"PRICING STRATEGIES IN MARKETS WITH DYNAMIC ELASTICITIES"

by

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Pricing Strategies in Markets with Dynamic Elasticities

ABSTRACT

This paper approaches strategic pricing over the product lifecycle while considering the impact of dynamic price elasticities. Extending the work of Simon (1979), a general optimal control formulation is proposed which relies on functional forms which have empirical foundations and can be calibrated in a managerial context. In addition to typical skimming and penetration strategies, dynamic elasticities can lead to "saw tooth" strategies; optimal prices may, for example, decrease, then increase, then decrease over the lifecycle. Several normative results, based on numerical simulations, are presented and compared to those found in the literature.

Key Words: Pricing, Diffusion, Durable Products, Dynamic Elasticities
When a firm's objectives include maximizing profits over current and future periods, a number of factors complicate the pricing decision. A stream of normative literature has considered optimal pricing problems when sales follow a product lifecycle, or new product diffusion process, while costs decline as a function of cumulative production, or an experience curve, and the firm discounts future cash flows. More elaborate refinements include cases when pricing strategies are affected by repeat purchases, the degree to which an innovation can be copied, or when the demand for a given product is affected by the income distribution of the market potential. Competition, or the threat of new entrants into a monopolistic market, has also been considered (see the literature reviews in Simon 1989, Chapters 5 and 6; Hanssens, Parsons, and Shultz 1990, Chapter 8, and Mahajan, Muller and Bass 1990).

The literature has generally assumed that price elasticities are either constant or proportional to price, but do not vary systematically over the product lifecycle. A number of theoretical and empirical studies have suggested however, that brand or category-level price elasticities can follow any number of paths (see Simon 1979, 1989, Chapter 5, and Lilien and Yoon 1988 for literature reviews). Based on theoretical considerations, Mickwitz (1959) contends that elasticities should increase then decrease, while Parsons (1975) finds that elasticities should decrease. Nagle (1987, pp. 152-153) notes that elasticities are lowest during early phases of the product lifecycle and reach their maximum levels during the maturity/decline phases. Tellis (1988) concurs by arguing that few competitive substitutes exist during early stages of the lifecycle and that consumers may be ill-informed of competitive alternatives. While hypothesized paths may vary based on one considering either brand-level or category-level elasticities, empirical studies have found an equal variety of elasticity dynamics. Simon (1979) finds that brand-level elasticities initially fall, and then increase (for household cleansers and pharmaceuticals). Liu and Hanssens (1981) find that elasticities increase over the product lifecycle for inexpensive gift items. In a meta-analysis of previous studies, Tellis (1988) reports that brand-level price elasticities also increase over the lifecycle. Lilien and Yoon (1988) find, when investigating industrial chemicals, that category sales elasticities are either stable or decline over the lifecycle. Elasticities, hereafter referred to in absolute values, have been found therefore to increase, increase then decrease, decrease, or decrease then increase over the brand and/or category lifecycle.

In this paper we extend Simon's (1979) derivation of optimal pricing strategies when elasticities vary by explicitly considering the diffusion process while also assuming situations where profits are discounted, units costs decline with cumulative production, and elasticities change, in a variety of patterns, over the time-continuous lifecycle. Although the framework proposed is fundamentally
monopolistic, dynamic elasticities allow for an atomistic consideration of competition (i.e. elasticities may vary due to changes in non-reactive substitutes or changes in consumer tastes). We focus on using functional forms which have been and can be easily calibrated in a managerial context. These forms create, however, mathematical intractabilities which are dealt with via simulation.

1. Model Formulation

In order to determine optimal pricing levels over the product lifecycle, one can formulate an optimal control model with one state variable (the sales rate) and one control variable (price). We will assume that the firm discounts future cash flows and that an experience effect acts on production costs. Demand will shift over time as a function of cumulative sales (a diffusion process) and the levels of price. Price elasticities are assumed to vary over the product lifecycle by an unspecified time function. A restrictive assumption associated with this formulation is that consumers base their decisions on current and not anticipated prices. For some products (e.g. high technology electronics), this assumption may be too restrictive (see Narasimhan 1989). The planning horizon of the firm is assumed to be finite (i.e. over a given product lifecycle) and cumulative sales in time \( t=0 \) are assumed to equal zero. The firm is assumed to maximize profits as expressed in Equation (1).

\[
\max_{P(t)} \Pi = \int_0^T e^{-rt} \left( P(t) - kX(t)^{\alpha} \right) X(t) dt
\]

subject to the constraint:

\[
\frac{dX(t)}{dt} = \dot{X}(t) = f(X) P(t)^{n(t)}
\]

where \( r \) is a constant discount rate, \( k \) is a constant initial cost, \( \alpha \) is the learning parameter on costs, \( f(x) \) is an unspecified product lifecycle or diffusion model; \( X(t) \) is the sales rate in period \( t \) and \( n(t) \) is the dynamic price elasticity of demand associated with \( P(t) \). This formulation is closely associated with those of Bass (1980), Dolan and Jeuland (1981) and Robinson and Lakhani (1975), which are generalized by Kalish (1983) in his discussion of separable demand functions. Unlike these formulations, Equation (2) considers price elasticities which can vary over the product lifecycle; as \( n(t) \) is a general form, any time path of elasticity dynamics can be considered.
Equation (2) assumes that elasticities are constant at any moment in time; the demand curve shifts over time due to $f(x)$ and will pivot depending on the values of $n(t)$.

In order to derive the optimal levels of price, the maximum principal of optimal control theory states that the solution is obtained using its Hamiltonian formulation (Kamien and Schwartz, 1983, p. 151). The Hamiltonian is, after dropping the time subscript $t$:

$$H(P, X, \lambda) = e^{-rt} [P - kX^{-\alpha}] f(X) P^n + \lambda f(X) P^n$$

where $\lambda$ is a shadow price on the constraint having the terminal condition $\lambda(T) = 0$. The three necessary conditions associated with Equation (3) are:

$$\begin{align*}
(4) \quad & \frac{\partial H}{\partial P} = 0 \\
(5) \quad & \frac{\partial H}{\partial X} = -\dot{\lambda} \\
(6) \quad & \dot{X} = f(X) P^n
\end{align*}$$

and the second order condition on price is

$$\frac{\partial^2 H}{\partial P^2} \leq 0$$

From these conditions, one can show that the optimal changes in price, for a given period $t$, are given in Equation (8).1

$$\dot{P}^* = (n(n+1))^{-1} \left[ n(Pn + Pn^2 - n^2kX^{-\alpha}) + nP - nP^{n+1} fX \right]$$

This differential equation indicates that changes in optimal price are affected by a firm's discount rate, unit costs driven by the experience effect, the contemporary price elasticity of demand, the first derivative of the elasticity function with respect to time, and the stage of the product lifecycle (diffusion rate). Relaxing the assumption of constant price elasticities creates intractabilities which prevent a closed form solution of Equation (1) for optimal prices. Using the properties of Equation (8), however, one can evaluate various scenarios and, via numerical simulation, derive optimal pricing strategies.
2. Strategy Derivations

2.1 Methodology

Since optimal strategies need to be simulated, care must be taken to consider functional forms and parameter values which reflect situations which appear plausible in a managerial context. Otherwise, strategy guidelines which appear general (via numerous simulations) may reflect a range of parameter values which are not likely to be encountered in practice. Fortunately, numerous empirical studies have been conducted on new product diffusion models, learning parameters, and dynamic price elasticities. Using parameter values estimated in the literature, one can generate a number of strategies that are based on models which can be calibrated, and, therefore, implemented by managers.

We begin by specifying a sales response function which considers both diffusion and dynamic price elasticity parameters:

\[ \dot{X}(t) = \left[ (a + b \frac{X(t)}{M}) (M - X(t)) \right] P^c + dt + et^2 \]

where the constant diffusion parameters are \( a \) and \( b \), the dynamic elasticity parameters are \( c \), \( d \), and \( e \), and where \( M \) is a constant market potential; \( X(t) \) is cumulative adoptions up to but not including time \( t \), \( P(t) \) is the price at time \( t \), and \( \dot{X}(t) \) is adoptions in time \( t \). Equation (9) is a modified version of the first purchase model proposed by Bass (1969, 1980) which allows for dynamic elasticities. The Bass model has seen wide application in fitting the sales of durable products, agricultural innovations, medical innovations and various telecommunications services (see Mahajan, Muller and Bass for a review of Bass model extensions and applications). In separate analyses, empirical applications of Equation (9) have proved effective in fitting the purchases of a number of consumer durables. The separable functional form allows prices to affect both the coefficient of innovation or external influence (a) and the coefficient of imitation or external influence (b). As elasticities are dynamic, the affect of price on the diffusion parameters will vary over time; in all cases, the relative importance of the coefficient of external influence declines over time. While one might wish to consider non-separable forms (as discussed by Kalish 1983) or those in which price affects the market potential (Kalish 1985, Horsky 1990), similar intractabilities arise when elasticities are allowed to systematically vary over the lifecycle. The application of Equation (9) is used, therefore, for illustrative purposes while understanding that this form has been found acceptable for some product categories, but may not prove the most appropriate for others.
A two-step procedure is used to generate optimal price paths given the response function in Equation (10): (1) for any starting price, Equation (8) is simulated for a given set of parameter values and (2) an iterative wide area grid search coupled with a steepest gradient method is used to determine the starting price that maximizes profits over the time periods considered.3 A manager might set the starting price to be the highest expected reservation price. For a given set of parameter values, the initial price selected generally affects the magnitude but not the functional form (path) of the optimal prices over time.

Based on independent empirical tests of Equation (9) on a number of consumer durable goods categories, and the meta-analysis reported by Tellis (1988) who finds average elasticities of durables to equal -2, elasticities are allowed to vary between -4 and -1. Based on the meta-analysis of empirical studies by Sultan, Farley and Lehmann (1990) who report an average value of .03 for the coefficient of external influence (a) and .38 for the coefficient of internal influence (b), the diffusion parameters are allowed to vary between .01 and .9. The learning parameter is assumed to vary between 0 and .6, based on values reported in Simon (1989, p. 128) for household durable products (actual values reported vary between .09 and .54). Discount rates investigated vary between .01 (non-myopic management) and .25 (myopic management). Various price elasticity dynamics can be considered:

Case 1. elasticities begin high, then decline, then increase
Case 2. elasticities begin low, then increase, then decline
Case 3. elasticities begin high, then decline
Case 4. elasticities begin low, then increase
Case 5. elasticities are constant.

As the constant elasticity case, Case 5, has been considered in the literature, the reader is referred to the work cited above; simulations of Equation (8) for the constant elasticity case (e.g. n(t)=-2) generates the same recommendations. Likewise, only Cases 1 and 2 are reported here because they generalize Cases 3 and 4 respectively. Rather than report all simulations for Cases 1 and 2, we will focus on the sensitivity of particular pricing strategies to extreme changes (though within a realistic range) of particular parameters (say, the corporate discount rate). The goal is to illustrate the relative importance of each factor (diffusion, learning curve, dynamic elasticities, and discounting) over the ranges of parameter values that are likely to be encountered in practice. Specifically, 56 scenarios (2X2X2X7 design) across the following factors are considered in order to illustrate the impact of each:
- Elasticity Dynamics: Case 1 and Case 2
- Learning Curve Effects: $\alpha = 0$, and $\alpha = .6$
- Diffusion Effects: $a = .01 < b = .90$, and $a = .90 > b = .01$
- Discount Effect: $r = .01$, $r = .03$, $r = .05$, $r = .10$, $r = .15$, $r = .20$ and $r = .25$

The value of discount rates range from nearly zero (nonmyopic) to a relatively high level, $r = .25$ (myopic).

### 2.2 Pricing Strategies

Figure 1 provides a summary of simulations which illustrate various managerial situations, depending on the elasticity dynamics, the diffusion process and learning on costs. While magnitudes can be greatly affected, the functional forms simulated are generally invariant to the level of discount rates studied. Cell 1 shows, for example, the difference between a low and high discount rate on pricing. For the remaining cells only one function is shown per cell for greater clarity in presentation. Across cells, eight industry situations are represented. For example, in Cells 1, 2, 3 and 4 there is no learning on costs which might reflect cost dynamics for consumer non-durables (e.g. pharmaceuticals, frequently purchased products, etc.). Within these four cells, Cells 2 and 4 represent situations where diffusion is driven via a Fourt and Woodlock (1960) trial process reflecting low consumer learning requirements (a new "me-too" entrant into a mature category). Cells 5 and 7, for example, reflect typical situations for consumer durables where diffusion effects and learning effects on costs are high; the difference between Cells 5 and 7 is the effect of elasticity dynamics. Cells 1, 2, 5, and 6 (Case 1), reflect situations whereby consumers are first highly sensitive to price changes, followed by a period where the product is perceived as a necessity, followed by a period where consumers become price sensitive (perhaps due to non-reactive competitive substitutes) toward the end of the lifecycle. Cells 3, 4, 7, and 8 might reflect situations when a product, during the middle of its lifecycle, faces some shock which is reflected by high price elasticities (e.g. a short-lived substitute, a period of intense competition followed by a shake-out or a well-publicized product liability problem).

Comparing the simulations to results derived for the non-dynamic elasticity case (e.g. as reported in literature cited above), a number of common and different strategies emerge. A number of intuitive results are generally observed concerning the magnitude of prices, including (1) high discount rates generally lead to higher prices early on in the lifecycle compared to lower discount rates, (2) relatively larger innovation/external diffusion influences lead to higher prices early on, and lower prices later in the lifecycle, compared to relatively larger imitation/internal influences.
(e.g. comparing Cells 7 and 8), (3) higher learning rates generally lead to lower absolute prices in the beginning and over the remaining lifecycle, compared to low or no learning rates (e.g. comparing Cells 1 and 5), (4) higher elasticities lead to lower prices compared to lower elasticities.

In his study of price elasticity dynamics, Simon (1979) finds that a price penetration strategy was optimal in a specific case. Two additional strategies have been found optimal in the literature studying new product diffusion using static/proportional elasticities (e.g. Kalish, 1983, Bass and Bultez, 1982, Dolan and Jeuland, 1981):
- decreasing prices (skimming)
- increasing then deceasing.

The time dynamics of elasticities, and the interaction with the three other factors yields, however, a number of strategies not commonly found in the literature.

Comparing, for example, Cells 1 and 3 demonstrates that dynamic elasticities can dramatically affect the optimal time path (functional form) of optimal prices. Two additional strategies are derived here based on the consideration of elasticity dynamics:
- decreasing, then increasing, then decreasing (Cell 5)
- decreasing, then increasing (Cells 3, 4 and 8)

Similar "saw tooth" or non-monotonic pricing strategies, as shown in Cell 5, can be envisioned for more complex elasticity dynamics, including cubic or cyclical time paths. Given a quadratic form of elasticity dynamics, a number of general guidelines can be proposed:
- aside from absolute magnitudes, for products having no or a sufficiently low level of learning on costs, diffusion effects (the values of a or b) will have little impact on the time path of optimal prices (comparing Cells 1 and 2, or Cells 3 and 4);
- for products having high learning effects on costs, the time path of prices can be sensitive to the diffusion effects, especially when elasticities follow the pattern in Case 2 (e.g. comparing Cells 7 and 8);
- in situations where elasticities begin low and then increase during the early phases of the lifecycle, price skimming will generally be optimal (Cells 3, 4 and 8); only the combination of learning on costs being high, and imitation/internal influences being large will imply price penetration being optimal (Cell 7).
- in situations where elasticities are high at the end of the lifecycle after a period of being low, prices will decline (Cells 1, 2, 3 or 4), irrespective of the discount rate, diffusion effect, or learning rate on costs.
in situations where elasticities begin high and then decline during the early phases of the lifecycle, optimal pricing patterns are increasing then decreasing (Cells 1, 2 and 6), or "saw toothed", decreasing, increasing, then decreasing (Cell 5).

- in situations where residual markets have low elasticities later in the lifecycle after a period of being high, prices should increase (Cells 3, 4, 7 and 8);

The last two conclusions provide interesting insight to pricing strategies in declining markets. Cell 5 shows a saw tooth strategy where firms, facing Case 1, will initially follow the learning curve (skimming) up to a point where low elasticities dominate pricing policies; prices fall when elasticities begin to increase. Cells 3, 4 and 8 show situations where firms first skim the market. As elasticities increase, prices and sales fall to low levels (or firms, may in actuality temporarily exit the market). When elasticities decline to lower levels, prices and sales increase, as if in a new cycle. Only the combination of high learning on costs, and high imitation/internal diffusion effects result in classical price penetration strategies.

3. Conclusions and Future Extensions

Simon (1989, p.124) notes that the issue of elasticity dynamics "is empirically not well researched." This paper illustrates the importance of knowing such dynamics for firms formulating optimal pricing strategies. Both the time path and magnitude of pricing can be greatly affected by the evolution of elasticities. The simulation approach provides original insights in dynamic pricing strategies while reasonably handling mathematical intractabilities generated by models which can be calibrated in practice. In particular, simulations reveal conditions when typically prescribed skimming or penetration strategies will not be optimal. "Saw tooth", or non-monotonic policies appear optimal under certain realistic situations. Though based on a monopolistic formulation, the simulations capture situations of atomistic competition or industries which can coordinate pricing activities across firms. Logical extensions of this research include the explicit consideration of non-cooperative competition, additional marketing mix elements, and industries having particular purchasing behaviour (e.g. repeat purchase goods) or cost structures (e.g. both fixed and variable). Finally, attempts to generalize the results to all functional forms or parameter values may prove worthwhile.
FOOTNOTES

1. A more detailed discussion of the derivation of Equation 8 is available in Appendix A.

2. A summary of empirical tests of Equation 9 on a variety of consumer durables is available upon request.

3. The software package SimGauss was used to numerically solve Equation 8; the constant $k$ was set to equal 30; $M$ was set to equal 100000. Inelastic ranges with $n(t)>-1$ are not reported as these result in strategies of increasing prices.

4. Kalish (1983) notes the possibility of this pattern in cases of positive discount rates and learning effects on costs. Cells 5 shows that this pattern depends on costs dynamics if elasticities follow the pattern in Case 1 (high elasticities, then low, then high), and a strong diffusion effect ($a < b$).
REFERENCES


Figure 1. Optimal Price Paths Under Dynamic Elasticities

<table>
<thead>
<tr>
<th>Elasticity Dynamics:</th>
<th>Elasticity Dynamics:</th>
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<tbody>
<tr>
<td>CASE 1: High, Low, High</td>
<td>CASE 2: Low, High, Low</td>
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<table>
<thead>
<tr>
<th>Cell</th>
<th>a (b)</th>
<th>a ) b</th>
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<tbody>
<tr>
<td>1</td>
<td>400</td>
<td>r=0.2</td>
</tr>
<tr>
<td>2</td>
<td>400</td>
<td>r=0.1</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>400</td>
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<td>5</td>
<td>100</td>
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<td>6</td>
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<td>7</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>100</td>
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Learning:  
No Learning:  

r=0.1

Scales used approximate actual simulated values.
The following provides details on the calculation of equation 8 in the paper. Recalling the Hamiltonian formulation (Equation 3 in the paper):\(^1\)

\[
H = e^{-\tau}(P - kX^\alpha) f(X) P^n + \lambda f(x) P^n
\]

Applying equation 4 to equation 3 we obtain (dropping the time subscript).

\[
\frac{\partial H}{\partial P} = (n+1) e^{-\tau} f(x) P^n - nkx^\alpha e^{-\tau} f(x) P^{n-1} + n\lambda f(x) P^{n-1} = 0
\]

or, rearranging (9),

\[
e^{-\tau} f(x) P^{n-1} [(n+1) P - nkx^\alpha + n\lambda e^\tau] = 0
\]

Since \(e^{-\tau} f(x) P^{n-1} > 0\), we obtain,

\[
(n+1) P - nkx^\alpha + n\lambda e^\tau = 0
\]

or, rearranging (11),

\[
P^*(t) = \frac{n}{n+1} \left( kX^\alpha - \lambda e^\tau \right) > 0
\]

or, rearranging (11)

\[
\lambda^* = \frac{nkX^\alpha - (n+1)P}{ne^\tau}
\]

or, rearranging

\[
\lambda^* = e^{-\tau} kX^\alpha \cdot \frac{(n+1)}{n} P e^\tau
\]

or, rearranging (14)

\[
\lambda^* = e^{-\tau} kX^\alpha \cdot Pe^\tau - n^{-1} Pe^{-\tau}
\]

Differentiating (15), one obtains (note: \(n(t)\) is time dynamic):

\[
\dot{\lambda}^* = -e^{-\tau} \alpha kX^{-1-0} \dot{X} - rX^\alpha e^\tau - \dot{P} e^{-\tau} + rPe^{-\tau} - \left( \frac{-\dot{P} + \ddot{P}n}{n^2} \right) e^{-\tau} - re^{-\tau} \frac{P}{n}
\]

\[
1. \quad \text{We use the discounted Hamiltonian, without loss of generality, as opposed to the current value Hamiltonian.}
\]
or, rearranging (16), yields

\[(17) \quad \dot{\lambda}^* = e^{-r\left[\alpha kX^{-\alpha-1} \dot{X} + rkX^{-\alpha} + \dot{P} - rP - \dot{n} P/n^2 + \dot{P}/n - rP/n \right]}.
\]

When applying equation 5 to equation 3, one obtains

\[(18) \quad \frac{\partial H}{\partial X} = e^{-rt} f_x P^{n+1} - e^{-rt} k P^n \left[X^{-\alpha} f_x - \alpha X^{-\alpha-1} f(X)\right] + \lambda f_x P^n
\]
or, rearranging,

\[(19) \quad \frac{\partial H}{\partial X} = -\dot{\lambda}^* = e^{-rt} \left[f_x P^{n+1} - kX^{-\alpha} f_x P^n + \alpha kX^{-\alpha-1} f(X) P^n + \lambda f_x P^n e^{rt}\right].
\]

Substituting (15) and (17) into (19) and rearranging and cancelling terms yields

\[
\dot{P}^* = r \left(\frac{P_n + P_{n+2} - n^2 kX^{-\alpha}}{n(n+1)}\right) + \dot{n} P - n P^{n+1} f_x
\]

\[(8) \quad \text{This is the function reported as Equation 8 in the paper.} \]
1988

88/01 Michael LAWRENCE and Spyros MAKRIDAKIS

88/02 Spyros MAKRIDAKIS
"Predicting recessions and other turning points", January 1988.

88/03 James TEBOUL

88/04 Susan SCHNEIDER

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88/08 Reinhard ANGELMAR and Susan SCHNEIDER

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88/10 Bernard SINCLAIR-DESGAGNÉ

88/11 Bernard SINCLAIR-DESGAGNÉ
"When stationary strategies are equilibrium bidding strategy: The single-crossing property", February 1988.

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"Business firms and managers in the 21st century", February 1988

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"Alexithymia in organizational life; the organization man revisited", February 1988.

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"Monopolistic competition, costs of adjustment and the behavior of European employment", September 1987.

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88/20 Jean DERMINE, Damien NEVEN and J.F. THISSE

88/21 James TEBOUL
"De-industrialize service for quality", March 1988 (88/03 Revised).

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"Proper Quadratic Functions with an Application to AT&T", May 1987 (Revised March 1988).
<table>
<thead>
<tr>
<th>Reference</th>
<th>Authors</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>88/34</td>
<td>Mihkel M. TOMBAK</td>
<td>&quot;Flexibility: an important dimension in manufacturing&quot;, June 1988.</td>
</tr>
<tr>
<td>88/36</td>
<td>Vikas TIBREWALA and Bruce BUCHANAN</td>
<td>&quot;A Predictive Test of the NBD Model that Controls for Non-stationarity&quot;, June 1988.</td>
</tr>
</tbody>
</table>
Philippe NAERT and Piet VANDEN ABBEELE

88/48 Michael BURDA

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88/63 Fernando NASCIMENTO and Wilfried R. VANHONACKER

88/64 Kasra FERDOWS

88/65 Arnoud DE MEYER and Kasra FERDOWS
"Quality up, technology down", October 1988.

88/66 Nathalie DIERKENS
"A discussion of exact measures of information asymmetry: the example of Myers and Majluf model or the importance of the asset structure of the firm", December 1988.

88/67 Paul S. ADLER and Kasra FERDOWS

89/01 Joyce K. BYRER and Tawfik JELASSI

89/02 Louis A. LE BLANC and Tawfik JELASSI
<table>
<thead>
<tr>
<th>No.</th>
<th>Authors</th>
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<th>Date</th>
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</thead>
<tbody>
<tr>
<td>89/09</td>
<td>Damien NEVEN, Carmen MATUTES and Marcel CORSTIENS</td>
<td>&quot;Brand proliferation and entry deterrence&quot;, February 1989.</td>
<td>89/19</td>
</tr>
<tr>
<td>89/12</td>
<td>Wilfried VANHONACKER</td>
<td>&quot;Estimating dynamic response models when the data are subject to different temporal aggregation&quot;, January 1989.</td>
<td>89/22</td>
</tr>
<tr>
<td>89/14</td>
<td></td>
<td></td>
<td>89/24</td>
</tr>
</tbody>
</table>
89/25 Roger BETANCOURT and David GAUTSCHI
"Two essential characteristics of retail markets and their economic consequences" March 1989.

89/26 Charles BEAN, Edmond MALINVAUD, Peter BERNHOLZ, Francesco GIAV AZZI and Charles WYPLOSZ

89/27 David KRACKHARDT and Martin KILDUFF

89/28 Martin KILDUFF

89/29 Robert GOGEL and Jean-Claude LARRECHE

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89/31 Michael C. BURDA and Stefan GERLACH

89/32 Peter HAUG and Tawfik JELASSI

89/33 Bernard SINCLAIR-DESGAGNE

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89/36 Martin KILDUFF

89/37 Manfred KETS DE VRIES

89/38 Manfred KETS DE VRIES

89/39 Robert KORAJCZYK and Claude VIALLET
"An empirical investigation of international asset pricing", (Revised June 1989).

89/40 Balaji CHAKRAVARTHY
"Management systems for innovation and productivity", June 1989.

89/41 B. SINCLAIR-DESAGNAGNE and Nathalie DIERKENS

89/42 Robert ANSON and Tawfik JELASSI

89/43 Michael BURDA

89/44 Balaji CHAKRAVARTHY and Peter L'ORANGE

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89/62 Arnoud DE MEYER

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