How does technological advance affect the quality and variety of information products?

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Abstract

Anecdotal evidence suggests that producers of information products (TV programs, movies, computer software) may respond to potentially cost saving technological change by increasing, rather than reducing, their total production investments in the "first copy" of each product, possibly at the expense of product variety. Comparative statics show that under reasonable assumptions about consumer demand and production technology, a monopolist is in fact induced to increase first copy investments as a result of either what are defined as "quality-enhancing" or "cost-reducing" types of technological advance. In a competitive industry, first copy investments also rise for both types of technological change, while variety falls or stays the same. Results suggest that contrary to often held expectations, potentially cost saving technological advances in information industries may result in greater market concentration.

I. Introduction and background

In their classic treatise on the economics of the performing arts, Baumol & Bowen (1968) established that a lack of opportunities for increased productivity in presentation of theatre, symphony concerts, and the like, implied that the arts were destined to become more and more costly relative to other goods and services. That would lead to a decline in their availability, unless there were comparable increases in public or foundation subsidy. It is evident, however, that the production of some information goods, such as movies, television programs, and computer software, have been subject to major technological advance. As computer technology has developed over the past two or three decades, special effects have become a key part of Hollywood's movie and television output Computer software, of course, has been made possible by computers themselves, and technological advances in games and other applications have obviously been dramatic.

How does technological change in the creation of such information goods affect the quality and variety of products that are made available? Several authors have addressed tradeoffs between product quality and variety in differentiated product industries (Shaked & Sutton, 1987; Sutton, 1991, 2001; Berry & Waldfogel, 2003). The effects of technological advance on these tradeoffs, however, does not appear to have been considered in the economic literature.

How production technology affects such tradeoffs has evident implications for market concentration in information industries. If technological advance tends to favor variety over quality, the result may be fragmentation of market shares. Conversely, incentives to increase product quality relative to variety imply a rise in industry concentration.

We address these issues using simple theoretical models. We do not attempt to develop general results for the effects of technological change on product quality, variety, or industry concentration. Rather, our purpose is to explain what seems to be a prevalent tendency for the result of technological change in information production to be a triumph of quality (or at least production budgets) over variety—even in cases where the technology is ostensibly cost-reducing. For example, major cost-reducing advances in movie animation made possible by CGI (Computer Generated Imagery) technology since the mid 1990s have, paradoxically, been associated with relatively rapid increases in the production costs of animated compared to other features films.[1]

Often, in fact, observers seem to greet news of production cost-reducing advances in information industries with relief that smaller independent operators--such as desktop publishers, or independent filmmakers with PC animation programs, or cheap digital cameras and editing equipment--will finally have the means to challenge industry domination by highly capitalized, established firms. For example, a *Scientific American* article in 2000 declared an independent film production revolution in the making, remarking that "It is now possible for all of us to try to become desktop Scorceses" (Broderick, 2000, p. 68).

There seems little evidence, though, that such fragmentation actually occurs. The motion picture industry in general, as well as computer games and other applications software, are apparent examples. From 1975 to 2003, average production costs of MPAA-member produced theatrical features rose about 20-fold (from \$3.1 to \$63.8 million), but was only a 41% increase in the number of movies that MPAA companies distributed annually in the U.S. (from 138 to 194) (MPAA, 2004; Kagan Media Research). In spite of dramatic technological advance occurring over this period, market shares of the dominant players have remained stable or have increased.[2] Available data for Korean computer game production show that from 1999 to 2003, average development costs per game rose by 237% in Korean won (Korean Game Development and Promotion Institute, 2002, 2004).[1]

Turning to the relevant economic literature, Lancaster (1975), Spence (1976), and Dixit and Stiglitz (1977) first studied tradeoffs between production setup costs and variety in differentiated product markets, with explicit modeling of the television case by

[1] Although a given movie has been said to cost 45% less to produce with CGI technology in comparison to 2-D technology (Eller, 2002), the average actual budgets of CGI animated movies released in the U.S. from 1998-2002 were approximately twice as high as those of 2-D movies: \$89.8 vs. \$46.9 million, respectively. For details of these data, see Waterman (2005).

[2] Throughout the 1975-2003 period, MPAA-distributed movies have accounted for 80 to 90% of the total box-office in the United States. Market shares of independents were 7.2% in the 2001-2003 period, down from a high of 19.0% in the 1986-90 period. (Variety (various); Nielsen-EDI Summary Database). Because the MPAA bases its average production cost data on a subset (of undisclosed size) of all MPAA releases, these trends in number of releases and average costs are not precisely comparable.

Spence and Owen (1977). These authors generally assumed, however, that set up or first copy costs, and thus product quality, are exogenous.

Later authors developed endogenous quality models in which product quality can be varied by raising or lowering set up, or first copy costs. Shaked and Sutton (1987) develop such a model in which individual consumers differ in terms of their valuation of quality. They show that if marginal costs are constant or increase slowly enough, high quality firms can undercut low quality firms as market size increases, resulting in a lower bound on industry concentration. Larger markets, that is, do not necessarily result in greater product variety. Sutton (2001) builds upon that model and Sutton (1991) to investigate the effects of R&D intensity on industry concentration. As the basis for an extensive empirical study, his theoretical model shows that industry concentration depends positively on the elasticity of product quality with respect to R& D spending and on the substitutability of products at the consumer level.

It is evident that first copy investment is a central determinant of product quality in information industries, and that the level of investment is an important decision variable. Examples include investments in computer software product development, the production costs of movies or television programs, and the creation of newspaper or magazine content. Berry and Waldfogel (2003) develop an endogenous quality model based on Shaked & Sutton (1987) to empirically demonstrate that the average quality of daily newspapers increases with local market size, but that market fragmentation does not occur. That result contrasts with increasing fragmentation as market size grows in the case of restaurants, a product in which quality primarily depends upon variable costs.

Other frameworks have been used to investigate the tradeoffs between the quality and variety of differentiated products with endogenous setup costs and constant marginal costs of production and distribution. Economides (1989) considers the tradeoffs in a model that represents product space along a straight line. Waterman (1990) uses a modified version of Salop's (1979) circular model of monopolistic competition, with specific applications to media products, to show that increases in demand (or for the television case, a conversion from advertiser to direct pay support), may induce producers to increase production investments and thus product quality, without necessarily increasing product variety. Economides (1993) shows similar tradeoffs between product quality and variety in a circular model framework, but without direct application to media products.

II. Assumptions and Models

Turning to our attempts to explain these phenomena, it is useful to conceive of technological change as one of two types: “cost-reducing” or “quality enhancing.” In live action films, for example, computer technology now permits digitally generated movie extras to routinely take the place of live actors. To the extent that such technology results in essentially equivalent outcomes for the movie viewer, this technology is cost reducing. We are all familiar, however, with how computer technology has made possible the increasingly spectacular special effects in Hollywood blockbusters. Basically, these technologies can be thought of as quality enhancing. Of course, technological changes in movies and other media can be both cost reducing and quality enhancing. In other information product industries, like computer software, there has clearly been a dramatic march forward in development processes on both fronts. Ever faster and efficient computers have greatly shortened the time it takes to carry out a given programming task, and they also make possible far more useful (or fun) software creations.

Three theoretical models representing alternative market structures and assumptions about production inputs are presented below. These frameworks do not permit generalizations about the effects of technological change on product quality and variety. Rather, they are intended to demonstrate that with plausibly defined demand and production conditions, the effect of either cost-reducing or quality-enhancing technological change in information industries can simply be increased production investments, along with reduced, or at least not necessarily greater, product variety.

In the first model to follow, we consider the case of a monopolist producing a single information product that has only one variable input. In a second model, we consider a two variable input case for the monopoly case. Only quality (and not variety) can vary in these models, but the basic driving forces behind our findings are most clearly shown in these simple situations. The third model represents a monopolistically competitive industry in which firms employ two inputs in a Salop-style circular model. In those models, both quality and variety can change. Selected welfare results are also reported.

A. Model I: Single Input Monopoly

Let us say, just for color, that movies consist only of a series of filmed explosions, and that the producer faces no other costs than those of producing the film negative (or first copy) itself. In this case, the only decision variable of the producer is how many explosions to include in the movie.

Define

$$(1)\ \Pi = P(J\text{-}\alpha P)E^{\beta} - C_E E$$

where: demand, $Q = (J\text{-}\alpha P)E^{\beta}$; P = price; J and α are demand parameters, where $J, \alpha > 0$; E = number of explosions; C_E = constant cost per explosion; β = the elasticity of audience demand w.r.t. to the number of explosions in the movie, where $0 < \beta < 1$. Total production investment is $K = C_E E$.

Essentially, the demand function acts as a movie production function in which explosions are the inputs and audience the output. Such a function could take a variety of different forms. While there is a very large literature on production functions, little of it seems to be characteristic of information products, and that which is, seems to offer relatively little guidance.[3] As specified, the demand (ie, audience production) function has appealing characteristics. The first derivative of demand with respect to E is positive, and the second derivative negative. That is, more explosions always help, but there are diminishing returns to audience interest as more and more of them are used. The multiplicative form of the function means that the marginal effect of increasing production investments is to proportionately shift the demand line with respect to price outward.

[3] Some related research involves team sports. A recent empirical study of English Football by Carmichael, Thomas, & Ward (2000) reviews this literature, beginning with Scully (1974). These studies generally develop linear empirical models to estimate the marginal contributions of vectors of playing skills, or of individual players, to team win-loss records. A number of empirical studies have attempted to estimate the marginal effects of particular actors, Academy Awards, etc. on movie boxoffice results, using linear regression models (eg, Smith and Smith, 1986, Ravid,1999; DeVany & Walls, 1999). Other authors have investigated the production of computer software by estimating how well alternative functional relationships between output (as measured, for example, by lines of code) and hours of labor input (Hu, 1997). Overall, the economic literature on production appears to offer little guidance.

The firm maximizes profit w.r.t. P and E, yielding:

(2) $P^{*} = J/2\alpha$

(3) $E^{*} = (J^{2}\beta/4\alpha)^{1/(1-\beta)}\, C_{E}^{\;-1/(1-\beta)}$

(4) $K^{*} = C_{E} E^{*} = (J^{2}\beta/4\alpha)^{\;1/(1-\beta)}\, C_{E}^{\;-\beta/(1-\beta)}$

The effects of cost reducing and quality enhancing technologies can be separately considered in this model. Cost-reducing technology simply works through the parameter C_E. That is, a lower C_E means that an explosion with the same audience appeal is cheaper. Quality enhancing technology can be interpreted to work through the parameter β. That is, the audience demand function w.r.t. E shifts upward if β is higher. Alternatively, quality-enhancing technology can operate through an outward shift of the demand function with respect to price: that is, an increase in J, a decrease in α , or some combination. By the latter mechanisms, the effects of increasing the number of explosions on audience size are magnified accordingly

To understand equilibrium effects of technological change, we are interested in dE^{*}/dC_E and dK^{*}/dC_E, $dE^{*}/d\beta$ and $dK^{*}/d\beta$, and comparably for the J and α parameters.

It is easily shown from (3) and (4) that, $dE^{*}/dJ > 0$, $dE^{*}/d\alpha < 0$, and thus, $dK^{*}/dJ > 0$, and $dK^{*}/d\alpha < 0$. As we would expect, that is, quality enhancing technology by either of these mechanisms increases incentives to invest in movie explosions. It is also evident from (3) and (4) that both dE^{*}/dC_E and dK^{*}/dC_E are unambiguously negative. A lower cost of explosions, that is, increases the number of them used; also, the lower cost results is greater total spending on explosions (which in this case represents total movie production costs) because the total number of explosions used rises faster than costs per explosion fall.

It can be shown that the two other derivatives of interest, $dE^{*}/d\beta$, and therefore $dK^{*}/d\beta$, are positive as long as $E^{*} > e^{-1/\beta}$. Given the assumed range of β, that equality always holds if E^{*} is at least one. While one might argue that cases of E^{*} less than one are of interest, the intuitively plausible result that producers are induced to expand the use of explosion inputs when their marginal effect on demand rises, holds for a range of plausible demand parameters.[4]

A numerical illustration

A simple example can compare the potential effects of quality-enhancing and cost-reducing inputs in the single input monopoly case. Using (1) above, let $J = 200$ and $\alpha = 1$ for an initial case. From equation (2), $P = 100$ and so $P(J\text{-}\alpha P) = \$10{,}000$. Also let β, the elasticity of demand with respect to the number of explosions, equal .5.

The first row of Figure 3 shows that for the initial case, the marginal value of the first explosion in a given movie (ie, $P(J\text{-}\ \alpha P)E^{\beta}$, where $E = 1$) is \$10,000. As the last three columns show, there are diminishing returns to audience demand from including additional explosions (as E rises to 2, 3, and 4).

Figure 3
Illustration of the effects of technological change:
The single input monopoly case

Number of explosions	1st	2nd	3rd	4th
Marginal value, initial case	\$10,000	\$4,142	\$3,178	\$2,680
Marginal value, doubled impact	\$20,000	\$8,284	\$6,356	\$5,360

If we assume for the initial case that each explosion costs \$6,000, the profit maximizing result is that only one explosion is used, since demand only rises by \$4,142 for the second.

Now, however, consider a quality-enhancing technological change, such as an improvement in the realism of explosions from computer enhancement. If we say that

[4] Specifically, the inequality $E^* > e^{-1/\beta}$ holds unambiguously only for case in which $E^* > .37$. To see how an increase in β could lead to production of a lower number of explosions, note that $Q_{\beta}' = (J\text{-}\ \alpha P)E^{\beta}\ln e < 0$.. In that case, a quality enhancing technology change actually reduces consumers' marginal valuations and quantity demanded at every price, an intuitively perverse result.

demand simply doubles for each number of explosions used, this represents a doubling of $J^2/4\alpha$. As indicated in Figure 3, the marginal value of explosions jumps to those on the bottom row of the table. In this case, three explosions will be used, at a total cost of \$18,000. The number of explosions used in the movie thus triples, as does the amount of money spent on them.

Consider finally a cost-reducing technology for explosions, such that the same explosion becomes only half as expensive to conduct, the cost dropping from \$6000 to \$3000 each. The producer's response in this case is also to increase the number of explosions from one to three. Total movie production expenditures increase in this case as well, though only from \$6000 to \$9000.

In both the quality enhancing and cost reducing cases, the response to improved movie production technology is thus to expand the scope of production with more inputs, and at a greater total investment.

B. Model II: Two Input Monopoly

Model I can be made more realistic by increasing the number of inputs used in the movie production process. Here, we think of movies as consisting of two inputs, explosions (E), and stars (S).

Define:

$$(5)\ \ \Pi = P(J\text{-}\alpha P)E^{\beta}S^{\gamma} - C_E E - C_S S,$$

where S = number of stars, and C_S is the constant cost of stars. The constraints on β assumed in model I again apply, and comparably, $0 < \gamma < 1$, and $S'_{\gamma} > 0$, and $S''_{\gamma} < 0$. That is, the elasticity of demand w.r.t. the number of stars is also below one and increases with more stars at a decreasing rate.

In this model, then, demand is defined in the form of a standard Cobb-Douglas production function. The number of consumers who watch the movie is "produced" by the combination of inputs. Like a standard production function, we also assume that $\beta + \gamma < 1$. That is, there are decreasing returns to scale; a doubling of both the number of stars and the number of explosions will result in less than a doubling of demand, a reasonable assumption.

Maximizing (5) w.r.t to *P, S,* and *E*, and taking the simple case of $\gamma = \beta$ for tractability, yields:

(6) $P^* = J/2\alpha$

(7) $E^* = (J^2\beta/4\alpha)^{1/(1-2\beta)}\, C_E^{\ (\beta-1)/(1-2\beta)}\, C_S^{\ -\beta/(1-2\beta)}$

(8) $S^* = (J^2\beta/4\alpha)^{1/(1-2\beta)}\, C_E^{\ (\beta-1)/(1-2\beta)}\, C_S^{\ -\beta/(1-2\beta)}$

(9) $K^* = C_E E^* + C_S S^*$

Second order conditions require $\beta < .5$ for a maximum, which is consistent with the assumption of $\beta + \gamma < 0$, given $\beta = \gamma$.

Again, as we would expect, total differentiation shows that $dE^*/dJ > 0$, $dE^*/d\alpha < 0$. Total differentiation of (7) shows that if $J^4/\alpha^2 C_E C_S > 16/\beta^2\, e^{(2\beta-1)/\beta}$, then $dE^*/d\beta > 0$. A sufficient condition for this inequality to hold is if $E^* > 1$ and $S^* > 1$.[5] Following from the $\beta = \gamma$ assumption, the comparable derivatives of S^* w.r.t. to these parameters are identical. It the follows from (9) that K^* is also increasing (decreasing) in these same parameters. That is, an outward shift in demand increases total production investments. w.r.t. price; a higher elasticity of demand w.r.t. either explosions or stars also increases total investments if $dE^*/d\beta > 0$ and $dS^*/d\beta > 0$.

Differentiation of (7) and (8) also shows that dE^*/dC_E and dS^*/dC_S are unambiguously negative, as we would again expect. It then follows from (9) that dK^*/dC_E, and dK^*/dC_S are also unambiguously negative.

These results parallel those of model I, but the positive effect of one input's cost reduction on total production investment has a more interesting interpretation, because of a positive demand interaction effect between *S* and *E*. In particular, a fall in C_E results in

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[5] A sufficient condition for $dE^*/d\beta > 0$ in terms of the demand and cost parameters, or all $0 < \beta < 1$ is $J^4/(\alpha^2 C_E C_S) > 64$

more explosions being used, which in itself induces the producer to substitute away from stars into explosions. The net effect, however, is also to increase the number of stars used, and thus total spending on stars. That occurs because with more explosions, the Cobb-Douglas form of the demand function means that there is a higher marginal effect on demand for each star that is used. In this respect, the multiplicative Cobb-Douglas form has intuitive appeal. Unless production values are sufficiently high in other respects, it may not be cost-effective to hire a popular star.

In summary, the result of the two input model is also that a lowering of production factor costs, as well as a quality-enhancing technological change, may induce a monopolist to increase, rather than to reduce, total production investments.

C. Model III: Monopolistic competition, two inputs

In the following model, both product variety and quality can vary, using a circular "address" model of monopolistic competition with free entry (Salop, 1979). The two input case, involving both explosions and stars, is considered.

In the circular framework, product space is represented by the circumference of the circle, its length normalized to 1. Consumers are uniformly positioned along the circumference, with density also equal to 1. The location of each consumer is indicated by X_i. There are a total of *n* differentiated products, whose locations are indicated by X_j, $j = 1 \ldots . n$. Each individual is assumed to consume only one product, and each firm produces only one product. Firms are also uniformly distributed along the circumference.

The utility of consumer *i* from consuming product *j* is defined to be dependent on two factors: (1) x_{ij}, which is defined as the distance in product space between that consumer's location and X_j, and (2) a vertical dimension indicating product quality. In this case, however, product quality is represented in terms of two elements, E_j, which is the number of explosions used, and S-j, which represents the number of stars.

Specifically, define:

(10) $U_{ij} = (1- \lambda x_{ij}) E_i^{\beta} S_j^{\gamma}$

where $0 < \beta < 1$, $U'_\beta > 0$, $U''_\beta < 0$; comparably, $0 < \gamma < 1$, and $S'_\gamma > 0$, and $S''_\gamma < 0$. Here again, β is the elasticity of demand w.r.t. production investment, and gamma is the demand elasticity with respect to the number of stars. Again, demand is effectively defined in the form of a standard Cobb-Douglas production function. It is again assumed that $\beta + \gamma < 1$. That is, there are decreasing returns to scale; a doubling of both the number of stars and the number of explosions will result in less than a doubling of demand.

Without loss of generality, we drop the subscript *i,* set $j = 1$ and consider only the competition for consumers within the product space between products 1 and 2. The point of indifference of the marginal consumer between products 1 and 2 is:

$$(11)\quad (1-\lambda x_{12})E_1^{\beta}S_1^{\gamma} - P_1 = (1 - \lambda/n + \lambda x_{12})E_2^{\beta}S_2^{\gamma} - P_2.$$

Profits for firm 1 are then:

$$(12)\qquad \Pi = 2P_1x_{12} - C_E E_1 - C_S S_1 = 0$$

The representative firm maximizes (12) w.r.t. P_1, E_1, and S_1. We assume that all firms make entry, pricing and investment decisions simultaneously.[6] Solving (11) for x_{12} and substituting into (12), then differentiating (12) w.r.t. P_1 , E_1 , S_1, applying symmetry, and adding the zero profit condition, yields four equations in four unknowns, *E, P, S*, and *n.* We take the simple case of $\beta = \gamma$ for tractability, which implies $S = (C_E / C_S)\, E$. Second order conditions again require $\beta < .5$.

Resulting are:

$$(13)\qquad E^* = P^*/n^* = [2\beta^2/\lambda\,(\beta+1)^2]^{1/(1-2\beta)}\, C_E^{(\beta-1)/(1-2\beta)}\, C_S^{-\beta/(1-2\beta)}$$

$$(14)\qquad K^* = C_E E^* = [2\beta^2/\lambda\,(\beta+1)^2]^{1/(1-2\beta)}\, C_E^{-\beta/(1-2\beta)}\, C_S^{-\beta/(1-2\beta)}$$

6 Economides (1993) derives results using the circular framework for two alternative game structures: a three stage game in which entry takes place in the first stage, location in the second, and price/quality choice in the third. The four-stage game separates out the quality and price choices into 2 stages. Results differ somewhat, but are qualitatively the same with respect to quality and variety tradeoffs.

(15) $n^{*} = (\lambda + \lambda\beta)/2\beta$

Symmetric equations to (13) and (14) result for S^{*} and $C_S S^{*}$.

Examination of (13) and (14) reveals that both E^{*}, and K^{*} rise with a fall in C_E (and comparably for C_S). Like the monopolist, competitive producers respond to cost-reducing technological change by increasing total investments, an effect that is enhanced by the positive demand interaction effect between stars and explosions.

Comparably to the two-input monopoly case, differentiation of (13) reveals that E^{*}, and thus $C_E E^{*}$, are rising in β if E^* and S^* are both at least one.[7] Differentiation of (14) also reveals that total investment, $K^* = (C_E E^{*} + C_S S^{*})$, rises under the same conditions with quality-enhancing technological change. As differentiation of (15) shows, however, the measure of product variety, n*, falls unambiguously with a rise in beta

The interpretation of these results is that increased consumer responsiveness to a given production investment shifts the balance toward higher setup investments in individual information products relative to product variety. Thus, quality-enhancing technological improvements lead to greater investments in a smaller variety of products. Differentiation of (13) also shows that P^{*} rises with β, indicating that higher prices can be charged for higher quality products. Note from (15), however, that product variety, n^{*}, is independent of C_E or C_S. When these costs fall, prices rise with the resulting increase in investments, but at exactly the same rate as the rise in investments, neutralizing the effects on entry.

In summary, the two input competitive model shows that first copy investments rise unambiguously as a result of cost-reducing technological change, and in the case of quality-enhancing technology, rises under reasonable assumptions. Product variety declines in the latter case, while in the cost-reducing case, rising first copy investments are accompanied by no change in variety.

How do outcomes of the competitive models compare with those of the welfare optimum?

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[7] The exact sufficient condition for $dE^*/d\beta$ to be positive is $1/\lambda^2 C_E C_S > 20.25$. This condition may hold if either E^* and S^* are less than one depending on other parameter values, but $E^*, S^* > 1$ is a sufficient condition.

Total welfare is the sum of consumers' surplus over all consumers in the market, less the aggregate cost of producing all n products:

$$(16)\ W = 2n\int_0^{1/2n} E^{\beta} S^{\gamma} (1\text{-}\lambda \bar{x})\, dx - n\, C_E E - n\, C_S S$$

Maximization w.r.t. n, E, and S, again assuming $\beta = \gamma$, and $\beta < .5$, yields:

$$(17)\ n_w^{*} = (\lambda + 2\beta\lambda)/8\beta$$

$$(18)\ E_w^{*} = [8\beta^2/\lambda(1+2\beta)^2]^{1/(1\text{-}2\beta)}\ C_E^{\,(\beta\text{-}1)/(1\text{-}2\beta)}\ C_S^{\,\text{-}\beta/(1\text{-}2\beta)}$$

and comparably for S^{*}.

From (14) and (13), respectively:

$$(19)\ n_{\Pi}^{*} = 2n_w^{*} + \lambda/4\beta$$

$$(20)\ E_{\Pi}^{*} < E_w^{*}$$

where Π indicates the maximum profit outcome. Comparable to the results of other models based in the circular framework of monopolistic competition with endogenous product quality (Salop,1979; Waterman, 1990; and Economides 1993), variety tends to be overproduced, and individual firms under invest. Moreover, it is easily shown that $E_{\Pi}^{*} n_{\Pi}^{*} < E_w^{*} n_w^{*}$. That is, aggregate industry investment is also below the welfare optimum.

It is well-known that welfare results in differentiated product models are subject to the particular form of the demand function, and this model is no exception. Nevertheless, welfare results seem to give us little cause for concern that higher investments in themselves, even at the expense of variety, reduce welfare.[8]

[8] A caveat to this observation is the extent to which higher movie budgets reflect higher rents paid to talent. It is not clear, however, whether a similar phenomenon would accompany a shift toward higher variety for a given level of total production investments.

III. Discussion and conclusions

Under plausible demand and cost conditions, either cost-reducing or quality-enhancing technological change may induce producers of information products to increase first copy (sunk cost) investments. In a competitive market, product variety may fall as a result of quality-enhancing technology, and may at least not increase as a result of cost-reducing technology. The implication of these results, that technological advance in information production may result in higher market concentration rather than market fragmentation, parallels the finding of Berry and Waldfogel (2003) that larger market size fails to result in fragmentation in the case of daily newspapers because incumbent firms can undercut rivals by expanding product quality.

The novel feature of the models in the present analysis is simply that all inputs appear in both the firm's demand and cost functions. That is, all inputs are potentially quality enhancing. Under those conditions, even a straightforward cut in the wholesale price of any one input in the production process, for example, induces the firm to increase total outlays on that input, because it is not only cheaper to use, but higher use of the input is quality enhancing, in turn increasing demand.

The "more-more" finding in the two input models—that is, the positive demand interaction effect, such that a fall in the cost of one input induces the producer to increase the use of both inputs--contrasts with other explanations for why high quality inputs tend to be combined with other high quality inputs in multi-input product processes. Reliability theory in economic and operations research predicts generally that this phenomenon occurs because the negative consequence of having a "weakest link" increases on the margin as the quality of other inputs rises. (See Kremer, 1993). In a sociological analysis of labor inputs into motion picture productions, Faulkner (1987) argues that cumulative career attainments are governed by the propensity of labor to seek out contracts that pair them with equivalently skilled persons. In the present model, by contrast, the value of some inputs is enhanced by combination with others via their influences on demand.

It is evident that our results are not necessarily robust to alternative specifications of the production (demand) function. Certainly, for example, one could posit functions in which input cost reductions have an insufficiently large quality-enhancing effect to lead to higher total expenditures and/or to lower variety. The basic relationships between production inputs and demand in our models, however, suggest insights into whether certain developing technological changes, such as the cheaper digital cameras for independent filmmakers are likely to result in a need to make lower investments, resulting in higher variety--or *vice versa*. If cheap digital cameras simply reduce movie production costs, but offer few opportunities to increase production quality, their dominant result is likely to just be lower total production costs. If the dominant effect of digital equipment is to create new opportunities to producers and directors to improve production values, the result may in fact be higher quality and costs, with no fragmentation, and possibly increased concentration.

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