Diversity And Superiority In Innovation Processes

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EXTENDED ABSTRACT

A product group consists of product varieties (phenotypes) that compete for the same customer budget. The paper introduces an approach to identifying separate markets by means of product group (genotype) delineation. The paper contrasts two basic ideas for analysing competition within a product group. The first idea relates to Lancaster's suggestion that every product variety can be identified by its attributes or characteristics (L-model). The second idea relates to the monopolistic-competition model as popularised by Krugman (DS-model). With this latter approach, a product group potentially contains a large set of varieties, where customers as a group have a taste for variety. For each of the two paradigms, the paper presents and compares the process by which novel product varieties are introduced. In the framework of Lancaster, evolution tends to reduce the number of varieties due to development of superior alternatives. The Krugman framework rather predicts an evolution where the number of varieties may increase without limits. The contribution of the paper is to contrast the two perspectives, by comparing the change processes and by assessing the adhering equilibrium solutions. A major question is how these two conflicting perspectives should be interpreted. The paper ends by suggesting a framework that can resolve the conflict between the two perspectives.

The L-model provides a theoretical framework for how a separated market can be delineated, whereas the DS-model is more ad hoc in this sense. The prime demarcation aspect is however that in the DS-model diversity of products is generated by customers' taste for variety. This must not be interpreted as a case, in which each customer consumes of all varieties at each point in time. A more reasonable interpretation is that a customer during a time period exercises the taste for variety. In contrast, a customer in the L-model purchases two or several varieties only when there is no product available with the desired combination of attributes. Hence, in the L-model the tendency is towards a smaller set of superior varieties. However, heterogeneity among customers will counteract this tendency and generate product diversity in the L-model.

The possibility of a superior product variety for each customer group is inherent in the L-model. One may also observe this phenomenon can associated with so-called technology lock-in effects (Arthur, 1989). In order to understand this, we may consider a product group for which an essential feature is mutual compatibility with other product variants. As some variant gets a large market share, the compatibility aspect will be an important attribute with a decisive role in customers' preference functions. This type of feature is completely absent in the DS-model.

In the L-model scale economies explain the dynamics when a superior product increases its market share by replacing established products. Scale economies are the driving force behind competitive exclusion. In the DS-model scale economies provide incentives for firms to develop economies of scope and to continue to expand the number of varieties.

1. INTRODUCTION

In this paper two different views on how and why product innovations continue to emerge are presented and compared. Moreover, the two views predict quite different dynamic consequences of innovation processes. The first view is here associated with the characteristics model (L-model) introduced by Lancaster (1971), while the second relates to the monopolistic-competition revolution (DS-model) associated with Dixit and Stiglitz (1977). The message from the L-model is that regardless whether one considers intermediate or final users, technological evolution consists mainly of substituting new means of consumer satisfaction for old ones (Batten and Johansson, 1989). Hence, substitution is emphasised. Turning to the DS-model, we are instead confronted with a view that product innovations are driven by a background of consumers' taste (or passion) for variety. In this case substitution is replaced by an ever increasing set of partly complementary varieties.

The Lancaster approach is radical by suggesting that the researcher should look for objective attributes of every product variety and group products in such a way that a separated market contains products that have the same attribute space. In addition, the selection of attributes has to satisfy the condition that they are revealed essential in the preference function of at least some customer group.

The initial Dixit-Stiglitz model (1977) assumes that all product varieties in a separated market are partial substitutes, and the associated product group contains varieties that "compete" more intensively within the group than with products in other submarkets. The problems around this approach are intensively discussed in Dixit and Stiglitz (2004a, 2004b). A method to accomplish a structure that can treat both internal aspects of a one product group and the overall composition of product groups is suggested in Fujita and Thisse (2002). The method is to let the overall preference function of customers have a Cobb-Douglas formulation of "sub-utility" variables, where each variable reflects the composition of varieties in each separate product group.

The common feature of the L-model and DS-model presented in this paper is that they rather reflect competition between product varieties than competition between firms. The paper extends the features of the two models in several ways. The analysis has the ambition reveal how the two models of product competition can help us to understand the dynamics of product varieties and to interpret the results in a framework of product innovations. In addition, the analysis also sheds light on the issue of spatial submarkets, partly reflecting functional regions in a global economy.

The final motivation for the paper is to assess common and conflicting features of the two archetypes of models. This assessment helps to show how far the analysis ca proceed along each route. Moreover, the paper also formulates suggestions about how two the two strands of analysis might be combined.

2. PRODUCTION AND INNOVATION CONDITIONS IN THE TWO MODELS

The basic assumption about production that is applied here has been frequently used in models by Krugman (1990) as a means to depict economies of scale. We assume that a one-product firm, *f*, has the following cost function:

$$C_f(x_i) = F + G + vx_i \tag{2.1}$$

where *F* represents firm-specific fixed costs and *G* innovation costs referring to product *i*. It is obvious from (2,1) that unit cost, $c_f = C_f(x_i)/x_i$, will fall as output increases. Next, consider that the market has a given set, *N*, of products. For firm *f* we assume that there is a subset, $N_f \subset N$, of products such that these products jointly can rely on the fixed cost *F*, whereas each of them requires a product-specific investment that causes a fixed cost *G*. We shall refer to N_f as firm *f*'s scope group of products.

Consider now that firm *f* produces n products in a given market, where each product $i \in N_f$. To further simplify matters we can assume that most other firms in the same market produce just one product. In such a market with many products, n remains a large number, and then we can assume that firm *f* lacks market power. In addition, we assume that the supply of every product $i \in N_f$ satisfies $x_i = x_0$. In this setting, the market competition is essentially competition between products and not between firms. As a consequence, the total cost of firm *f* is assumed to satisfy the condition in (2.2):

$$C(n) = F + nG + vnx_0 \tag{2.2}$$

Given this, let $C_f(1)$ and $C_f(n)$ denote the total cost of a one-product and an n-product firm, respectively. The unit cost of firm *f* is smaller when the firm has developed many products, because

$$C_f(1)/x_0 - C(n)/nx_0 = (F/x_0)(1-1/n) \tag{2.3}$$

First, we can observe that $C(1)/x_0$ applies to all single-product firms. Hence, the unit cost difference in (2.3) can be interpreted as the unit cost difference between firm *f* and any other single-product firm. The formula tells us that the incentives to exploit scope economies depend on how the size of *F* compares with that of *G*. For each additional variety that firm *f* may develop, firm *f*'s incentive to further increase n will decline.

The assumptions introduced above for the cost of production remain within the normal frames of economic analysis. The innovation assumption is different and is stated explicitly below:

Introduction assumption: Ideas about product varieties arrive to potential entrepreneurs in a random process. When such an idea arrives, the potential entrepreneur decides to make the introduction (start-up) investment, *F*, given that there is no firm already in operation. In addition the firm has to develop the product at the cost *G*. For an already established firm, *f*, the latter is the only new fixed cost, given that the new product *i* belongs to N_f. If a new product idea $j \notin N_f$, the idea has to be materialised in a new firm.

3. COMPETITION BETWEEN PRODUCTS IN THE L-MODEL

3.1 Preferences and Demand in the L-model

In Lancaster's (1971, 1982) model of consumer behaviour, products possess objectively measurable characteristics (attributes). The presentation will follow the exposition in Batten and Johansson (1989), in which the demand model is extended to incorporate all types of customers. The latter use products, singly or in combination, as inputs to a production or consumption process. Preference orderings are assumed to rank collections of attributes, while products can be ranked only indirectly via the attributes they posses.

Consider now a market and its associated product group, where product varieties in a group have certain attributes in common. The market is associated with a product space, X , and an attribute space, *Z*, such that

$$\begin{aligned} x &= (x_1,...,x_n) \in X = \{x \in R^n : x \geq 0\} \\ z &= (z_1,...,z_m) \in Z = \{z \in R^m : z \geq 0\} \end{aligned} \tag{3.1}$$

where *x* is a product and *z* an attribute vector. Following Lancaster, we assume that there is a mapping *C* that transforms every vector of products into a vector of attributes such that *z* = *C*(*x*). Finally, we shall assume that each customer has a real-valued preference function u(*z*) = $u(C(x))$. This preference function may refer to a longer time period, within which a customer combines in intervals to use a small automobile of city type and a large van for country-side trips.

In order to ascertain variety in the Lancaster model, it is possible to introduced customer groups, g = 1,2, … $\bar{g}$, each group with its own preference function u^g and purchasing budget m^g . Customers in a group are treated as identical, and thus when the text refers to customer *g*, that is a reference to the group as a whole (aggregated). In the model all customers in a group are assumed to be identical. Hence, the behaviour of the group is a simple aggregation of the behaviour of a typical customer in the group. For every customer group, u^g is continuous, strictly quasi-concave and differentiable with all first-order derivatives positive, i.e., u^g is well behaved.

The choice set of a customer *g* is given by $K(p, m^g = \{x \in X : px \leq m^g\}$, where *p* = $(p_1,..., p_n)$ is a price vector. The transformation $z = C(x)$ of a chosen *x*-vector can be either of the following:

$$z = Bx \tag{3.2a}$$

$$z = \{b^i x_i \ , i = 1,...,n\} \tag{3.2b}$$

In (3.2a) the customer combines different product as expressed by the *B*-matrix where each column *i* is a vector $b^i = (b_1^i,...,b_m^i)$ with at least one element is positive, and where b_s^i signifies the amount of attribute *s* that is associated with one unit of product *i*. In case (3.2b), that we will not apply subsequently, the typical customer chooses only one product.

A customer who maximises the preference function u^g generates the following demand function:

$$F^g(p,m^g) = \{x \in K(p,m^g) : u^g(Bx) = \max_x u^g(Bx)\} \tag{3.3}$$

The function F^g may be set-valued for certain price vectors. When $F^g(p,m^g)$ is vector valued the demand for a given product *i* and customer group *g* can be written as (Batten and Johansson, 1989):

$$x_i^g = v_i^g(p)m^g / p_i \tag{3.4}$$

where v_i^g is a function of *p* that shows the share of m^g that is spent by customer *g* on product *i*. With the help of this formulation we can express the notional demand, $V_i(p)$ for product *i* across the customer groups in (2.8):

$$V_i(p) = v_i(p)m / p_i \tag{3.5}$$

which informs about how much customers would like to buy of product *i*. This notional demand can materialise in purchases, given that the supply is sufficiently large.

3.2 New Products and Catastrophic Shifts in Demand

Let us consider a specific customer group and let there be m distinct attributes, which are positively valued by these customers. Moreover, let there be n different products which are uniquely differentiated in the sense that their attribute vectors $b^1,...,b^n$ are linearly independent. Given this, consider that a new product, labelled n+1 is introduced to the market such that b^{n+1} can be expressed as a linear combination og the initial n attribute vectors. In particular, let the new attribute vector be intermediate in the sense that

$$b^{n+1} = \sum_{i=1}^{n} \alpha_i b^i \tag{3.6}$$

as $\alpha_i \geq 0$ for all *i* and $\alpha_j > 0$ for at least on *j*. As we shall see this type of intermediate product variety can be a strong threat to several or all of the initially established products. The thing is that the new product may attract customers of those products *j* for which $\alpha_j > 0$. Such a case is illustrated in Figure 1, which describes a market with two attributes z_1 and z_2. The initial products are represented by the vectors b^1 and b^2, while b^3 refers to the new, rivalry product. The figure describes a price constellation such that $v_1^g(p)b^1 / p_1 + v_2^g(p)b^2 / p_2 = b^3 / p_3$, where we observe that $v_3^g(p) = 1$. In essence this means that the new product can provide customers with the preference function u^g an outcome that is as least as good as the best combination of product 1 and 2. In addition, the new product will sell a larger quantity than each of the two initial products, which matters indeed when scale economies are present. Obviously, if the price p_3 can be further reduced, the two initial products will "catastrophically" lose their demand altogether.

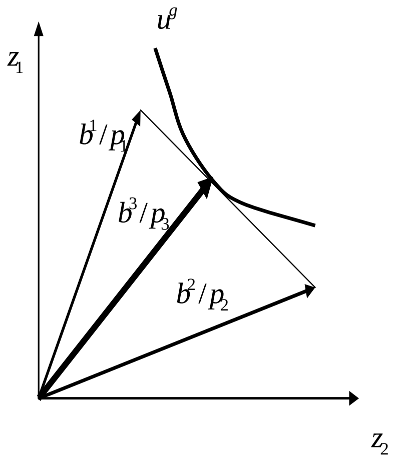

Figure 1: Introduction of an intermediate product

Conclusion 1: The L-model, as specified by (3.1)-(3.5) demonstrates which attribute combination a new product should have in order to represent a competitive alternative to one or several already established products.

Conclusion2: The first conclusion reveals the possibility for a superior product variety to enter the market and squeeze out many existing varieties, and thus reducing the richness of alternative varieties, while at the same time enriching the composition of attributes that can be obtained from the "superior" product.

Conclusion 3: Suppose that there is only one customer group, where each customer has the same well-behaved preference function. When this is the case the L-model describes "competitive exclusion". In this case, this means that for each product-group market there is a strong tendency towards solutions where one "superior" product dominates the market. The driving force of this process is the presence of scale economies. At the same time, with many distinct customer groups with sufficiently different preference functions, the process in (3.8) can generate market solutions with a diversified set of product varieties.

4. COMPETITION BETWEEN PRODUCTS IN THE DS-MODEL

Similar to section 3, we shall in this section consider an economy with several product groups, each associated with a separated market. The overall preference function is assumed to have the following form:

$$U = U_1^{1-a_1} U_2^{a}, \quad 0 < a < 1 \qquad (4.1)$$

where U_2 signifies the preference value (sub-utility) that stems from purchases of product varieties in product group 2, whereas U_1 represents the preference value associated with all other product groups in in the economy. A typical customer is assumed to have the following sub-utility function with regard to product group 2:

$$U_2 = \sum_{k=1}^{n} q_k^{\phi}, \; 0 < \phi < 1 \qquad (4.2)$$

The formulation in (4.1) implies that for customers who maximise *U* for a given budget share $\hat{m}$, the budget share allocated to product group 2 becomes *a*. Hence, we can write $m = a_2 \hat{m}$ to denote the budget set off for product 2. With a given number of customers the corresponding aggregate budget is *M*.

We assume that all customers optimise their preference function, which is equivalent to maximising the Lagrange function $\Lambda = \sum_k q_k^{\phi} + \lambda(m - \sum_k p_k q_k)$, where p_k denotes the price of product variety *k*. The solution is $p_k = \phi q_k^{\phi-1} / \lambda$. Next, consider that the number of varieties, *n*, is large enough to make negligible the effect that a change in any p_k may have on λ, the marginal utility of money (Dixit and Stiglitz, 2004). To the extent that this makes income effects negligible, we can introduce the variable $\theta = 1/(1-\phi) > 1$ to obtain the following demand function:

$$x_k = \alpha_k p_k^{-\theta} M, \qquad (4.3)$$

where the parameter θ represents the price elasticity and where $\alpha_k = \alpha$ for all products in the product group. The derivation of (4.2) and the nature of α are described in Appendix 1. The value of α can be considered a constant in a temporary monopolistic-competition equilibrium (MCE). As discussed in Appendix 1, this value of α is a local approximation and represents a price index for the market (Fujita, Krugmand and Venables (1999).

Assume now that a supplier of product k has the following costs function:

$$C_k = \overline{F} + v x_k \qquad (4.4)$$

where $\overline{F}$ = F + G in formula (2.1) and hence denotes fixed costs that may represent start-up costs including R&D expenditures. Together, (4.2)-(4.4) define a model of monopolistic competition. From these two formulas we can derive a profit expression, from which we can find the price corresponding to profit maximisation, which comes out as $p_k = v\sigma$, where $\sigma = \theta/(\theta - 1)$. This solution implies that each firm perceives its competitive environment as given. Since all firms that supply products in the same product group have similar demand and cost functions, the price will be the same across these firms. If sufficiently many firms enter into the pertinent market, profits will approach zero, and then we can determine the number of products as $n^* = M / F\theta$ (Appendix 1). In this equilibrium the mark-up, $\sigma - 1$ = $1/(\theta - 1)$, is just large enough to allow each firm to cover its fixed costs. Moreover, the output of each variety is =

Conclusion 4: As shown in Appendix 1, in equilibrium each firm produces just one variety and the output satisfies $x_k = x_0$ = $(\overline{F}/v)(\theta - 1)$ for every firm.

Conclusion 5: The number of products, $n^* = M / F\theta$, can be thought of as an equilibrium property. When the actual number of products, n, is lower than n^* we also have that the actual price, $p = v\sigma > F/x$, since x will be larger when $n < n^*$ (Brakman) In this case we say that there is a "gap in the market".

How can we conceive that the market is out of equilibrium, in the sense clarified in the above conclusion? How can there be a gap in the market? First, as new varieties arrive gradually the market solution in each point in time will generically deviate from the reference solution, where $n = n^*$. If the market is in monopolistic equilibrium, a gap will gradually develop as the market-size parameter, M, expands over time.

4.3 Monopolistic Competition with Economies of Scope

With the presence of economies of scope, one can formulate an MCE solution, in which some firms remain small and produce just one variety such that $x_k = (\overline{F}/v)(\theta - 1)$ = x_0 , whereas other firms that can utilise scope economies and produce several varieties. This type of solution exists as explained below:

Conclusion 6: Also when economies of scope is present for some firms, each firm will perceive an exogenously given environment of competitors as long as the number of varieties is large enough. When this is true the profit-maximising firm of every variety remains $p_k = v\sigma$. The interpretation is that the market setting is such that products compete with each other, whereas every firm lacks market power also when it supplies more than one variety.

5. COMPARING THE TWO MODELS

The introduction process, based on a random arrival of ideas, has different implications in the two models. In the DS-model it drives market solutions to situations where the number of varieties is maximal and where the price level equals average cost, although this amy not hold universally, when a market has "islands" on which economies of scope rules. In contradistinction, new product ideas may have radical consequences in the L-model such that already established product varieties lose market shares or even disappear altogether.

The major difference between the two models is the nature of their respective market solutions. In the DS-model already established products remain and constitute components of a long-term equilibrium. In the L-model a time-invariant market solution can always be disturb by new product innovations

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