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This research was supported by an Undergraduate Creative Activities and Research Experiences (UCARE) grant from UNL. The research was conducted when Anneke Gustafson, currently a Master's student at the University of Nebraska-Lincoln (UNL), was an undergraduate student at UNL. Amalia Yiannaka, the faculty sponsor, is an assistant professor of agricultural economics. Faculty review of the manuscript was coordinated by Professor Azzeddine Azzam, Department of Agricultural Economics, University of Nebraska-Lincoln.

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Effects of Consumer Perceptions on the Marketing of Second Generation Genetically Modified Products

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Effects of Consumer Perceptions on the Marketing of Second Generation Genetically Modified Products *

Anneke Gustafson and Amalia Yiannaka

Abstract

The paper examines how the market/consumer acceptance of a second generation, consumer oriented, genetically modified product (new GMP) affects a company's marketing strategy and its decision to invest in the research and development (R&D) of the new product. Two relationships between the products available in the market and their effect on the monopolist's marketing strategy are considered, namely, vertical and horizontal product differentiation. Analytical results show that when the new GMP in a vertically differentiated market is viewed as the low quality product it has to be priced lower than the conventional product to capture a positive market share while when it is viewed as the high quality product, it may be able to capture the entire market. Results also show that the innovating firm may have to price the new GMP lower in the horizontally differentiated than in the vertically differentiated market in order to enhance its market share.

KEYWORDS: second generation genetically modified product, vertical product differentiation, horizontal product differentiation, consumer heterogeneity

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1. Introduction

In recent years biotechnology has become an important part of the agricultural production sector. As first generation, producer oriented, genetically modified products (GMPs) (e.g., products that aided production and generally increased crop yields) were opposed by the general public in many countries, biotechnology companies are now working on developing second generation genetically modified products which are aimed at the final consumer rather than the producers (Lusk 2003).

Second generation GM products generally have traits that are desirable to consumers, such as added nutritional value (e.g., vitamin A enriched rice known as Golden Rice) and are aimed at reducing consumer opposition to genetically modified foods. Although few are currently on the market, those being marketed or developed include high oleic soybeans; sunflower seeds; canola; high lysine corn; and high protein wheat. A change in public opinion about genetic modification is also being attempted through the development of second generation GMPs that have characteristics beneficial for residents of developing countries, where the health needs for certain characteristics are large. Examples include the aforementioned vitamin A enriched rice as well as vitamin A enriched maize; the first is targeted at Asian and the second at African and South American countries.

The commercialization of second generation GM products will depend largely on perceived consumer value of the additional attributes, the level of consumer aversion to GMPs and relative prices of conventional and GM varieties (Giannakas and Yiannaka 2003). If consumers see the end-use benefits, such as health benefits, of such products as being large, their acceptance of the product will increase and they will likely pay a premium for the good. On the other hand, if there is no perceived end-use benefit, or if little value is placed on the additional attribute, consumers are less likely to accept the GMP and will do so only at a price lower than that of the conventional product (Lusk 2003).

The level of aversion to genetically modified products differs amongst consumers, and often, this seems largely dependant on their nation of residence. In addition, the need within the country for the functional characteristic provided by the new GMPs will also affect their consumption, as it will change the value placed on the characteristic by consumers. For instance, if a large portion of the population is deficient in vitamin A, a product such as Golden Rice will have a high value placed on the vitamin A characteristic that is present in Golden Rice and not in the conventional product. If the population is not deficient in vitamin A, very little value may be placed on receiving the additional vitamin A through

the consumption of Golden Rice. Thus, the market demand for vitamin A enriched rice in a country such as the Philippines, where a large portion of the population is deficient in vitamin A, will be quite different than the demand for the same product in the United States where vitamin A deficiency is not a widespread problem. Note however, that even though the value placed on the additional attribute will be much higher in the Philippines than in the United States the price premium that the consumer in the Philippines would be willing and able to pay to consume the new GMP will likely be low given the large portion of the budget that is spent on food in that country.

In this context, if Golden Rice were offered in the Philippines at the same price as the conventional product, and if the products are viewed as being otherwise the same (e.g., in taste and appearance) it can be assumed that the products would be vertically differentiated, with all consumers ranking the Golden Rice higher than the conventional product. If the same product were offered in the United States at the same price as the conventional product, it is likely that the products would be viewed as being horizontally differentiated by consumers (i.e., consumers would not uniformly rank the two products) and both would be present in the market. Therefore, a product that captures the whole market in one country may not be consumed in another. Thus, the target market/country will affect the firm's marketing strategy.

The goal of this project is to determine how the market/consumer acceptance of a second generation, consumer oriented, genetically modified product (new GMP) will affect a company's marketing strategy and its decision to invest in the research and development (R&D) of the new product. Specifically, the paper examines the effect of consumer perceptions about the relationship between a new GMP and its conventional counterpart (i.e., vertically or horizontally differentiated) on the price that can be charged for the new GMP and the quality level of the additional attribute that will be developed by the biotech company introducing the product in the market.

2. The Analytical Model

A theoretical model is used to analytically examine the above issues. This model assumes heterogeneous consumers who have different willingness to pay for the products available and a monopolist who develops and introduces to the market a new GMP. The market that we are examining consists of two products: a new generation genetically modified product and a conventional product that is supplied in a competitive market. It is assumed that each consumer consumes one

unit of either the new GMP or the conventional product and that this purchase represents a small portion of the individual's budget.

Following Giannakas and Yiannaka (2003), it is assumed that consumers are heterogeneous and differ in their aversion to the process of genetic modification. The differentiating consumer attribute, denoted by α, takes values between zero and one and consumers are assumed to be uniformly distributed between these values. Thus, a consumer with an α value equal to zero has no aversion to the process of genetic modification, and therefore, is indifferent between the two products when those are offered at the same price. The consumer with an α value equal to one is the most averse to genetic modification.

The expectations about the market share that could be captured by the new GMP will affect whether or not the company chooses to conduct research and development on the product. The market shares of the products in this market depend in turn on the way consumers view these products. The mass of consumers is set at unity so finding the consumer who is indifferent between the two products offered in the market, denoted by $\hat{\alpha}$, will determine the market shares of both the new GMP and the conventional product. The demand for each product can then be determined from the market shares.

- **The Market Conditions**

We examine two possible relationships between the products and their effect on the monopolist's marketing strategy: the case where the products are vertically differentiated and the case where the products are horizontally differentiated. The products are vertically differentiated when consumers can uniformly quality rank them; that is, if the two products are offered at the same price, all consumers will purchase only one of the products (high quality) and the other product (low quality) will not be consumed at all. The products are horizontally differentiated when, if offered at the same price, both products have a positive market share. A modification of the heterogeneous consumer model developed by Giannakas and Yiannaka (2003) that accounts for both vertical and horizontal differentiation is used in our analysis.

The utility received from consuming a new GMP and a conventional product is given in equation (1):

(1) $U_{gm}^{N} = U + V - P_{gm}^{N} - \gamma\alpha$ if a unit of the new GMP is consumed

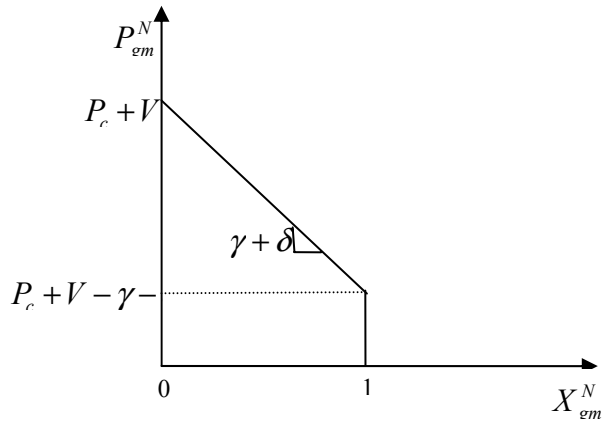
$U_{c} = U - P_{c} + \delta\alpha$ if a unit of the conventional product is consumed

where U is a base level of utility received by consumers, V is the value consumers place on the new product attribute (e.g., vitamin A in GoldenRice) which reflects the quality of the product as it is viewed by consumers, P_{gm}^N and P_c are the equilibrium prices of the new GMP and the conventional product, respectively, γ is a non-negative utility discount factor associated with the consumption of the GM product and δ is a non-negative utility enhancement factor associated with the consumption of the conventional product. Thus, consumers in our model inelastically consume one unit of either the new GMP or the conventional product.

The indifferent consumer derives the same level of utility from the consumption of both products. Therefore, by finding the indifferent consumer, it is possible to determine the market shares that will be captured by each product. This indifferent consumer is found by setting the above equations equal to each other and solving for α. Solving this, the indifferent consumer is found to be located at (i.e., has a differentiating attribute equal to) $\hat{\alpha} = \frac{V - P_{gm}^N + P_c}{\gamma + \delta}$. Consumers located to the left of $\hat{\alpha}$ will consume the new GMP while consumers located to the right of $\hat{\alpha}$ will consume the conventional product. Thus, the market share of the new-GMP, X_{gm}^N, is equal to $\hat{\alpha}$, i.e., $\mathrm{X_{gm}^N} = \frac{V - P_{gm}^N + P_c}{\gamma + \delta}$. The market share of the conventional product, X_c, is equal to $1 - \hat{\alpha}$, i.e., $\mathrm{X_c} = 1 - \hat{\alpha} = \frac{\gamma + \delta - (V - P_{gm}^N + P_c)}{\gamma + \delta}$. Solving the equation $\mathrm{X_{gm}^N} = \frac{V - P_{gm}^N + P_c}{\gamma + \delta}$ for the price of the new GM product gives the inverse demand for the new GM product, $P_{gm}^N = V + P_c - X_{gm}^N(\gamma + \delta)$, while solving the equation $\mathrm{X_c} = 1 - \hat{\alpha} = \frac{\gamma + \delta - (V - P_{gm}^N + P_c)}{\gamma + \delta}$ for the price of the conventional product results in the inverse demand for the conventional product, $P_c = \gamma + \delta - V + P_{gm}^N - X_c(\gamma + \delta)$. Note that when P_{gm}^N falls below the critical value $V + P_c - \gamma - \delta$ the new GMP captures the entire market (i.e., $X_{gm}^N = 1$); when P_c is lower than $P_{gm}^N - V$ the new GMP makes zero sales (i.e., $X_{gm}^N = 0$ and

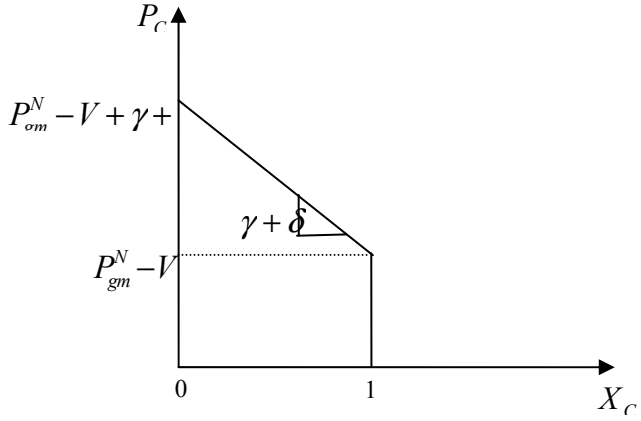
$X_c = 1$). Representations of the inverse demands for the GM and the conventional products are given in Figure 1.

Therefore, the market shares of (and the demands for) the two products are determined by the value that consumers place on the additional characteristic in the new-GMP, V, the prices of both the new-GMP and the conventional product, the level of aversion to the process of genetic modification, γ, and the level of utility enhancement received from consuming the conventional product, δ.



Panel (i):

$$P^N_{gm} = V + P_c - X^N_{gm}(\gamma + \delta)$$



Panel (ii):

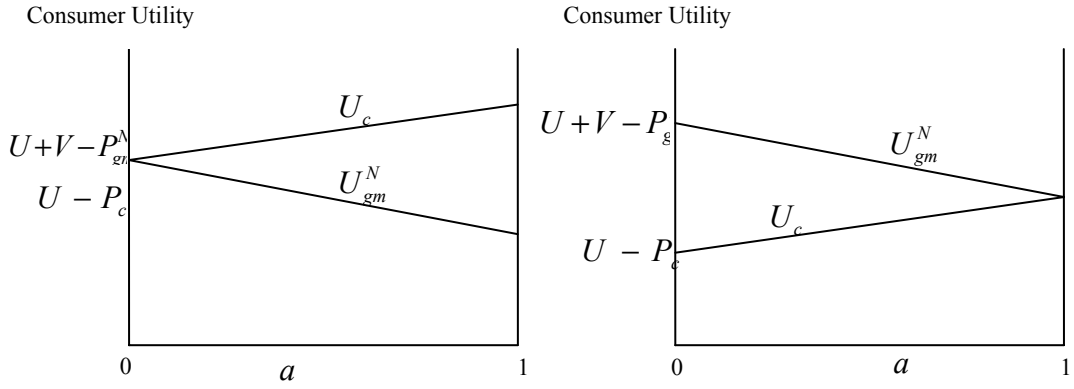
$$P_C = \gamma + \delta - V + P^N_{gm} - X_C(\gamma + \delta)$$

Figure 1. Inverse Demands for the New GMP and the Conventional Product

Vertical Product Differentiation

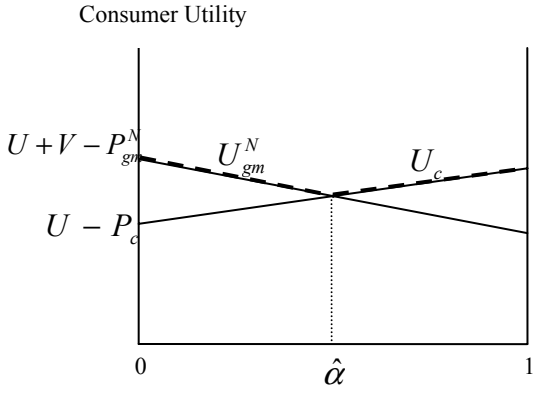
When the price of the new GMP is equal to the price of the conventional product ($P_{gm}^{N} = P_c$), and the value consumers place on the additional characteristic of the new GMP is either $V = 0$ (Case I) or $V = \gamma + \delta > 0$ (Case II), then the products are vertically differentiated as when sold at the same prices only one product will have a positive market share. Under Case I where $V = 0$ and the two products are offered in the market at the same price, $\hat{\alpha} = X_{gm}^{N} = 0$, and the conventional product captures the entire market. Thus, in this case the new GMP is viewed as the low quality product by all consumers. Under Case II where $V = \gamma + \delta > 0$ and the two products are offered in the market at the same price, $\hat{\alpha} = X_{gm}^{N} = 1$ and the new GMP captures the entire market. Thus, in this case, the new GMP is viewed as the high quality product by all consumers. Given the above, for both products to be able to capture a positive market share under vertical differentiation the following conditions must hold: $P_{gm}^{N} < P_c$ under Case I (where the new GMP is perceived to be inferior to the conventional product) and $P_{gm}^{N} > P_c$ under Case II (where the new GMP is perceived as superior to the conventional product). Given the above, the greater is the value consumers place on the new GMP's additional attribute, the higher is the price that can be charged by the monopolist. Likewise, the lower is consumer aversion to genetic modification, the more likely it is that the new GMP will be viewed as the high quality product in this market, ceteris paribus.

A representation of the vertically differentiated market under Cases I and II and under Case III where product prices are such that both products capture a positive market share are illustrated in panels (i), (ii) and (iii) of Figure 2, respectively. Aggregate consumer welfare in this market is given by the area under the utility curve U_c in panel (i) Figure 2, the utility curve U_{gm}^{N} in panel (ii) Figure 2 and the kinked dashed line in panel (iii) Figure 2.



Panel (i). Case I: The market is captured by the conventional product ($V = 0$ and $P_c = P_{gm}^N$)

Panel (ii). Case II: The market is captured by the new GM product ($V = \gamma + \delta > 0$ and $P_c = P_{gm}^N$)



Panel (iii). Case III: Both products capture a portion of the market (($V = 0$ and $P_c > P_{gm}^N$) or ($V = \gamma + \delta > 0$ and $P_c < P_{gm}^N$)

Figure 2. Market Effects under Vertical Product Differentiation

Horizontal Product Differentiation

When the price of the new GM product is equal to the price of the conventional product ($P_{gm}^{N} = P_c$) and the value consumers place on the additional characteristic, V, is such that $0 < V < \gamma + \delta$, then the products are horizontally differentiated as at the same prices each product will have a positive market share. A representation of this market can be seen in Figure 3. Aggregate consumer welfare is the area under the bold curve. In this case, the indifferent consumer, $\hat{\alpha}$, falls between zero and one, resulting in a horizontally differentiated market.

In this market setting, when the value placed on the additional characteristic of the new GM product by consumers is substantially greater than the difference in prices of the new GM and conventional products (i.e., when $V \geq P_{gm}^{N} - P_c + \gamma + \delta$) only the new GM product will be consumed and the conventional product will be driven out of the market. Note that, when products are horizontally differentiated the value that consumers place on the additional attribute, V, must be higher than under vertical differentiation for the new GMP to capture the entire market.

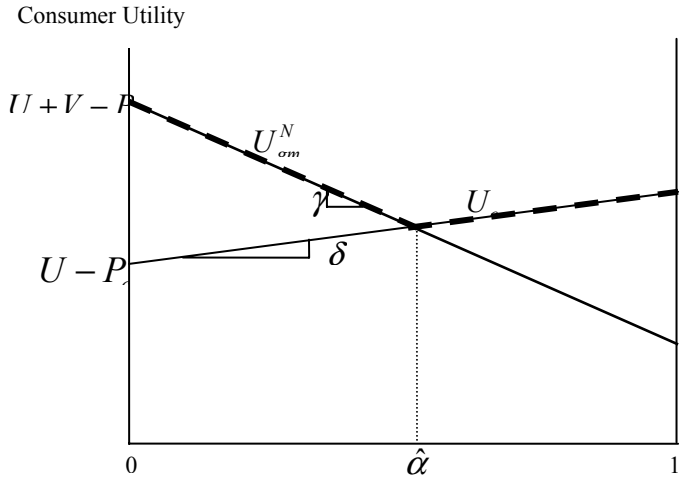


Figure 3. Market Effects under Horizontal Product Differentiation.

- **The Monopolist's Profits**

Having determined how the value consumers place on the additional attribute of the new GMP, the level of aversion to genetic modification, the utility enhancement from the consumption of the new product and the product prices affect the perceived relationship between the two products, the monopolist decides on the quality level of the new GMP that should be developed and how the new product should be priced. In order for the new GM product to enter the market, profits have to be greater than or equal to zero ($\pi \geq 0$). The profits for the monopolist are given by equation (2):

$$\pi = P_{gm}^{N} X_{gm}^{N} - F_{gm}^{N} \tag{2}$$

where F_{gm}^{N} are the R&D costs that need to be incurred in order to produce the new GMP.[1] Note that these costs are sunk, since once incurred, they cannot be recovered. Since what differentiates the new GMP from 'traditional' (first generation) GMPs is the additional attribute that appeals to consumers, we assume that the R&D costs are an increasing function of the additional attribute V of the form, $F_{gm}^{N} = \frac{V^2}{2}$, with $\frac{\partial F_{gm}^{N}}{\partial V} > 0$ and $\frac{\partial^2 F_{gm}^{N}}{\partial V^2} > 0$. Thus, it is assumed that the quality of the new GMP (which is endogenous to the monopolist) is directly related and perfectly correlated to the value consumers place on the additional attribute. In other words, the greater is the effort the monopolist exerts in developing the new product attribute, the higher is the value that consumers place on this attribute.[2]

It is further assumed that, once the R&D costs for the development of the new GMP have been incurred and the product has been developed, it is costless to reproduce; that is, the marginal costs of producing the new GMP are zero. Thus, the burden of developing the new GMP falls on fixed rather than variable costs

[1] Since this is a static model, the requirement that the profits in equation (2) are greater than or equal to zero is a sufficient condition for the development of the new GMP.

[2] This assumption is made to simplify our analysis. We could have assumed that the quality of the new GMP, q_{gm}^{N}, is related to the value consumers place on the product in the following way, $V = \vartheta q_{gm}^{N}$ where $\vartheta \in [0,1]$. The assumption we make here is equivalent to assuming that $\vartheta = 1$. This assumption does not change the qualitative nature of the results.

(see Beath and Katsoulacos (1991) for a discussion of the cost of new product development).

Substituting for X_{gm}^N and F_{gm}^N in equation (2) we get:

$$(3) \qquad \pi = P_{gm}^N\left(\frac{V - P_{gm}^N + P_c}{\gamma + \delta}\right) - \frac{V^2}{2}$$

Equation (3) indicates that the profits that can be captured by the monopolist depend on the prices of the conventional and genetically modified products, the quality of the product captured in the value consumers place on the additional attribute, V, the utility enhancement from the consumption of the conventional product, δ, and the utility discount from the consumption of the genetically modified product, γ.

The objective of the monopolist is to choose the price, P_{gm}^N and the quality of the product reflected in the additional attribute, V, that maximize the profits in equation (3), i.e.,

$$(4) \qquad \max_{P_{gm}^N, V} \pi = P_{gm}^N\left(\frac{V - P_{gm}^N + P_c}{\gamma + \delta}\right) - \frac{V^2}{2}$$

Optimization of the objective function in equation (4) with respect to P_{gm}^N and V yields the following first order conditions (F.O.C.) for a maximum:

$$\frac{\partial \pi}{\partial P_{gm}^N} = 0 \Rightarrow P_{gm}^{N*} = \frac{V + P_c}{2}$$

$$(5) \qquad \frac{\partial \pi}{\partial V} = 0 \Rightarrow V^* = \frac{P_{gm}^N}{\gamma + \delta}$$

Simultaneously solving the equations in (5) yields the optimal price for the new GMP and the optimal value for the additional attribute given by:

$$(6) \qquad P_{gm}^{N*} = \frac{P_c(\gamma + \delta)}{2(\gamma + \delta) - 1} \text{ and } V^* = \frac{P_c}{2(\gamma + \delta) - 1}.$$

Equation (6) indicates that the optimal price of the new GMP is proportional to the price of the conventional product. As expected, the higher the price of the conventional product, the higher is the price of the new GMP that maximizes the

monopolist's profits. In addition, the greater is the consumer aversion to GMPs, the smaller is the monopolist's incentive to invest in the development of the new GMP and the smaller is the profit maximizing value of V. In contrast, the greater is the price of the conventional product, the easier it is for the new GMP to compete with the conventional product and the greater is the monopolist's incentive to invest in the additional attribute, V.

Substituting the optimal values for P_{gm}^{N} and V into the profit function (equation 3) gives the maximum level of profits that can be captured by the monopolist when he introduces the new GMP in the market. This substitution results in the optimal profit function:

$$(7) \qquad \pi^{*} = \frac{P_c^2}{4\gamma + 4\delta - 2}$$

Thus, the optimal level of profits that can be captured by the introduction of the new GMP are increasing in the price of the conventional product and are decreasing in the level of aversion to GMPs, γ, and the utility enhancement from consuming the traditional product, δ (i.e., $\frac{\partial \pi^{*}}{\partial \gamma} = \frac{\partial \pi^{*}}{\partial \delta} = -\frac{4P_c^2}{(4\gamma + 4\delta - 2)^2} < 0$ $\forall \gamma, \delta \geq 0$).

Consumer perceptions about the products available in the market are important in determining whether or not companies will develop a new-GM product. Companies must garner information on the value consumers will place on the additional attribute of their product, as well as on the consumer aversion to the process of genetic modification. This will allow the company to determine whether they will be able to recover their costs and make a profit. If the price would have to be quite low in order for the product to be consumed (as in Case I under vertical differentiation where the new GMP is perceived by consumers as being the low quality product), the company may not be able to cover costs, and may, therefore, not invest in the research and development required to produce the product.

3. Results and Discussion

This paper examines the effect of consumer perceptions about a consumer oriented genetically modified product and its conventional counterpart on the de-

mand for the new GMP and a firm's decision to invest in its development and commercialization.

The demand for the new GMP is largely dependant on the country in which the product is being marketed as aversion to genetic modification amongst consumers differs across countries and the need for the additional attribute present in the new GMP may vary between countries. A company's decision to develop and market a product depends on the value consumers place on the additional attribute, the consumer aversion to the process of genetic modification, the utility enhancement received from consuming the conventional rather than the new GM product and the prices of the products in the market.

The decisions and marketing strategies of the innovating firm are also affected by the nature of differentiation of the new GMPs and their conventional counterparts. In particular, our study shows that when a new GMP in a vertically differentiated market is viewed as the low quality product it has to be priced lower than the conventional product to capture a positive market share. This limitation in the pricing strategy of the firm can jeopardize its ability to recoup its R&D costs and result in the lack of incentives for the development of the new GMP. If the new GMP is viewed as the high quality product in a vertically differentiated market, the new GMP may be able to capture the entire market unless the conventional product is priced low enough.

Our results also show that it is harder for the new GMP to capture the entire market under horizontal product differentiation than under vertical product differentiation where the new GMP is viewed as the high quality product, i.e., the value that consumers place on the additional attribute, V, must be higher under horizontal than under vertical differentiation for the new GMP to capture the entire market ($V \geq P_{gm}^{N} - P_c + \gamma + \delta$ versus $V = \gamma + \delta > 0$, respectively). This implies that in a horizontally differentiated market, the company producing the new GMP will attempt to create the highest value for the additional attribute possible in order to capture as much of the market as possible.

Finally, our analysis shows that the innovating firm may have to price the new GMP lower in the horizontally differentiated than in the vertically differentiated market in order to enhance its market share. Given the above, the firm developing the new GMP will likely prefer to compete in a vertically differentiated market where its product is viewed by consumers as the high quality product.

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