Commodity R&D, Patenting and Promotion

by

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Abstract

There is considerable evidence of high returns to public investments in agricultural R&D, but because intellectual property in agriculture is considered a public good, little R&D investment by growers themselves. This study investigates the potential for growers to increase commodity sales through product research, development, patenting and promotion in a dynamic commodity-market model. Theoretical hypotheses derived from the solution to this model are tested in an empirical example from Washington apples. Estimation results show that, despite significant spillovers to research and promotion expenditure, growers can improve the effectiveness of generic commodity promotion by funding R&D programs as well.

Keywords: advertising, commodity, optimal control, patents, Poisson model, research and development.

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Introduction

Beginning with the Morrill Land Grant Act in 1862, publicly funded agricultural research and development (R&D) has been cited as the primary reason for the sustained relatively high rate of productivity growth in US agriculture. As evidence of this success, empirical studies estimate social rates of return to agricultural R&D to be generally higher than the cost of capital invested (Fuglie et al., 1996). However, most of these studies consider only process R&D, or R&D designed to lower production costs.

Alternatively, product R&D is becoming increasingly important as growers, food processors, and retailers through private-labels seek to differentiate, add value, and even brand many products that have previously been regarded as mere commodities. In fact, product R&D, defined in general terms as efforts directed at developing food products with new attributes that consumers demand such as sweetness, improved texture, or storability, may soon become the largest component of agricultural R&D spending. As recently as 1992, fully 40% of the $3.4 billion spent by private industry on R&D went toward designing and testing new products (Fuglie et al, 1996). Even with this amount of spending, relatively little found its way to fruit varieties, and even less to successful endeavors. This relatively low level of activity may be due to the fact that most commodity organizations in the U.S. do not actively conduct R&D, despite their role as the primary marketing agents for many farm products.[1] Consequently, understanding the role of product R&D, or the design and development of new and better raw food products, is increasingly important as the search for value added products intensifies

[1] Notable exceptions to this observation do exist. The largest boards with the most funding – the National Livestock and Meat Board and the National Dairy Board – allocate a significant portion of their checkoff funds toward product research and development. These boards, however, are the exception rather than the rule.

amid declining returns for traditional or bulk commodities.[2]

The limited role played by commodity organizations is particularly surprising given that similar grower associations in countries such as New Zealand, Australia, or South Africa actively sponsor product R&D and, in fact, often hold trademarks on the results. U.S. commodity organizations, on the other hand, tend to focus on either purely generic promotion efforts, or local programs designed to create a regional "brand" of a commodity. Collective promotion programs, as opposed to privately funded ones, are often thought to be necessary because of the free rider problem -- if a product is difficult to brand, then the promotion efforts of one producer will benefit all others whether or not they help fund the promotion. Consequently, no individual producer has an incentive to promote his or her product. Although numerous empirical studies demonstrate the ability of commodity organizations sanctioned under the 1937 Agricultural Marketing Agreement Act, or similar state legislation, to overcome this free rider problem and, in fact, provide positive returns to their members (Alston, et al., 1996; Vande Kamp and Kaiser, 2000, for example), the number of ongoing challenges to the constitutionality of these boards suggests that grower support is not universal. Given that the primary obstacle to private funding of R&D consists of a very similar free rider problem (Alston and Pardey, 1996; Huffman and Evenson, 1993; Katz, 1986) -- the ownership of intellectual property rights over the output of applied research -- it seems that commodity organizations may be able to play a similar role in helping growers develop new products.

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[2] This distinction is finer than this introduction suggests. While many new products, such as hybrid rice and corn varieties, are technically the result of product R&D, their primary benefit has been in increasing yields and, hence, reducing per bushel production costs. However, product R&D is narrowly defined here as activities that lead to products with improved characteristics demanded by consumers, such as convenience, taste, or nutritional characteristics. While a large empirical literature attempts to separate the effects of product and process R&D on profitability and concentration (Lunn, 1986; Levin and Reiss, 1988), the endogeneity of market structure is less of an issue in production agriculture, so this study focuses on the complementarity between commodity advertising and the component of R&D that addresses demand-side attributes.

Recognizing the potential benefits to this new role becomes even more important when the possible complementarities between commodity promotion and development within a complete marketing program are considered (Chou and Shy, 1991). For other consumer goods, firms such as Procter and Gamble or Gillette would not consider developing a new product without heavily promoting it. Similarly, products that fail to provide attributes that consumers value cannot be made financially viable simply through heavy promotion and advertising. Clearly, these companies recognize the value of product development and promotion as inseparable parts of an effective marketing strategy. As commodity organizations become more sophisticated in their approach to marketing, their exploitation of the benefits potentially available to both developing and promoting new products seems inevitable.

Consequently, the objective of this study is to determine whether there exists empirical evidence of complementarities between commodity research and promotion expenditures. We construct a simple economic model of a representative firm engaged in both research and promotion and then use this model to demonstrate how these two activities interact and how the incentives to engage in one depend upon the effectiveness of the other. By allowing for spillovers of both promotion and research, the model addresses the key problem in initiating and maintaining collective marketing efforts — the free rider problem of providing public goods. The implications of this theoretical model are then tested by developing a dynamic empirical model of promotion, R&D, and patent productivity. Using data on generic apple advertising, government product R&D expenditures, and the number of apple patents granted per year, we estimate a simultaneous model of these activities in order to determine if there is any empirical support for our hypothesis that these two activities are, in aggregate, complements or are in fact separate phenomenon. Describing the incentives to promote and to conduct research first requires a clear difference be drawn between the economic effects of these two activities -- a distinction that has not always been clear.

An Economic Model of Product Development and Promotion

Typically, studies that compare the incentives to invest in cost-reducing, or process R&D and commodity promotion treat the former as a supply-shifter and the latter as a demand-shifter (Fang and Goddard, 1995; Wohlgenant, 1993; Levin and Reiss, 1984). Lemieux and Wohlgenant (1989) and Voon and Edwards (1992), however, consider examples of product R&D where agricultural research is assumed to shift domestic and export demand, respectively, without the aid of promotion. Similarly, Wohlgenant (1993) assumes that the economic effects of product R&D and promotion are observationally equivalent. However, differentiating between these two activities is critical because, as argued above, a significant part of total R&D spending is directed toward product, and not process innovation. Further, it may be somewhat of an oversimplification to assume that because they both serve to change demand that their effects are indistinguishable. Although both activities are assumed to affect commodity demand, their influences differ in strength, persistence, and appropriability -- three key factors in determining the returns to investment in each. By considering each as a separate activity, it is also possible to model not only their unique impact on demand, but also the possibility of synergistic effects between the two. These effects are commonly ignored in the economic literature, but may be significant. The objective of this section is, therefore, to develop a theoretical model of firms' investment in advertising and product R&D that accounts for these differences.

Theoretical models of optimal promotion investment have long recognized the dynamic nature of the problem faced by marketing managers (Vidale and Wolfe, 1957; Nerlove and Arrow, 1962; Jacquemin, 1973). Funds invested today affect demand in future periods because consumers are slow to forget impressions of products that they have formed through trial, experience, and learning (Kotowitz and Matheson, 1979), or because a continuous program of promotion and investment creates an asset akin to brand-equity, an asset that Nerlove and Arrow (1962) define as "goodwill." However, the creation of goodwill requires more than words and images designed to attract consumers' preferences towards a particular product. On the assumption that goodwill implies a positive reputation for quality, value, and effectiveness, then the term implies a significant investment in product design, both prior to introduction and across product life-cycles in the longer-run. Research and promotion, therefore, contribute to the creation and maintenance of goodwill in different ways and at different rates over time. Moreover, the growth in goodwill from each source occurs in a fundamentally different way due to the three differences between R&D and advertising defined above: persistence, appropriability, and complementarity. First, whereas most advertising and promotion programs are intended to produce almost immediate returns, improvements to the product itself take months, or even years, from conception to implementation. This is particularly true for new plant varieties. Therefore, we assume that the stock of goodwill grows with new investment, but decays by a constant proportion each period. Reflecting likely differences in the persistence of each activity's impact on demand, this study differentiates between the decay-paths of the stock of R&D and advertising by defining two state variables, or types of goodwill, each with its own rate of depreciation:

$$\begin{aligned} \dot{B}_t &= b_{it} - \delta_{iB} B_t \\ \dot{A}_t &= a_{it} - \delta_{iA} A_t, \end{aligned} \qquad \textbf{(1)}$$

where $\dot{B}_t$, $\dot{A}_t$ are the rates of growth of each stock, and ?$_k$ is the constant rate of depreciation of stock *k*.

Second, we allow for spillovers in both advertising and R&D to other commodity marketers using conjectural variations parameters in a manner similar to Levin and Reiss (1984), Carey and Bolton (1996), and Jacquemin (1973). This assumption allows the model to include all types of advertising as special cases, from pure brand advertising to generic. In the former case, advertising by one firm causes others to advertise so: $\phi = \partial A_t / \partial a_{it} > 1$, whereas generic advertising benefits all other sellers, causing them to free ride: $\phi = \partial A_t / \partial a_{it} < 1$. By including such aggregate response parameters for both advertising (?) and R&D (?), the model will indicate the effect of varying degrees of appropriability of both advertising and research on the optimal demand for each. Third, complementarity is modeled by specifying demand as a function of both activities separately, and interacting in a multiplicative manner (Chintagunta and Jain, 1992). However, R&D by itself does not change demand, but rather the product of successful R&D, or patented new products. Consequently, we model the productivity of R&D through an innovation function (Hausman, 1984; Griliches, 1990; Hall, Griliches and Hausman, 1986; Lanjouw, Pakes, and Putnam, 1998; Wang, Cockburn and Puterman, 1998; Cincera, 1997) where the probability of observing N_{it} innovations for commodity i in period t is given by: $P[N_{it}] = \lambda_{it}^{N_{it}} e^{-\lambda_{it}} / N_{it}!$, which implies an expected number of patents each time period: $E[N_{it}] = \lambda_{it} = \exp[\beta_0 + \sum_j \beta_j X_{jt}]$, where $\boldsymbol{X}_t$ consists of annual public spending on R&D for the commodity in question, *B*. Demand for the commodity is then modeled as a function of both promotion and new product introductions in a manner similar to Chintagunta and Jain (1992). Unlike the case of most consumer packaged goods, however, the objective of commodity promotion cannot realistically be to increase price, primarily because most commodities are heavily traded (Kinnucan, 1999), but rather to increase the volume of sales. Consequently, we assume commodity prices to be exogenous to commodity boards' marketing decisions. To simplify notation, define *N* as its expected value and suppress the time and individual firm subscripts so the direct demand curve can be written as:

$$q(A,N) = \alpha_o A + \alpha_1 A^2 + \alpha_2 N + \alpha_3 N^2 + \alpha_4 AN, \tag{7}$$

which, as opposed to a linear demand specification, allows demand to be concave in *A* and *N* and can be interpreted as a second-order approximation to any arbitrary demand function. Notice that this function models the possible complementarity between *A* and *B* in a very simple way as the marginal productivity of one is a linear function of the other.

Assuming advertising and R&D costs are convex and separable, the Hamiltonian can be written directly as:

$$H(A_t, B_t, q_t | \Psi) = p_t q_t(A_t, N_t) - C_{At} - C_{Bt} + \lambda_t \dot{A}_t + \eta_t \dot{B}_t, \tag{8}$$

where $e^{-rt}\lambda$, $e^{-rt}\eta$ and ? are the marginal present values of an increment to the stock of product knowledge, product quality, and innovative activity, respectively. Applying the maximum principle to (5) and differentiating the first-order conditions provides dynamic demand equations for advertising (a_t) and R&D (b_t) given by:

$$a^* = (pq_A\phi - w_A) + (r + \delta_A)^{-1}[pq_A - pq_{AA}\phi\dot{A} - pq_{AB}\phi\dot{B}], \tag{11}$$

and:

$$b^* = (pq_N N_B \theta - w_B) + (r + \delta_B)^{-1}[pq_N N_B - p(q_{NN}N_B + q_N N_{BB})\theta\dot{B} - pq_{NA}\theta\dot{A}], \tag{12}$$

where $q_A = \partial q/\partial A = \alpha_0 + 2\alpha_1 A + \alpha_4 N$, $q_N = \partial q/\partial N = \alpha_2 + 2\alpha_3 N + \alpha_4 A$, $N_B = \partial N/\partial B = \beta_1 N$,

and the second derivatives follow straightforwardly. Comparative static analysis of these demand equations reveals the nature of the complementarity between advertising and R&D.

Specifically, differentiating the demand for advertising with respect to the stock of R&D:

$$\frac{da}{dB} = p q_{NA} \phi N_B + (r + \delta_A)^{-1} [p q_{NA} (N_B + \phi (N_B \dot{B} - N_{BB} \delta_B))], \qquad \textbf{(16)}$$

shows that, assuming ($?_4 > 0$), and the patent productivity function is concave ($0 < ?_1 < 1$), the demand for advertising rises in the stock of R&D only if: $N_B \dot{B} - N_{BB} \delta_B > 0$, or if the net rate of productivity growth of R&D investments exceeds the rate at which previous increases in R&D efficiency become obsolete. These assumptions also ensure that the complementarity between *a* and *B* rises in the value of ?, or the extent of rivalry among advertisers. In other words, the more a given message is seen as generic, thereby promoting all products in the category, the less incentive an individual firm has to develop and market new products within that category.

A similar exercise determines whether a similar complementarity applies in the opposite direction - from advertising to R&D. Differentiating the demand for current R&D spending by the stock of advertising goodwill gives:

$$\frac{db}{dA} = p q_{NA} N_B \theta + (r + \delta_B)^{-1} [p q_{NA} (N_B - N_{BB} \dot{B} \theta + \theta \delta_A)], \qquad \textbf{(18)}$$

which implies that the rate of investing in R&D rises in the stock of advertising goodwill only if: $(N_B - N_{BB} \dot{B} \theta) + \theta \delta_A > 0$. A sufficient condition for this to hold requires either the productivity of R&D in creating new patents ($?_1 = N_B$) or the appropriability of R&D investment to be low enough, so that $(\beta_1 \theta)^{-1} > \dot{B}$. These conditions imply that a firm will only conduct more R&D as its stock of advertising goodwill rises if they are unable to create new products, or retain their benefits, at a rate sufficient to take advantage of their greater ability to advertise. Next, to formalize the effects of appropriability on a firm's demand for advertising and R&D, we differentiate the demand functions for each in the conduct parameters, ? and ?, respectively:

$$\frac{db}{d\theta} = pq_N N_B - (r + \delta_B)^{-1} [p(q_{NN} N_B + q_N N_{BB})\dot{B} + pq_{NA}\dot{A}]. \tag{21}$$

Recall that higher values of ? mean that a given firm's R&D investment has a relatively large impact on the total stock of R&D or product development knowledge. Therefore, equation (12) implies that if the current marginal value product of adding to the stock of R&D is greater than the discounted value of an increment to the stock of R&D in the future, then a higher value of ? will induce higher levels of individual firm investment. As a corollary, the more investment by one firm displaces investment by others (? < 1), the less incentive a firm will have to invest in R&D on its own. Clearly, a firm need invest less today to achieve a given level of sales the more other members of the industry invest in knowledge that it can use as well. A similar exercise defines equivalent conditions for the impact of advertising spillover on current expenditures. Namely, if the present value of increasing current advertising and R&D stocks is greater than the discounted marginal value of higher future sales, then "brand" advertising, or advertising with a higher value of ?, will induce more individual investment in advertising.

Finally, we investigate the effects of patenting by comparing "patent" and "no patent" versions of equation (7), it is evident that the net effect once again depends upon the growth rate of each stock relative to its annualized opportunity cost and the strength of the marginal product (?$_2$ and ?$_3$) and interaction parameters (?$_4$) as shown by an expression that is very similar to (10) above:

$$b_1 - b_0 = pnq_N N_B - (r + \delta_B)^{-1} [pn(q_{NN} N_B + q_N N_{BB})\dot{B} + pnq_{NA}\dot{A}], \tag{22}$$

where b_1 is the investment in R&D with patenting, and b_0 is investment without patent laws. Investment will rise, therefore, if the current aggregate value of new products created is greater than the capitalized value of the investment in R&D and advertising required to bring them about. Resolution of the sign of these comparative static derivatives, however, requires knowledge of the parameters of both the commodity demand function and the equations of motion for advertising and R&D.

Econometric Model of Promotion and R&D

The econometric model consists of structural equations for new product development and aggregate demand as well as the first order conditions for optimal expenditure on advertising and R&D. Specification of the full model is necessary both to recover the aggregate response parameters and to ensure that the estimated parameters are consistent with the theory outlined above. We estimate the model using a two-stage procedure where the first stage consists of a negative-binomial model of patent productivity (Cameron and Trivedi, 1986) and the second-stage model consists of structural equations of output, advertising, and R&D demand. Due to the simultaneity of these variables, we estimate the entire model with the data described next using non-linear three-stage least squares.

Specifically, the data consist of annual advertising funded by Washington apple growers through the Washington Apple Commission (WAC, 1998), R&D investments by the United States Department of Agriculture (USDA), and patent awards to both private breeders and USDA scientists (Patent and Trademark Office, 1999) for the period 1973-1998. Details on how we account for the accumulation of R&D and advertising stocks are available from the authors, but are similar to methods used by Slade (1995) and Ehrlich and Fisher (1982).

Results and Discussion

Table 1 provides the results from estimating both stages of the R&D and advertising model. In the first stage, the estimate of $?_1$ suggests that R&D expenditures have a significant impact on the rate at which new apple varieties are patented. More specifically, this productivity estimate implies an elasticity of 0.21, so that a 10% increase in funding can be expected to generate a 2% increase in patent formation. Grower interests, however, are only served if the increase in patent activity causes an increase in sales volume, whether due to an increase in the share of total fruit consumption due to the particular commodity, or an increase in fruit consumption overall.

Because the coefficient of determination is not well defined in a non-linear 3SLS model, we calculate a psuedo-R^2, or the coefficient of determination between observed and predicted dependent variable values. As shown in table 1, the psuedo-R^2 is 0.649 for the advertising demand equation, 0.766 for the R&D equation, and 0.683 for the output equation, suggesting that the model provides a relatively good fit to our limited data. Moreover, the second panel of table 1 shows that generic apple advertising causes sales to increase with a partial elasticity of 0.248 at the mean of sample advertising and sales, but at a declining rate as advertising increases. This result is consistent with previous studies' assessment of the effect of generic advertising on apple demand (Ward, 1993; Richards and Patterson, 2000). The development of new varieties, on the other hand, also causes sales to increase at a declining rate. Again at the mean of the data, the partial elasticity of sales with respect to new variety generation is 0.035. Further, it is expected that commodity promotion and new variety creation exhibit synergistic, or complementary effects. Although positive complementarities are statistically significant only if evaluated with a one-sided hypothesis test, the implied partial elasticity of 0.024 suggests that the creation and promotion of new varieties can indeed increase total apple sales more effectively than either activity conducted in isolation. Next, we estimate the extent to which both R&D and advertising by one organization spillover to the industry in general.

For R&D investments, the point estimate of ? in table 1 suggests that the stock of aggregate "new product knowledge" increases by 34% of every dollar that is currently invested. This implies that while R&D is not a perfect public good, with investments by one organization perfectly offset by reductions by another to leave the aggregate stock of knowledge unchanged (? = 0), there is a significant amount of leakage. As a result, the short run elasticity of individual investments in R&D is only 0.001 (t-ratio = 2.458). With respect to annual investments in advertising goodwill, the effect is similar, but attenuated by, presumably, a greater ability to develop a brand image for a product that is readily identified with a particular source (Washington) than the ability to appropriate plant-development knowledge. In this case, the spillover parameter is also less than one (? = 0.595), but is significantly higher than the R&D counterpart due to this ability to develop brand awareness for a particular type of fruit. Given that apple advertising is funded by levies deducted from individual growers' sales receipts, this level of free-riding may indeed explain much of the recent grower dissatisfaction with these programs. Calculating the short-run elasticity of sales shows that the disincentive for others to advertise embodied in generic promotion causes the elasticity to fall to 0.103 (t-ratio = 2.494), or 58% lower than the impact of the total stock of advertising goodwill. Clearly, if growers were able to effectively brand their product, thereby appropriating more of the benefits from both developing and promoting new varieties, then the overall effectiveness of commodity organizations' programs would likely improve both directly and indirectly through a reduction in the incentives to free-ride on others' participation. Finally, we also find that R&D and advertising differ in terms of their persistence as well. sing the iterative-search method of Ehrlich and Fisher (1982), we find a depreciation rate of 0.51 for advertising and 0.11 for R&D. Interpreting the equations of motion for the stocks of advertising goodwill and product development knowledge as representing a "partial adjustment" dynamic, these estimated values imply that advertising takes approximately two years to arrive at its desired value in response to a shock, whereas the impact of a one-time investment in R&D lasts for almost ten years. This is consistent with our expectations as there exists a fundamental tradeoff between a high short-run advertising impact that disappears relatively quickly and a small short-run impact of new product investments that rises only after the product becomes widely known and, hopefully, accepted by the buying public -- a result which may offer part of the explanation for why commodity organizations do not conduct more basic variety research.

Conclusions and Implications

There are many reasons why commodity organizations currently do not directly research, develop, and patent their own varieties. Economic infeasibility, however, is not necessarily one of them. This study shows that research and development directed at creating new plant varieties that meet evident consumer needs can not only exist as a viable activity for commodity commissions, but can also significantly increase the return of their existing generic promotion programs. Rather than simply help to promote the commodities that are grown by its members, commodity commissions would be well served by taking active roles in defining, developing, and sustaining the market for not only new varieties, but a range of value-added products based in their raw commodities. Perhaps more importantly, future legal challenges to generic promotion programs will be mute as organizations will have a direct, proprietary link to the "brand" that they promote.

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Table 1. Patent Productivity and Demand for Advertising and R&D: WA Apples

Coefficient[1]	Variable	Estimate	t-ratio	Elasticity	t-ratio
Stage One: Patent Productivity - Negative Binomial Estimates					
?$_0$	**Constant**	0.425	0.712	--	--
?$_1$	**B**	0.768	2.435	0.209	2.635
?	$g(N_t)$	0.114	0.7	--	--
Stage Two: Demand for Advertising and R&D - 3SLS Estimates					
Coefficient[2]	**Variable**	**Estimate**	**t-ratio**	**Elasticity**	**t-ratio**
?$_0$	A	0.046	2.971	0.248	1.367
?$_1$	A^2	-0.002	-2.581	--	--
?$_2$	N	0.016	1.965	0.035	1.808
?$_3$	N^2	-0.006	-2.73	--	--
?$_4$	AN	0.004	1.941	0.024	1.941
?	**dB/db**	0.341	0.887	--	--
?	**dA/da**	0.595	3.317	--	--

[1] The likelihood ratio test statistic comparing the estimated against a null model is 15.166 with one degree of freedom. The critical chi-square value at a 5% level of significance is 3.84.
[2] The psuedo-R^2 values for each equation are as follows: advertising demand: 0.649, R&D demand: 0.766, apple sales: 0.683.