DISCONTINUOUS INNOVATION DIFFUSION ANALYSIS

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The market place derives its dynamism from the inherent willingness of a consuming population to innovate. Many technological firms have been exploiting the consumer markets with their technology based discontinuous innovations. Several companies have been marketing small computers that, in pricing and programming structure, are amenable to adoption by individual consumers. This study is an attempt to study the diffusion/adoption process of personal computers in the Indian context from both a behavioural theory and marketing strategy perspective.

INTRODUCTION

The overall pattern of the technological innovation diffusion process can be thought of as a complex net of communication paths linking the various stages of the process. The basic constructs of diffusion - the innovation, adopter categories, the adoption process, personal influence and the pattern of diffusion have helped in conceptualizing the information dissemination process and in suggesting the value of particular change-agent interventions.

DISCONTINUOUS INNOVATION

Anderson and Ortinau (1988) have adopted an innovation classification scheme based on behavioural interpretations. The product innovation, when perceived by consumers as being a new product established by a major technological advancement, is known as a discontinuous innovation. Such product innovations are marked by the severity of learning requirements for the adopters as they result in entirely new product categories. The product search attributes can be highlighted by product display and advertising. The experience attributes can only be acquired by constant use of the said products. Hence it is difficult to forecast the diffusion rates since it may be necessary to 'educate' potential customers about the new technology before they can evaluate it and deduce a judgement of desirability.

A technological innovation creates one kind of uncertainty in the minds of potential adopters (about its expected consequences), as well as representing an opportunity for reduced uncertainty in another sense (that of the information base of the technology). The latter type of potential uncertainty reduction represents the possible efficacy of the innovation in solving an individual's felt need or perceived problem. This impels an individual to exert effort in order to learn about the innovation. Once such information seeking activities have reduced the uncertainty about the innovation's expected consequences to a tolerable level for the individual, a decision concerning adoption or rejection will be made (Rogers, 1983).

LITERATURE REVIEW

A brief review of relevant literature is presented. The fundamental diffusion model (Bass, 1969) can be written as

$$\frac{dN(t)}{dt} = a\,[\,\bar{N}(t) - N(t)\,] + bN(t)\,[\,\bar{N}(t) - N(t)\,]$$

where

a is the coefficient of innovation
b is the coefficient of imitation
$[\bar{N}(t) - N(t)]$ is the number of potential adopters available at that time

The above equation can be rewritten as

$$\frac{dN(t)}{dt} = g(t)\,[\,\bar{N}(t) - N(t)\,]$$

and

$$N = N_o \quad \text{at} \quad t = t_o$$

The value of g(t), the product growth coefficient, depends on the specific product innovation, the marketing system in which the innovation is diffused and other elements such as the channels and change-agents (Mahajan and Peterson, 1979).

In dynamic diffusion models,

$$\bar{N}(t) = f[S(t)]$$

where S(t) is a vector of all relevant exogenous and endogenous variables, both controllable and non-controllable, affecting N(t). These factors include socio-economic conditions in the marketing system, price changes, government actions, marketing efforts and so on.

Dodson and Muller (1978) incorporated the effects of advertising and word-of-mouth in the dynamic diffusion model. They suggested that the population of potential customers $[\bar{N}(t) - N(t)]$ be segmented into a subgroup of consumers who know of the new product but do not buy it and a subgroup that knows and buys. Advertising was hypothesized to be responsible for the adoption decision of the second subgroup. To represent the dynamic nature of the market potential $\bar{N}(t)$, or the increase in the market potential, $\bar{N}(t) - N(t)$, two mechanisms by means of which the group $[P(t) - \bar{N}(t)]$ be made aware of the product, namely, advertising and word-of-mouth were suggested. The diffusion model is

$$\frac{d[\bar{N}(t) - N(t)]}{dt} = a[P(t) - \bar{N}(t)] + b\bar{N}(t)\,[P(t) - \bar{N}(t)] - C[\bar{N}(t) - N(t)] - d[\bar{N}(t) - N(t)]$$

where

a	is	the coefficient of advertising
b	is	the coefficient of imitation
c	is	the effect of advertising
d	is	the forgetting coefficient
P(t)	is	the population of a marketing system at time t

Shariff and Ramanathan (1982) studied the time pattern of the spread of innovations when the population was no longer binomial but of a polynomial type composed of adopters, rejectors after adoption, disapprovers and the uncommitted.

Shlomo Kalish (1985) opined that the rate of adoption was determined by awareness diffusion and the rate of growth of the potential adopters, each controlled by advertising and price respectively. The process of becoming aware was modelled as a simple epidemic type. The adoption, being conditional on awareness, occurs when the value of the product exceeds its selling price. In the case of durable goods, the sales rate equals the adoption rate. Each individual adopts one unit once.

Homer (1987) developed a system dynamics model to study the diffusion of medical technologies. The simulation model addresses both the adoption and extent of use of a technology product and endogenously accounts for changes in actual and perceived performance.

PC MARKET - THE INDIAN SCENE

The personal computer appeared on the Indian scene sometime during the end of 1985. Though IBM PC is not marketed in India, it is widely copied by over 50 vendors who sell the IBM PC clones. They account for 50 per cent of the PC market.

In terms of volume, the number PCs that have been sold in India during 1985-86 is 15000; 1986-87 is about 20000; 1987-88 is 22000; 1988-89 is 50000. While the world-wide trend in PC sales is expected to cross the 10 million mark in 1990-91, the Indian manufacturers would be lucky if their combined sales cross the one lakh mark.

The PC prices which crashed in 1986 when the then government declared its attachment for the computers, started rising from late 1987 through the first quarter of 1988. By June they had begun to touch the pre-1986 rates. In 1987-88 PC clone prices were up (due to budget) by about 33 per cent with increased cost of peripherals and services. The list price increased but the margin decreased for the manufacturers and dealers. The hike had to do more with international compulsions rather than local pressure. Due to a sudden and severe recession of DRAM chips in world markets, their prices began to rocket upwards. Memory costs went up by more than 5 times and while this had not affected the larger systems much it was murderous on smaller systems. Thus while more micros were installed in 1988 than in any other year the number was well short of the 55000 to 60000 expected. However, DRAM shortage helped the PC suppliers in a different way. From late 1986 and continuing through 1987 the sharp competition in the market had pushed PC prices down to what was clearly uneconomical levels.

The DRAM shortage provided an ideal excuse to hike up prices once again. While the PCs were becoming cheaper internationally, PC prices in India were ironically charting an uptrend. Prices of Indian IBM-compatible PCs had been rising without any attractive configurations or even price incentive rebates. For example, one company's PC costs (pre-budget) were approximately Rs.34000/- to Rs.37000/-; PC/XT Rs.45000/- to Rs.48000/-; PC/AT Rs.58000/- to Rs.62000/-. Another company's PCs were priced at Rs.27000/- to Rs.28000/-; PC/XT Rs.36000/- to Rs.38000/-; PC/AT Rs.54000/- to Rs.58000/-.

The 1987-88 import-export policy provided a number of sops for the hardware industry. However, the budget dealt a blow to the software industry by a new excise duty. While the imported computers attracted only 90 per cent duties, the duty level on imports of inputs to Indian-made systems went upto 98 per cent.

The year 1988-89 saw a transition in product cycles, shifting standards, takeovers and strategic realignment of products and markets. The PC acquired multi-functionality during the year; PC-FAX and PC-Telex becoming familiar. More computers were installed: Over 45000 micros and nearly 1500 minis were sold. The Indian computer industry recorded a 45 per cent growth to touch the Rs.500/- crore mark. Yet despite the increase in revenues, profits came down by the year end and scores of companies were left fighting for survival. One company slashed prices on their PC/AT to Rs.53000/- from Rs.66000/- inclusive of a 132-column printer, while another company gave it for Rs.45000/-.

The market was dominated by just a few companies and quite a few new products. In a market dominated by less than 10 major companies, the remaining 50 odd PC vendors have had to fight for 40 per cent of the share. In other words, of the nearly 45000 PCs, XTs and ATs sold last year, more than 30000 were accounted for by the big ten companies alone. The fierce competition in the market had led to polarisation of the market with the top four vendors between them accounting for 54 per cent share of the total micro market.

Just before the 1989 budget there was a price rise of around 10 per cent. In the budget, the government increased the excise component by 5 per cent which inflated the prices further. The policy change envisaged a shift in the import of various peripherals, from OGL to restricted list. The government also withdrew the 15 per cent cash compensatory support for exports. This policy split the industry into two distinct segments - the assemblers and the manufacturers, who are respectively for and against the OGL imports. With regard to the shifting to the restricted list, the PC cartel will have a firmer hold over the domestic market.

The "peoples' computer" was launched by a public sector company during the last week of November 1989. The cost advertised was Rs.10,500/- inclusive of 15.75 per cent excise duty. The price quoted was for a PC equipped with a single floppy drive. The real cost stood at Rs.15,493/- (inclusive of MS.DOS 4.01 system with manual and three application packages, sales-tax and octroi). With a printer added, the cost comes to about Rs.22,000/-.

As the indigenous computer market is a seller's market, the need for efficiency, cost-effectiveness, increased productivity could be

dispensed with and most computer manufacturers have got away with it. The Indian market has a visible lack of demand for PCs in the home and education sectors. In the home sector, the pricing levels are a deterring factor. So also is the lack of sufficient home entertainment and game programs. Indian households are likely to remain outside the scope of most of the PC marketing effort.

Investments in terms of marketing and distribution have pushed up costs to a level where the capital requirements are considerable. This has wiped out a number of vendors with a lower resource base.

Selling PCs to Indian customers can be exceedingly complex. The pattern of buying is significantly different across segments. The customer support function has its own woes - changing products, mobile manpower, hostile environment (dust, frequent interruption in power supply) and not-so-confident after-sales service. On the manufacturing side, obsolescence is the main problem. It is also not possible to fix any stable kind of a price/volume relationship, due to a continuously varying price (governmental regulations). Then, of course, the ubiqutous R & D problems.

According to the eighth plan approach paper, the computer industry is supposed to grow at 6 per cent (5.1 per cent during the seventh plan) and the installed base of micro computers alone would need to touch one million units (against 1,19,000 units as at the end of the seventh plan). Software exports would need to hit Rs.150 crores today. The Indian computer market will grow from Rs.700 crores in 1989 to Rs.1000 crores in 1990. The PC market would witness rapid price erosion and industry consolidation over the next two years.

In order to sell their products in an extremely competitive environment, the computer companies have already started offering liberal credit terms and other attractive packages. As the production capacity in the industry is now far in excess of demand, the industry will undergo a sweeping transformation. There will be a definite change of direction. Only a few companies will remain in the field of manufacturing computers and others will have to go in for value additions and specific applications.

The PC market is being excessively price driven that may result in PCs becoming commodity items. The first time user still needs hand holding. However, this is the segment that needs to be tapped if targets of 1,00,000 machines or more a year has to be met as projected for the peoples' computer.

Tables 1 and 2 sum up the Indian micro market.

MODEL DESCRIPTION

A generic system dynamics model is attempted to reflect the dynamics of the Indian micro market. Details and data have entirely been culled out from various Indian computer magazines and business newspapers. wherever needed, the data have been assumed in consistence with the prevailing situation in the Indian market. The major ten companies have been clubbed together to form the industry. The skeleton of the model is shown in Figure (1). Several submodels have also been defined. Sales sector submodel is shown in Figure (2). The model is

TABLE 1

INDIAN MICRO MARKET

CO	1986-1987			1987-1988					1988-1989				
	MICROS SOLD (Nos)	SALES VALUE (Cr. of Rs.)	UNIT PRICE (Rs.)	MICROS SOLD (Nos)	SALES VALUE (Cr. of Rs.)	MARKET SHARE (%)	UNIT PRICE (Rs.)	GROWTH (%)	MICROS SOLD (Nos)	SALES VALUE (Cr. of Rs.)	MARKET SHARE (%)	UNIT PRICE (Rs.)	HROWTH (%)
A	3920	12.92	33000	5900	20.58	5.60	34800	120	8284	44.10	9.90		49.36
B	4112	26.78	65000	4885	35.54	15.40	72700	32	7899	61.70	19.20		100.90
C	3344	17.26	52000	5210	26.59	11.60	57000	46	6834	47.80	15.50		72.83
D	1184	4.40	38000	3053	12.04	5.20	39500	33	3750	15.00	4.70	60000 on average	17.55
E	950	8.07	85000	1800	NA	4.70	60000	3.5	2700	14.20	4.40		28.86
F	815	5.56	68000	NA	NA	NA	NA	15	973	6.81	NA		28.46
G	NA	NA	NA	2100	6.80	2.90	32400	NA	4244	33.19	9.32		515.38
H	NA	NA	NA	NA	NA	NA	NA	NA	2754	12.02	NA		173.74
I	NA	NA	NA	NA	NA	NA	NA	NA	1533	7.93	2.20		231.20
J	NA	NA	NA	NA	NA	NA	NA	NA	905	6.31	1.70		73.33
INDUSTRY				40000	200	49.50	50000		52000	340.13	69.0		

NOTE: Company names are disguised. Data not available for companies established after 1987 and/or not manufacturing micros.

TABLE 2

INDIAN MICRO MARKET (CONTD.)

CO	INSTALLED BASE (Units)	UNITS SHIPPED (Units)	MICRO SALE PERCENT OF TOTAL REV. (1988-89)	SALES TURNOVER(CRORES OF RUPEES) 1985-86	1986-87	1987-88	1988-89	YEAR OF OPERATION	PRODUCTS
A	12569	690	81.92	1.85	16.40	36.04	53.78	1986	MICROS
B	17000	658	50.98	25.89	45.54	60.24	121.02	1978	MICROS,COMMON PRODUCTS
C	15900	570	50.87	19.58	37.31	54.36	93.95	1981	MICROS,MINIS,S/W, COMMON PRODUCTS
D	5000	250	54.74	12.45	17.56	23.31	27.40	1971	MICROS,CAD/CAM,S/W, COMMON PRODUCTS
E	NA	225	50.00	15.73	22.01	23.81	28.35	1972	MICROS,H/W,S/W, PROCESS CONTROL
F	NA	81	33.15	8.19	13.90	15.99	20.54	1980	MICROS,H/W,S/W, LANS
G	6400	354	82.97	NA	NA	6.50	40.00	1987	MICROS,COMMON PRODUCTS
H	9058	307	38.96	NA	4.23	11.27	30.85	1979	MICROS,MINIS, COMMON PRODUCTS
I	1564	102	95.77	NA	NA	NA	NA	1987	MICROS,MODEMS, TC CONTROLLERS
J	NA	75	89.88	2.24	3.37	4.05	7.02	1980	MICROS,LANS, COMMON PRODUCTS
INDUSTRY				234	347	510	1,095		

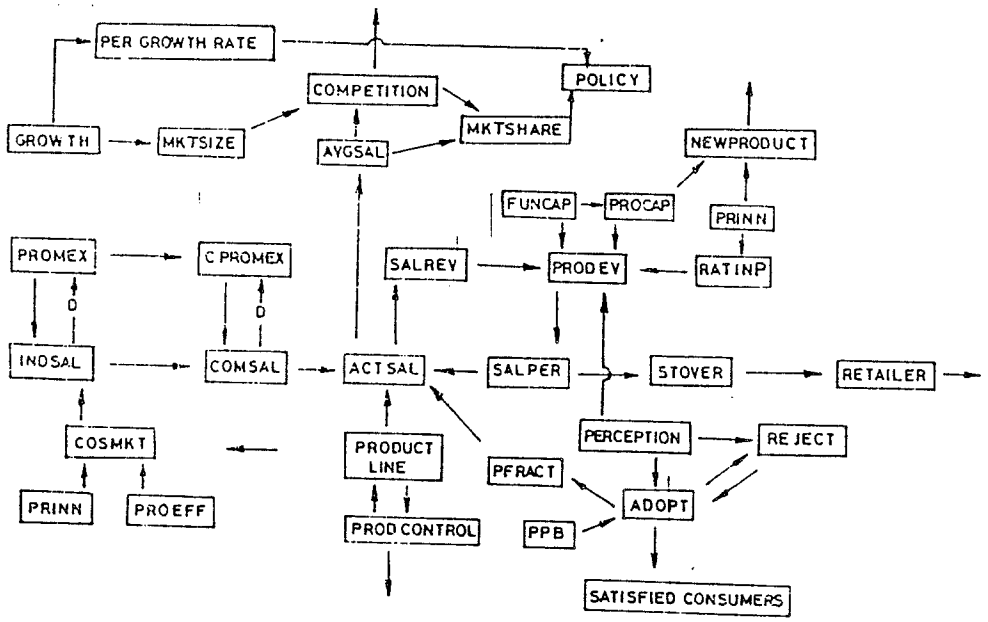

FIG.1-SKELETON OF THE MODEL

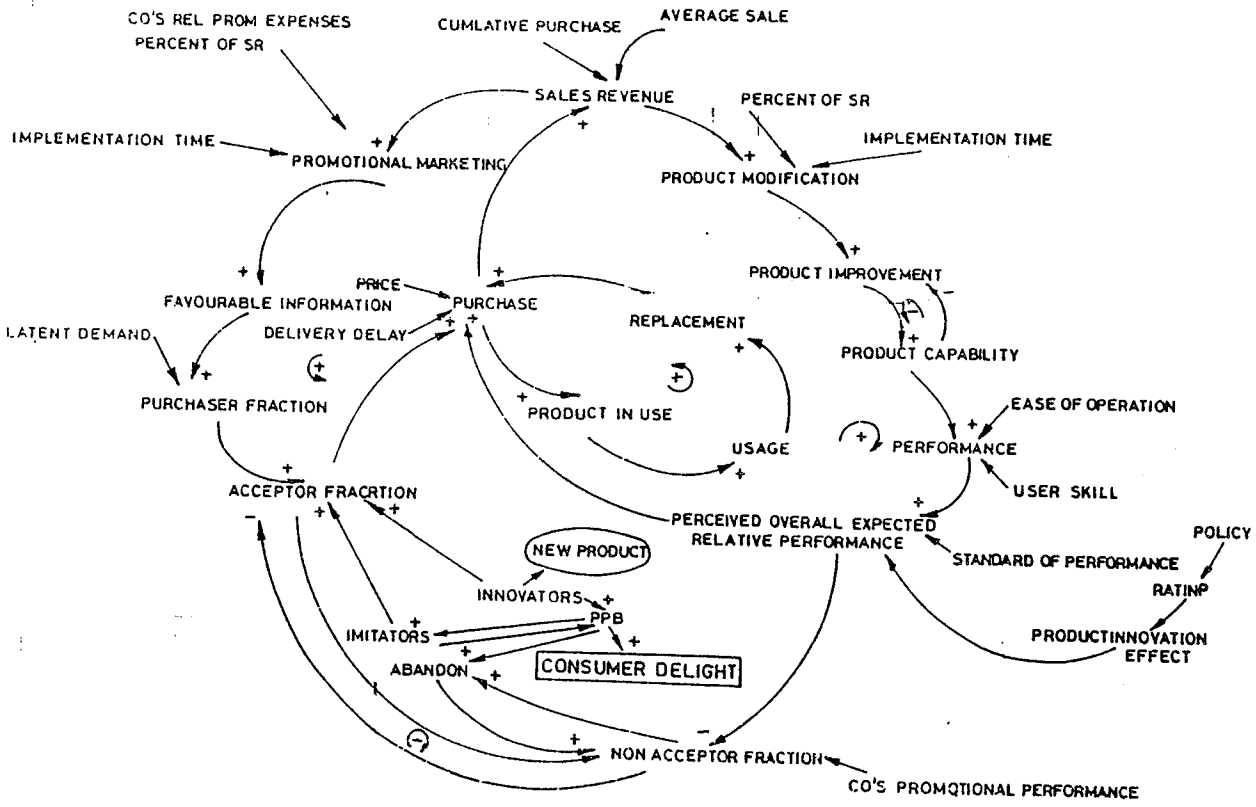

FIG.2-SALES SECTOR

based on the philosophy of Morecroft's (1986) and Homer's (1987) models. As the proposed model is still under progress and review, only the salient features are described.

The model starts with an awareness diffusion module. With a slight modification to the Tourism model of Jambekar and Brokaw (1989), the potential buyer pool can be thought of as

```
L    PBPOOL.K      = PBPOOL.J + (DT)(NRADVT.JK + NRSFCT.JK +
                     POSINT.JK - FORGET.JK - NEGINT.JK - AADOPT.JK)

     PBPOOL        = Potential buyer pool                          (Buyers)
     NRADVT        = Number reached through advertising            (Buyers/year)
     NRSFCT        = Number reached through sales force contact    (,,)
     POSINT        = Positive interaction between adopters
                     and potential buyers                          (,,)
     FORGET        = Number fogetting                              (,,)
     NEGINT        = Negative interaction between unhappy
                     adopters and potential buyers                 (,,)
     AADOPT        = Actual adopters who have purchased
                     the product                                   (,,)
```

The new product diffusion spreads through a combination of several communication processes - advertising, peer group discussions and sales force contact. NRADVT is a function of target audience and advertising expenditure. NRSFCT is a function of the number of sales-person allocated to promotion and their contact rates. The satisfied users and the potential buyers positively interact in an additive way while the unsatisfied users and potential buyers negatively interact in a multiplicative way and the respective coefficients of interaction have been assumed. A fraction of the people who are aware of the product become actual adopters and the number of adopters depend on the multiplier from cost which is modelled as a table function of average cost of the product versus fraction of adopters.

```
A    MLCOST.K      = TABHL (MLCOS, AVCOST, 50E3, 75E3, 5E3)
```

Promotional expenditure(PROMEX) is modelled as a per centage of total industry sales(INDSAL) which is equated to sales revenue (SALREV). The marketing effort represents real expenditure on promotional activities. The indicated marketing effort(IMKTEF) is a fraction (indicated) of sales revenue to marketing effort multiplied by average sales revenue(AVGREV). The indicated fraction is got by multiplying the fraction normal(FSRMEN) by (POSINT/AADOPT). The equations are

```
R    INDSAL.KL     = (ECCOND.K)(PROMEX.K)(TEST1.K)      (Rupees/year)
R    PROMEX.KL     = (DELAY3)(PROMXP.KL,BGDEL)          (Rupees/year)
A    PROMXP.KL     = (PERSAL)(INDSAL.KL)                (Rupees/year)
A    IMKTEF.K      = (IFSRME.K)(AVGREV.K)               (Rupees/year)
A    AVGREV.K      = SMOOTH(SALREV.K,REVAGT)            (Rupees)

A    IFSRME.K      = (FRSMEN)(POSINT.KL/AADOPT.KL)      (0-1)
A    ECCOND.K      = TABHL(ECCON,TIME.K,1985,1990,1)    (Gross domestic
                                                        product)
```

Where ECCOND is economic condition which is modelled as the growth of GDP over the years and its effect is thought of as resulting in increased disposable income (Reserve Bank of India Report) and is reflected in the company's share of the total market.

```
A    COSMKT.K     = (EFECON.K)(TEST2.K)                    (Dimensionless)
A    EFECON.K     = TABHL(EFECO,ECCOND.KL,1985,1990,1)     (Per capita)
```

The New Product Section is divided into three modules - New product development, functional capability of the product and the reputation of the company. The company's share of the market(COSMKT) is modelled as a function of product innovation effect(PRINN) and promotional effectiveness(PROEFF). The PRINN is a table function of rate of introducing new products(RATINP) and the PROEFF is a table function of relative advertising expenditure(RADEXP). The RATINP is a delayed variable of rate of start of new products(RSNEWP) over a period DELINP.

```
A    TEST1.K      = (GAMMA)(PRINN.K) + (PHI)(PROEFF.K) (Dimensionless)
A    PRINN.K      = TABHL(PRIN,RATINP.KL,0.1,.1)       (,,)
A    PROEFF.K     = TABHL(PROEF,RADEXP.KL,0,1,.1)      (,,)
R    RATINP.KL    = DELAY3(RSNEWP.JK,DELINP)*PPC       (Products/year)
```

The New product development section takes care of the product developments, which are the outgrowth of projects costing thousands of rupees in R and D activity and require years to complete.

```
L    PRODEV.K     = PRODEV.J+(DT)(PRODSR.JK-PRODCR.JK)
R    PRODSR.KL    = MAX(0,PRODCR.JK+(IPRODE.K-PRODEV.K)/PRODAT)
R    PRODCR.KL    = PRODEV.K/PRODCT.K
A    IPRODE.K     = (IFSRPD.K)(AVGREV.K)/SPRODT
A    PRRTPD.K     = PFCUR.K/RINCPD.K
A    PFCUR.K      = SMOOTH(CHFUR.JK/URATE,TPUCUR)
A    RINCPD.K     = SMOOTH(INCPD.K,INCST)
```

```
     PRODEV       = Product development projects              (Projects)
     PRODSR       = Product development start rate            (Projects/year)
     PRODCR       = Product development completion rate       (,,)
     IPRODE       = Indicated product development             (Projects)
     IFSRPD       = Indicated fraction of sales revenue to product development   (0-1)
     PRRTPD       = Perceived return to product development   (1/Project)
     PFCUR        = Perceived fraction of change to usage rate   (0-1)
     RINCPD       = Recent incorporation of product developments   (Projects/year)
     CHGUR        = Change in usage rate                      (Usage index)
     URATE        = Usage rate                                (,,)
```

The functional capability is modelled as

```
A    FUNCAP.K     = (PROCAP.K)(EEXPFC.K)
```

Where the product capability(PROCAP) is a level variable and the effect of experience on functional capability(EEXPFC) depends on the relative skill of the averageuser(REAUSR).

```
A    EEXPFC.K     = TABHL(EEXPF,REAUSR.K,0,.1)
A    REAUSR.K     = XUSER.K/XSUSER.K                    (Dimensionless)
A    XUSER.K      = SUMEXP.K/AADOPT.K
```

where SUMEXP is the Co-flow of all experience

```
L    SUMEXP.K     = SUMEXP.J+(DT)(SXINCR.JK-SXDROP.JK)
R    SXDROP.KL    = (XSURSER*DEP)+(XUSER.K*REJECT.JK)
```

```
     SXINCR       = Co-flow of experience increase rate
     SXDROP       = Co-flow of experience decrease rate
     XSUSER       = Experience of skilled user
```

The set of equations pertaining to the reputation module are

```
R    ESTREP.KL    = TABHL(ESTRE,AVPAGE,0,1,1)
L    AVPAGE.K     = AVPAGE.J+(DT)(1-(RATINP.JK*AVPAGE.J)/N)
     ESTREP       = Established reputation              (Dimensionless)
     AVPAGE       = Average Product age                        (Years)
```

The model will have two distinct modules based on use innovativeness and product integration. The former may be split into creativity and multi-use segments which measure respectively an individual's preference for variety (novelty) seeking within product usage and the ways in which a currently owned product is used. The product integration measures the utilization of the product, post adoption satisfaction and expected future use based on experience of related products (Dickerson and Gentry, 1983).

The post-purchase behaviour clarifies the rejectors(REJECT) by differentiating between satisifed(PSBUY) and unsatisfied(PUSBUY) buyers.

```
R    REJECT.KL    = (NORMAL)(USBUY.KL)
R    USBUY.KL     = (1-Q)*ADDOPT.KL
L    PSBUY.K      = PSBUY.J+(DT)(AADOPT.JK-USBUY.JK)
L    PUSBUY.K     = PUSBUY.J+(DT)(USBUY.JK)
```

The sales lost to new competition and the growth of competition are modelled in the competition sector.

```
R    SLOSNC.KL    = SALES.K/NORTIM*FMKTNC.K
A    FMKTNC.K     = TABHL(FMKTN,MKSTNC.K,0,1,.1)
A    MKSTNC.K     = (NCOMPC.K/(MNCOMP.K+NCOMPC.K))*SWNCOM
L    NCOMPC.K     = NCOMPC.J+(DT)(INCOM.JK-
                    FNCOMP.JK-MNCOMP.JK)
```

SLOSNC	=	Sales lost to new competition	(Units)
FMKTNC	=	Fraction of market lost to new competition	(Dimensionless)
MKTSNC	=	Marketing strength of new competition	(,,)
NCOMPC	=	New competition capacity	(Projects/year)
INCOMP	=	Increase in new competition	(,,)
FNCOMP	=	Failure of new competition	(,,)
MNCOMP	=	Maturing of competition	(,,)

CONCLUSION

The suggested policy alternatives could be rationalization of price, governmental policy, rationalization of excise duties, effect of alternative configurations and software with a matching service. The model, in its entirety, as contemplated will have several more sections including a corporate growth sector. Partial model testing has been done to debug the sales sector subsystem prior to the whole model simulation. This was done to expose the intended rationality of the decisions. The subsystem apparently responds. The nature of the behavioural variables make it difficult to interpret the results. Further work is on.

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