different licensing arrangements influence innovator revenues using data collected from the laboratory experiment. The conceptual models implies that the optimal licensing of patents for the innovator will not involve upfront fixed fees alone; the optimal contract will include royalties or royalties combined with an upfront fee. In addition to the question concerning the impact of fees and royalties on innovator revenues, the experimental data are also used to explore two other considerations in the design of licensing contracts for agricultural innovations. First, we examine the revenue implications for using an exclusive license versus a non-exclusive license. Second we look at the impact of demand uncertainty captured by a series of rounds that introduce price erosion for the patented product.

The data collected in the laboratory experiment allow us to test three hypotheses concerning the factors that influence innovator revenues. The first hypothesis is that innovator revenues will be greatest when royalties are used; it also allows us to test the implications of our conceptual model. By looking at treatment specific effects, this hypothesis is further tested to see if royalties used alone or used in conjunction with fixed fees generate higher revenues for the innovator. The second hypothesis is that a non-exclusive license will generate higher total revenues for the innovator. Given that growers are risk averse and that all growers have the outside option of producing the traditional product, we hypothesize that the non-exclusive license will generate more total revenue from growers. Furthermore, non-exclusive licenses 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. The third hypothesis is that demand uncertainty for the new variety will decrease

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subjects' enthusiasm for the new variety and will lead to lower innovator revenues. It is

expected that the presence of price uncertainty for the product using the patented input may

affect the optimal mix of fees and royalties and the optimal degree of exclusivity for the licensor.

Specifically, demand uncertainty is expected to increase will increase the likelihood of using

royalties and decrease the degree of exclusivity in the optimal contract design for the innovator.

In setting up the experiment, we needed to define several parameters to provide a market

structure for the subjects in the lab. First, the prices for the two products that the subjects

produced and sold needed to be defined. In equation (8) the price for the open variety is defined

and in equation (9) the price for the licensed variety is defined.

(8)
$$p_o = 3 - 0.001 Q_o$$

(9)
$$p_l = 2.5 - 0.001 Q_l$$

Second, the conditions that describe the individual and collective production constraints in a

given session (ω) needed to be defined. Equation (10) shows that total production of each

product is the sum of production levels across all subjects.   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.

(10)
$$\omega \equiv \begin{cases} Q_o = \sum_{i=1}^{20} q_o^i \\ Q_l = \sum_{i=1}^{20} q_o^i \\ Q_o + Q_l = 2000 \\ q_o^i + q_l^i = 100 \end{cases}$$

The empirical model follows from equation (2) to consider the effects of fixed fees (φ) and

royalties (ρ) on innovator revenues. It also considers the impact of exclusivity (χ), demand

uncertainty modeled as price erosion between periods within a round (ε), and various session and

round specific characteristics including the number of eligible bidders and total units produced (α) as shown in equation (11). With respect to the impact of fees versus royalties and the role of exclusivity, the model is specified two ways. In the first case a simplified model is specified that includes variables for the fee and the royalty to identify the effect of the two pricing mechanisms; in this case a variable for exclusive contracts is also included to identify the effect of exclusivity in the licensing of patents. In the second case, we instead include treatment-specific variables to capture and compare the effects of the pricing and exclusivity variables. In both cases the auction data from rounds four to thirteen (the competitive, non-practice rounds) are used, and the nonsensical bids were not used in the analysis.

(11) $$\Psi = f(\rho, \varphi, \chi, \varepsilon, \alpha)$$

In the laboratory each round was cleared by selecting a number of eligible bidders (one in the case of exclusive treatments and a random number between 1 and 20 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 this setup, the 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. To do this a range of the number of eligible bidders was included and a range of quantities of the new product that the eligible bidders could chose to produce was included. Therefore, in the empirical model we used the information collected in the twelve sessions in our experiment to simulate 24,000 possible outcomes.[5] This was done using the data from ten rounds in the twelve sessions. In each round we considered the outcome for twenty scenarios of eligible bidders (one

to twenty) and ten quantity choices for those eligible bidders (from 10 to 100 in 10-unit
increments).

Figure 1 provides an illustrative example of innovator revenues for the six treatments
across the full range of eligible bidders (one to twenty) when each eligible bidder choses to
produce 50 new products.[6] The innovator revenues are the average values by treatment over the
competitive rounds. It is interesting in Figure 1 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 simulated outcomes from
24,000 combinations of eligible bidders and production quantities to estimate the factors that
impact innovator revenues and to test the three hypotheses described above.

Results

In this section the econometric results are reported for various model specifications that estimate
revenue to the innovator from fixed fees and royalty payments. The auction data from the
experiment was applied to simulate a wide range of possible market outcomes, and this
information was used to estimate the impact of the pricing mechanisms, exclusivity, and price
erosion on innovator revenues. Overall, the empirical results suggest that innovator revenues are
greatest when royalties are used and smallest when fixed fees are used; pricing schemes that
employ fees and royalties generate revenues that fall in between the scheme that employs fees
alone and the scheme that pays royalties alone. 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 2 presents the baseline results from the analysis. The dependent variable is innovator revenue from fees and royalties collected from all eligible bidders, and each observation represents one combination of eligible bidders and a quantity that they each choose to produce for one round from the experiment (that includes ten periods). Data from the ten competitive rounds in the experiment (rounds four to thirteen) were used. The simulation exercise calculates innovator revenues following the auction method used in the laboratory experiment; more precisely, innovator revenues are calculated by setting the price of the patented input equal to the last accepted bid and allowing all subjects to pay the price of the last accepted bid. In the first column results are shown for the model that includes variables for the use of fees and royalties, and variables to capture the effects of exclusive contracts and price erosion; we also include variables to control for the number of eligible bidders (between 1 and 20) and the total number of new units produced across all subjects (between 0 and 2000). In this column the estimated coefficient on the fee variable is negative while it is positive on the royalty coefficient, and this suggests that innovator revenues are greater when royalties are used alone. The coefficients are positive for the exclusive and price erosion variables.

The second column in Table 2 replaces the fee, royalty, and exclusive variables with treatment specific variables as a way to look more closely at the effects of specific pricing schemes. The results show that the treatments that employ royalties alone have the largest positive coefficients, but the non-exclusive royalty treatment has the largest positive coefficient overall. The exclusive treatments generate larger positive coefficients for the fee only and the fee-royalty schemes, but not for the royalty only scheme. These results provide strong support for the first hypothesis that royalties generate greater revenues than do fees, and provide some support of the second hypothesis that non-exclusive licenses outperform exclusive licenses. The

baseline results, however, show a positive coefficient for the price erosion variable which is the opposite effect than expected as part of the third hypothesis. Additional estimation work was done to further explore ideas related to the second and third hypotheses and the details are presented below.

The structure of reporting results in Table 2 is followed in Table 3; however, in this case the simulation exercise calculates innovator revenue by using actual bids rather than allowing subjects to pay the price of the last accepted bid. These results are shown to further test the second hypothesis and to look more closely at the role of exclusivity in contracts that might be able to engage in price discrimination. This is relevant to the case of patented apple varieties as plant breeding programs consider licensing their varieties to growers in different states or, notably, to grower cooperatives in different countries. The results across the two columns in Table 3 show a similar pattern of results for fees and royalties, and again the treatment with a non-exclusive royalty payment has the largest positive coefficient in column two. However, the results in Table 3 show an opposite effect for the exclusive variable and suggest that exclusive contracts would generate less revenue for the innovator when price discrimination is possible. If there are grower cooperatives located in different regions that are very interested in a new variety, economic intuition would support the idea that revenues would be greater for the innovator if they could price-to-market the patented input.

Price erosion was included in the analysis to test the third hypothesis related to how demand uncertainty affects innovator revenue. In the baseline model, the price erosion variable was positive and statistically significant; we expected to find that demand uncertainty would have a negative effect on innovator revenue and therefore found this result to be counter-intuitive. In Table 4 two models were estimated—without and with price erosion—and

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innovator revenue was calculated by setting the price of the patented input equal to the last

accepted bid. In the first model we used data from rounds four to eight (the rounds without price

erosion) and in the second model we used data from rounds nine to thirteen (the rounds with

price erosion); the price erosion variable was dropped in these models. Similar to Table 2 and

Table 3, each model was estimated with the fee, royalty, and exclusive variables in one column

and the treatment-specific variables in a separate column. The results in Table 4 highlight that

the two sets of rounds (without and with price erosion) exhibit the same signs on coefficients, but

that the magnitude of the coefficient values are different. The treatments with royalties continue

to have the largest positive coefficients; with price erosion the non-exclusive royalty treatment

has the highest positive coefficient, yet without price erosion the exclusive royalty treatment has

the highest positive coefficient. Overall, the results in Table 4 suggest that, from the viewpoint

of the innovator, the presence of price erosion does not affect the fee versus royalty decision, but

it does affect the decision concerning the degree of contract exclusivity. In the absence of

demand uncertainty, innovator revenues are expected to be higher with an exclusive licensing

agreement. However, with demand uncertainty among licensees, which is likely the case for

patented apple varieties, the innovator's revenue is expected to be higher with a non-exclusive

licensing arrangement.

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 generating 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 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 not designed to replace all other varieties. For these reasons we expect that the degree of exclusivity for licenses is important, and that demand uncertainty about the market potential for these varieties will influence the conditions of an optimal contract. Therefore, this research not only contributes to the fee versus royalty debate in the licensing of patents, but it also examines how contract exclusivity and demand uncertainty impact innovator revenues and the optimal design of licensing contracts.

To address these questions we developed an experiment and used the data to test the implications of a model that extends work by Bousquet et al. (1998); the data were also used to further explore idiosyncratic factors specific to horticultural markets that are expected to influence innovator revenue streams from the licensing of patents. In the experiment subjects were asked to bid for access for a patented input that would be used to manufacture a differentiated product. Six treatments were employed to solicit bids that were financed by fees, royalties, and a combination of the two mechanisms; each pricing scheme was conducted with exclusive contracts and with non-exclusive contracts. All treatments also considered the role of demand uncertainty. The empirical results suggest that innovator revenues are largest when royalties are used alone. In the absence of demand uncertainty, innovator revenues are largest for an exclusive contract, but with demand uncertainty innovator revenues are greatest with non-exclusive contracts.

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. This research used experimental data and the findings support the consensus that royalties will provide greater revenues to the innovator compared to fees. The results also suggest that the innovator should employ a non-exclusive contract with royalties when there is demand uncertainty for the patented product. This indicates that a non-exclusive contract using royalties may be the most appropriate path for TTOs to pursue for new fruit varieties given the likelihood of demand uncertainty for these products. Demand uncertainty for patented fruit varieties in the United States is largely due to the great deal of competition among patented varieties, and with traditional varieties, for market share. 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.

Endnotes

[1] 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. This approach has caused much tension between growers that were not selected (and more familiar with publically available varieties) and university administrators (see Lehnart 2010). In other cases the patented varieties are initially made available to all growers in a specified region and are often referred to as managed varieties.

[2] 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 fee-royalty treatments we applied these quantities to the royalty portion of the bid to determine potential revenues to the innovator.

[3] All subjects were given the aggregate demand conditions for the two products and 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.

[4] 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.

[5] We also use the simulated data based on actual bidding activity because the experiment only yielded 120 observations for innovator revenue (each of the twelve sessions included ten competitive rounds).

[6] In this 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 Fifty New Products
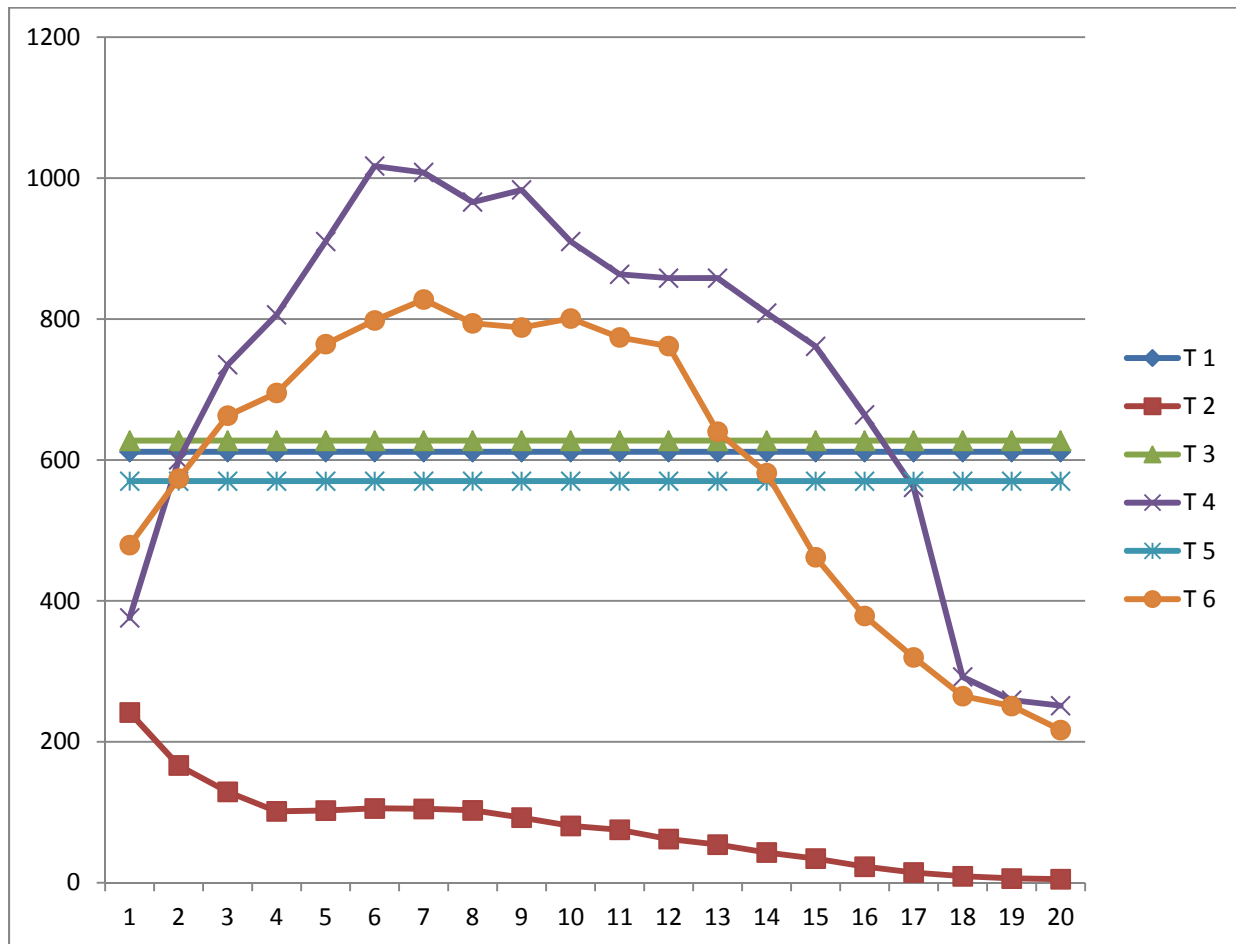
Note: Average innovator revenues across rounds are shown along the vertical axis and the number of eligible bidders is shown along the horizontal axis. Treatments are defined as follows: T1 is the exclusive fee treatment, T2 is the non-exclusive fee treatment, T3 is the exclusive royalty treatment, T4 is the non-exclusive royalty treatment, T5 is the exclusive fee-royalty combination treatment, and T6 is the non-exclusive fee-royalty combination 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
Combo	Fee	480	104.01	415.34	6000
Exclusive	Royalty	480	1046.10	22821.61	500000
Combo	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
Combo	Fee	419	77.41	139.39	700
Exclusive	Royalty	419	0.20	0.29	1
Combo	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. Regression Results Using All Auction Data and Nth Price Bids

	All auction data (nonsensical bids dropped) Rounds 4 to 13	
Fee	-96.09^{***}	
	(7.254)	
Royalty	302.8^{***}	
	(7.254)	
Exclusive	143.2^{***}	
	(5.923)	
Price Erosion	114.9^{***}	114.9^{***}
	(5.923)	(5.641)
Number of Eligible Bidders	35.79^{***}	35.79^{***}
	(0.514)	(0.489)
Unit Produced	-7.299^{***}	-7.299^{***}
	(1.031)	(0.982)
T1 (Exclusive fee only)		218.3^{***}
		(10.55)
T2 (Non-exclusive fee only)		-315.4^{***}
		(10.55)
T3 (Exclusive royalty only)		296.9^{***}
		(10.55)
T4 (Non-exclusive royalty only)		403.8^{***}
		(10.55)
T5 (Exclusive combo)		255.7^{***}
		(10.55)
T6 (Non-exclusive combo)		252.8^{***}
		(10.55)
Constant	-24.05	
	(12.56)	
N	24000	24000

Note: Standard errors are shown in parentheses, and * denotes $p < 0.05$, ** denotes $p < 0.01$, and *** denotes $p < 0.001$. Innovator revenue is calculated following the structure of the Nth price auction where the innovator charges all eligible bidders a price that is equal to the last accepted bid in that round.

Table 3. Regression Results Using All Auction Data and Actual Bids

	All auction data (nonsensical bids dropped) Rounds 4 to 13	
Fee	-73.26***	
	(14.71)	
Royalty	716.7***	
	(14.71)	
Exclusive	-765.6***	
	(12.01)	
Price Erosion	91.95***	91.95***
	(12.01)	(11.24)
Number of Eligible Bidders	74.07***	74.07***
	(1.041)	(0.974)
Unit Produced	36.70***	36.70***
	(2.090)	(1.956)
T1 (Exclusive fee only)		-414.2***
		(21.01)
T2 (Non-exclusive fee only)		-575.7***
		(21.01)
T3 (Exclusive royalty only)		-335.6***
		(21.01)
T4 (Non-exclusive royalty only)		925.7***
		(21.01)
T5 (Exclusive combo)		-376.8***
		(21.01)
T6 (Non-exclusive combo)		820.4***
		(21.01)
Constant	-38.85	
	(25.46)	
N	24000	24000

Note: Standard errors are shown in parentheses, and * denotes $p < 0.05$, ** denotes $p < 0.01$, and *** denotes $p < 0.001$. Innovator revenue is calculated using actual bids submitted.

Table 4. Regression Results Using Nth Price Bids and Considering the Role of Price Erosion

	Without Price Erosion (rounds 4 to 8)		With Price Erosion (rounds 9 to 13)	
Fee	-27.35*** (7.787)		-164.8*** (11.96)	
Royalty	277.9*** (7.787)		327.6*** (11.96)	
Exclusive	277.1*** (6.358)		9.326 (9.766)	
Number of Eligible Bidders	31.02*** (0.551)	31.02*** (0.534)	40.56*** (0.847)	40.56*** (0.790)
Unit Produced	-8.526*** (1.107)	-8.526*** (1.071)	-6.073*** (1.700)	-6.073*** (1.586)
T1 (Exclusive fee only)		310.3*** (11.08)		241.2*** (16.41)
T2 (Non-exclusive fee only)		-214.8*** (11.08)		-301.1*** (16.41)
T3 (Exclusive royalty only)		424.1*** (11.08)		284.6*** (16.41)
T4 (Non-exclusive royalty only)		282.0*** (11.08)		640.4*** (16.41)
T5 (Exclusive combo)		407.9*** (11.08)		218.4*** (16.41)
T6 (Non-exclusive combo)		243.6*** (11.08)		376.9*** (16.41)
Constant	-63.45*** (13.10)		130.3*** (20.12)	
N	12000	12000	12000	12000

Note: Standard errors are shown in parentheses, and * denotes $p < 0.05$, ** denotes $p < 0.01$, and *** denotes $p < 0.001$. Innovator revenue is calculated following the structure of the Nth price auction where the innovator charges all eligible bidders a price that is equal to the last accepted bid in that round.

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