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Modelling IS Successions in E-commerce

WP02/02

2002

ISSN 1478-8209

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Abstract

The paper considers the conditions governing the diffusion and development of e-commerce. The analysis builds on earlier discussions of technological successions and explores a number of factors, not normally considered, which are likely to have a bearing on the probability of e-commerce IS technologies displacing traditional IS technologies. The first factor is differentiation of the characteristic sets offered by the old and new technologies, and contrast this with higher performance specifications over the same set of characteristics. Second, we consider differential costs due to scale economies. Differential falling unit costs of alternative information systems (IS) affect demand when these are transmitted to prices, altering the price-quality combinations offered by old and new IS technology providers. Third, we consider time as a possible explanatory variable. Altering the time in which new IS technology providers are able to exploit their superior applications is likely to affect the probability of a technological succession occurring. Analysis is conducted via simulation techniques on an agent-based model that contain heterogeneous populations of adaptive users and providers who co-evolve over time.

1. Introduction: technological successions and punctuated equilibrium

Schumpeter laid stress on the importance of technological discontinuities in economic history. In contrast to Marshall, who on the front page of his 'Principles of Economics' stated that *Natura non facit saltum* (Nature does not leap), Schumpeter argued that "evolution is lopsided, discontinuous, disharmonious by nature... studded with violent outbursts and catastrophes... more like a series of explosions than a gentle, though incessant, transformation" (Schumpeter, 1939, p. 102). Schumpeter did not question the existence of long periods of gradual development marked by the incremental development of established technologies. However, he stressed that such periods are punctuated by short bursts in which radically new technologies – such as the steam engine, the dynamo, the internal combustion engine and the integrated circuit - yield alternative products, processes and associated knowledges that displace existing technologies and lead to key structural changes in the economy as old industries are displaced by new industries, and old employment patterns replaced by new ones. It is the appearance of these new major technological breakthroughs that drive the economic system in a new direction. Such a shift "so displaces its equilibrium point that the new one cannot be reached from the old one by infinitesimal steps. Add successively as many mail coaches as you please, you will never get a railway thereby" (Schumpeter, 1939, p.37).

We suggest that the concept of punctuated equilibrium developed in the ecological sciences can be usefully applied to this discussion of the relationship between incremental change and technological successions. The ecological theory of punctuated equilibrium was originally put forward by Gould and Eldridge (1977). They observe that "once they appear, species tend not to change very much at all. They may last 5 or 10 million years - sometimes even longer - and yet, while a few might undergo the sort of gradual, 'progressive' modification we have come to expect of evolution, most will stay pretty much as they were when they first evolved... But the mid-Paleozoic period shows us that the individual instances of species-stability 'punctuated' by occasional bursts of speciation... have immediate consequences for the ecological organisation, and thus the ecological history, of life" (Eldridge, 1987, p.82). In their discussion of species succession in ecological systems, Nicolis and Prigogine (1977) add that the new invaders must have a better capability of exploiting the same resources offered within an ecological niche. In other words, they must be able to do something ‘more’ or ‘better’ - whether it be capturing a certain type of prey, reproducing or avoiding death - than the previous incumbent. As a consequence, the fitness of successive species occupying a given niche will increase over time. The envelope of overall fitness is raised as more efficient species displace earlier incumbents within an ecological niche (Figure 1).

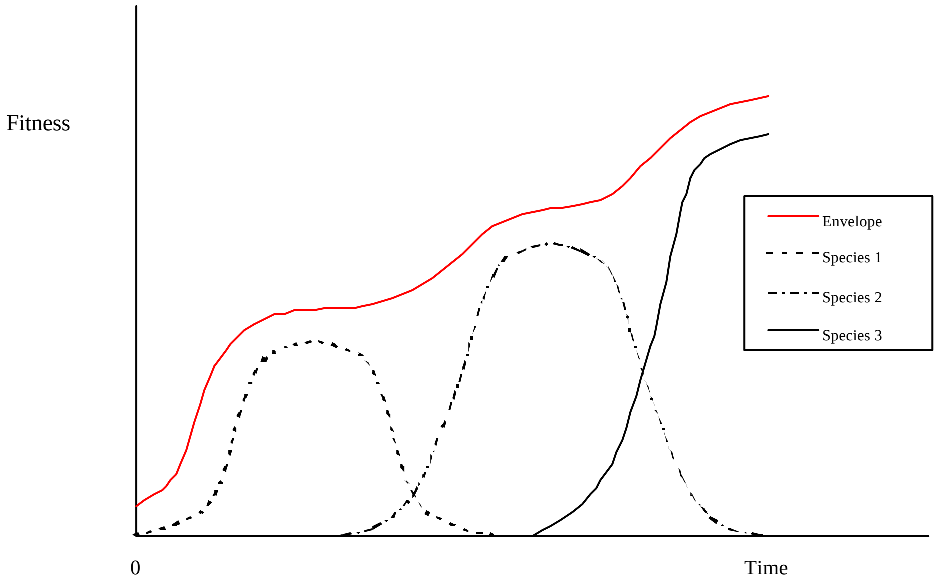

Figure 1. Succession by species of increasing fitness

Schumpeter’s discussion of economic evolution has much in common with the ecological theory subsequently developed by Gould and Eldridge. As noted, Schumpeter similarly discussed economic history in terms of punctuated equilibrium, the economic system spending long periods in one equilibrium state and then suddenly shifting to a new equilibrium. Economic history, according to Schumpeter, is marked by a sequence of such punctuations brought on by the development of radically new technological products, processes and associated knowledges. We suggest that punctuated equilibrium offers a useful general framework in which to bring together the discussions of radical and incremental technological innovation developed over the last couple of decades. Product competition can operate at two levels, between rival old and new technological artefacts and between rival variants of a technological artefact. In the remainder of this paper we shall address the conditions under which the advantages that have accrued to an established technology over time may be overcome by a new, alternative technology.

2. Technological successions in e-commerce

Turning to the diffusion of e-commerce IS technologies, we see that these are being applied to two rather different generic types of commercial activity: firm-to-household transactions (B2C) and inter-firm transactions (B2B). While accurate figures are notoriously difficult to come by, due to their commercial sensitivity, the bulk of activity thus far appears to be in B2B transactions. Forrester Consultancy estimated that a total value of $51 billion was traded electronically in the USA in 1998. Within this figure, B2B dwarfed B2C trade with $43bn of the total due to B2B trade. Forrester predicted this will double every year up to 2003, rising to $1.3 trillion. By contrast, B2C trade was predicted to rise to $108 billion (9.4% of B2B trade) up to 2003 (Bell, 1998).

How are we to understand the different diffusion dynamics in these two niches? A key issue, we suggest, is whether e-commerce technologies are being supported by new user groups that are using the technology to explore new types of preferences, or whether the technologies are being supported by established user groups whose preferences were formed through the use of older technologies. The evolution of consumer preferences is a particularly underdeveloped area within economics. Two of the current authors have emphasised the need to focus on demand side factors in order to understand the complex dynamics involved in emergent market structures (Windrum and Birchenhall, 1998). In the context of technological successions for radically new technology products, we suggest that the appearance of a new consumer group or ‘type’ that gives weight to the particular characteristics offered by a new technology is likely to be a necessary condition for a technological succession. Ongoing discussions about the development of distinct forms of youth culture on the Internet are of interest here. The Internet facilitates the (virtual) interaction of readers and writers in ways that are very difficult to achieve in print – especially for young people. Publishing on the Web by this age group is motivated by the desire to participate in, or create, a distinct community (Abbott, 1998). Computer-culture theorists such as Turkle (1995) go further, seeing in the new uses of computers "fundamental shifts in the way we create and experience human identity" (1995, p.10). Cyberculture, she argues, is distinct to other forms of culture and populated with distinctive species of human beings - hackers, MUDers and cyberpunks.

An important factor explaining the rapid diffusion of B2B IS technologies lies in their being substitutes that replace well-established EDI[1] technologies without altering the business-to-business practices or conventions fostered under these older technologies. There is a history of electronic trading in supply chains and the concept is not unfamiliar to firms. The shift in this area is from a set of proprietary EDI systems to a common, open IS standard that is based on TCP/IP (Internet) protocols. Diffusion is not associated with the emergence of new user types. We shall henceforth refer to this type of displacement as a 'partial succession'. By contrast, internet-based IS applications in B2C aim to support the development of radically new consumer products/services. This implies new business models that go way beyond household consumers ordering products over the Internet. Indeed the 'promise' of e-commerce is that every facet of business - from procurement, to billing, to human resources, to customer support – will be integrated within one system, fundamentally changing how consumers, small businesses and major corporations interact commercially. Diffusion in B2C is simultaneously associated with experiments by users who are exploring new types of preferences. If successful, diffusion of the new technology will be associated by a new product-user group coupling. Henceforth we shall refer to this type of displacement as a 'full succession'.

In addition to the emergence of new user groups, we shall explore three factors that are likely affect the probability of e-commerce IS technologies displacing traditional IS technologies. The first factor is differentiation of the characteristic sets offered by the old and new technologies, and contrast this with higher performance specifications over the same set of characteristics. The second factor we shall consider is differential costs due to scale economies. The third factor we consider is time. Altering the time in which new IS technology providers are able to exploit their superior applications is likely to affect the probability of a technological succession occurring. Given the large number of parameters involved in the analysis, and the desire to examine these in a meaningful manner, we employ simulation techniques on an agent-based model that contain heterogeneous populations of adaptive users and providers who co-evolve over time. The model is a hybrid Neo-Schumpeterian – New-Keynesian model. Providers employ various adjustment rules to their production routines, while simultaneously innovating in their IS systems through a combination of imitation (selective transfer) and internal R&D (selective mutation). The model contains an imperfect capital market, with investment financed from a provider's stock of wealth. Providers use a mark-up pricing rule and market prices are 'sticky': providers do not adjust to excess demands and the market does not necessarily clear in a single period. The simulation analysis is conducted through a statistical estimation of a set of logit models.

3. Conditions for a technological succession

An important starting point is Shy's (1996) discussion of consumer substitution between network size and quality in sequential technology competitions. In contrast to earlier papers by Farrell and Saloner (1985) and Katz and Shapiro (1986), the overlapping generations (OLG) model developed by Shy focuses on *repeated* technology adoptions. The model allows for different preferences between the 'old' consumer type and the 'young' consumer type, although preferences within each generation are assumed to be identical (i.e. homogeneous). The key question addressed by the model is whether the young consumer type will treat quality and installed user networks as substitutes and, hence, select the later technology (which is *de facto* assumed to be of higher quality) or alternatively treat them as complements, in which case they will select the old technology. In this paper we address a number of issues that are 'black boxed' by Shy but which are likely to have important implications for the general thrust of his argument.

A number of considerations can be identified in this respect. The first is *functional equivalence*. A technological succession involves the substitution of an established product or process by a new alternative that fulfils the same basic function (Grübler

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[1] EDI is the computerised inter-firm communication of trade documents in a standard format that permits the automatic handling of transactions.

et al., 1988; Grübler, 1990). Second, there is the *quality of alternative designs*. The standard economics model of choice ties relative fitness to the welfare associated alternative commodities. The economic literature contains some important precedents for an analytical treatment of how users first compare, and then rank, substitutable goods (e.g. Frenken, Saviotti and Trommetter, 1999). A third consideration is the *trade-off between quality and price*. A trade-off is likely to exist between the quality of the rival technologies and their price, tied to costs of producing these alternative bundles of characteristics. Given that user welfare depends on both the relative performance of each IS technology and their prices, this will affect demand and hence the outcome of a technological competition (Arthur, Ermoliev and Kaniovski,1987; Arthur, 1989). The fourth consideration we address is the existence of *new types of users*. As noted in section 2, this is likely to be a key factor affecting the complex dynamics of emergent market structures.

3.1 The adopter's choice problem

From the proceeding discussion we see that there is likely to be a number of factors influencing user preferences, and that these interact in a complex manner. Three factors in particular were highlighted above: production costs, price and performance quality. Formalising this, the probability of adopting the new IS technology B rather than the established IS technology A at time t is

$$\Pr\{U_A(x_A) + \mathrm{V_A}(m - p_A) < U_B(x_B) + \mathrm{V_B}(m - p_B)\} \qquad (1)$$

where x is the characteristic vector of an IS technology design

p is the price of that design

V is the indirect utility of money that can be obtained in other markets

Here we assume that all other markets are fixed and that this function has a constant form. $U(x)$ is the direct utility of consuming the good with characteristic vector x. Note that the utility of not buying a good is $V(m)$ and so a user will only accept offer (x, p) if $u_i(x) > V_i(m) - V_i(m-p_i)$. That is to say, an adopter only makes a purchase when direct utility outweighs the loss in indirect utility (i.e. the opportunity cost) of the purchase.

In the presence of heterogeneous preferences, a simple analytically tractable solution for equation (1) is unlikely to exist in all but the simplest of circumstances. Multiple equilibria solutions may exist in which it is impossible to predict *ex ante* whether there will be a technological succession, a technological lock-out, or a mixed solution (i.e. a partial succession with market sharing between the old and new technologies). First, multiple equilibria solutions can exist - even when the performance characteristics of one IS technology application are absolutely superior to those of another - if there is a high frequency of intermediate valuations within the user population. Second, rival technologies typically offer different relative strengths across a set of performance characteristics. Again, given heterogeneous preferences, it is impossible to predict *ex ante* whether a technological succession will occur. One way of tackling the problem is to construct a simulation model in order to analyse the consequences of heterogeneous user preferences, and the co-evolutionary dynamics of changing user preferences and the innovative activities of competing providers.

4. A formal model of IS successions

After initialisation, overall control of the model passes to a market 'object' that runs the model for the number of time periods specified in the model configuration. In each period this market object proceeds as follows,

i. It brings the user groups to market in a random order and gets the groups to determine their demands and purchases.

ii. It initiates the replicator dynamic for that period to redistribute the user population across the groups.

iii. It gets providers to adjust their capacity, level of production and to redesign their goods.

4.1 User dynamics

There are M user groups. Associated with group i = 1,.., M, a utility function u_i is defined over the offer space, namely the Cartesian product X×P of design space X and the price space P (positive real numbers) of the form

$$U_i(x,p) = \sum_k \alpha_{ik} v_k(x_k) + \beta_i w(m-p) = \alpha_i \cdot v(x) + \beta_i w(m-p) \quad (2)$$

Here *m* is the budget of the user and is assumed to be the same for all users. The term $\beta_i w(m-p)$ is the indirect utility obtained by spending the residual budget in other markets. All users in the same group are assumed to adopt the same utility function. Each provider offers to sell a good with some design *x* at some price *p*. Users use these utility functions to rank alternative offers and as a measure of well-being. Note that users always have the option of not accepting any of the offers and may keep all of their budget for use elsewhere. The utility of this option is $\beta_i w(m)$ and will be called the *null utility.* It can be seen that the utility functions differ across groups only in having different values for the coefficients α_i and β_i. Currently we use a simple square root function for the component functions, i.e.

$$v_k(x_k) = \sqrt{x_k} \quad \text{and} \quad w(m-p) = \sqrt{(m-p)} \qquad (3)$$

The population of users in each period is *G* and a form of the replicator dynamics described below governs the distribution across the M groups. Let G_{it} be the number of users of type *i* at time *t*. We use the subscript *t* only when necessary to distinguish between periods. In each period provider *j* offers a quantity Q_j of a particular design-price combination ($\boldsymbol{x}_j$, p_j). After providers have ‘posted’ these offers, user groups appear in the market in a random order. Let I(i), with i=1,.., *M*, be a permutation of the indices {1,.., *M*} so that I(1) is the first group to come to market. Note that this permutation will differ from period to period. Given the utility function $U_{I(1)}$ associated with this group, the users rank the offers (x_j, p_j) in descending order of preference.

Let J(j) j = 0,1,.., *M* represent this ranking, so that J(j) is a permutation of {0, 1,.., *M*}, where 0 represents the ‘null offer’, i.e. buy none of the goods. If the null offer is best (*i.e.* J(0) = 0) the users in that group exit the market without buying anything. If the provider ranked highest by the users has an offer which dominates the null offer (*i.e.* J(0) > 0) then all users in that group will ‘post’ a demand for one unit of that offer. If provider J(0) has produced a sufficient quantity of the good (*i.e.* $Q_{J(0)} \geq G_{I(1)}$) then all these demands will be converted into sales, all users in the group exit the market and the available quantity of the good is reduced by the volume of sales, i.e. $Q_{J(0)} \Leftarrow Q_{J(0)} - G_{I(1)}$ (where $\Leftarrow$ indicates assignment of the right-hand value to the left-hand value).

If demand exceeds supply (*i.e.* $Q_{J(0)} < G_{I(1)}$) then $Q_{J(0)}$ demands are converted into sales, $Q_{J(0)}$ of the user leave the market and the available quantity of the good becomes zero and the remaining users $G_1 - Q_{J(0)}$ consider their next best option J(1). The interaction of these remaining users with this offer is identical to interaction with J(0). If J(1) = 0 they leave the market, otherwise they post demands for the goods and these are met fully or partly depending on the quantity $Q_{J(1)}$ on offer. This process for group I(1) continues until all users in the group have left the market. Group I(2) enters the market and interacts with providers in the same way apart from the fact that the quantities available to this group will be reduced by any sales made to group I(1) users. This continues until all groups have entered and left the market. When group I(i), i > 1, enters the market the quantities available will be the Q_j’s minus any sales made to user groups I(k) for k=1,.., i-1.

After this process in period *t* each user group will have attained an average level of utility W_{it}. This is the average utility of the users in the group after they have consumed any good bought in this market. Note that all users will attain a utility no less than the null utility and thus W_{it} will be no less than the null utility.

Let $r_{it} = \frac{G_{it}}{G}$, where *G* is the total population, be the proportion of the user population in the *i*th group. Given these utilities the new distribution ρ_{it+1} is calculated as

$$r_{it+1} = \frac{r_{it} r W_{it}}{\sum_k r_{kt} r W_{kt}} \qquad (4)$$

where *r* is the factor determining the strength of the replicator effect of the differing utilities. Groups with above-average utilities grow larger and groups with below-average utility decline *i.e.* they have a negative grow rate.

4.2 Providers: prices, profits, wealth, production and capacity

Here we present a model of production that is distinctly Keynesian in flavour as adjustments to excess demand occur primarily through changes in output and production capacity rather than price. In the beginning of period t, provider j has monetary wealth M_{jt}, capacity or capital K_{jt}, design x_{jt}, a level of production y_{jt} and an inventory of unsold goods q_{jt}. The unit variable cost of production is given by the cost function

$$C(x) = \Sigma_k \gamma_k c_k(x_k) \qquad (5)$$

Note that the cost function is common to all providers and is seen to represent the available technology available to all providers. Note also that this cost is independent of the level of production. The cost function is available to providers in the sense that they can calculate the cost of a design prior to production. Currently the component functions are

$$c_k(x_k) = x_k^2 \qquad (6)$$

It is assumed providers face a fixed cost Φ so that the average total cost of producing output y of design x is $C(x) = \frac{f}{y}$. Hence with Φ > 0 there are increasing returns to scale in the sense that these average total costs are falling.

Providers set prices according to a simple mark up rule, namely

$$r_{jt} = (1 + h_{jt}) \left(C(x_{jt}) + \frac{f}{y_{jt}} \right) \qquad (7)$$

In current simulations there is a common and constant mark up so that $\eta_{it} = \eta$, but the model allows the mark up to adjust to excess demands and supplies.

At the start of the model, providers start with the same capacity and wealth but have their designs are randomly and independently generated. The variety between providers is initially in their designs and in their target user group; see the discussion of innovation below.

Given the design and level of production the provider offers a quantity $y_{jt} + q_{jt}$ of the design $\mathbf{x}_{jt}$ at a price p_{jt}. After users have made their choices, signalled their demands and made their purchases, providers adjust their capacities, their levels of production and consider modifications to their designs.

Given its sales s_{jt} and level of production, each provider calculates its net revenue for the period, namely $\Pi_{jt} = p_{jt}s_{jt} - y_{jt}\ C(x_{jt}) - \Phi$. This profit is added to its monetary wealth: $M_{jt+1} = M_{jt} + \Pi_{jt}$. If profit is negative and this monetary wealth becomes negative, then the provider has to sell capital sufficient stock to return monetary wealth to zero. If the provider has insufficient capital stock to restore zero monetary wealth then it becomes bankrupt in the sense that wealth and capital go to zero and the provider can no longer produce.

The provider calculates a new target level of production y^*_{jt+1} as follows:

$$y^*_{jt+1} = \chi d_{jt} + (1 - \chi)\, s_{jt} \qquad (8)$$

where $\chi \in [0,1]$ is partial adjustment term and d_{jt} is the level of demand for the jth provider's design in period t. The provider adjusts its capacity given this target level of output. Essentially, the provider aims to make capacity match this target level of output subject to the constraints that any increase in capacity cannot exceed its monetary wealth and that capacity cannot be negative. Given this target capacity, the provider partially adjusts its capacity toward this target,

$$K_{jt+1} = K_{jt} + \delta(K^*_{jt+1} - K_{jt}) \qquad (9)$$

where δ is a partial adjustment term and K^*_{jt+1} is the target level of capacity. $K^*_{jt+1} = y^*_{jt+1}$ if $(y^*_{jt+1} - K_{jt}) \leq M_{jt+1}$ otherwise $K^*_{jt+1} = K_{jt} + M_{jt+1}$.

Note that, after adjusting capacity, monetary wealth is adjusted as follows:

$$M_{jt+1} = M_{jt} - (K_{jt+1} - K_{jt}) \qquad (10)$$

4.3 Providers: Innovation

Providers modify their designs in two stages. In the first stage all providers consider mutations, while in the second stage all providers consider one-way transfers. Both are subject to filtering by providers' mental models. Each provider targets one of the user types. In this version of the model we simplify by assuming the provider knows the utility function of that user type. An innovation, mutation or transfer, is implemented only if it increases the utility of the target user type.

Mutations are carried out in isolation of other providers. Given design x for the jth provider at period t, the provider considers a mutated design x^*. Each component x^*_i mutates with probability μ and if it does mutate it has the value $x_i + \kappa\varepsilon$, where κ is a mutation factor and ε is a random number drawn from a standard normal distribution. The mutated design replaces the current design only if it increases the utility of the provider's target user type.

After mutation, providers consider further innovation based on imitation of rival providers. Each provider picks another provider in a biased random draw from the existing set of providers. This selection is biased toward to the more profitable providers. In fact it is based on Goldberg's 'roulette wheel' in that the probability of provider j being selected is proportional to the profit made by the provider j in the current period. Having selected a rival, the provider creates a new candidate design x^* by transferring part of the rival's design x^r to replace the matching elements of its current design. A random set H of characteristics is selected, as shown:

$$x^*_h = x^r_h \text{ for } h \in H \text{ and } x^*_h = x_h \text{ for } h \notin H. \qquad (11)$$

This selective transfer operator is different to crossover in genetic algorithms. Here there is no mutual exchange of elements, selective transfer is a one-way emulation. Hence the provider that is being emulated does not have to adjust its design as a consequence of this operator. The new design x^* replaces the current design x only if this increases the utility of the target user type.

4.4 Technological Shock

In the current model there is a technological shock at period T_1. This shock has three features. First, the IS characteristic space qualitatively changes, i.e. the set of characteristics associated with the new IS technology application differs from that of the old technology. More specifically, prior to time T_1, the IS characteristic space has characteristics dimensions 1 to h_1. After T_1, the IS characteristic has dimensions h_2 to h, where $1 \leq h_2 \leq h_1 < h$. Furthermore, before T_1 there is a limit $x_{\max}$ on characteristic values. We use D_1 and D_2 to represent the design spaces before and after T_1 respectively. Before T_1 all designs must belong to D_1 and users place positive weight on IS application characteristics 1 to h_1 and zero weights on characteristics h_1+1 to h.

Second, whereas providers prior to T_1 are producers of the old technology, after T_1 all market entrants are 'new' IS technology producers. At the same time, the user groups that emerge after T_1 are 'new' technology users. New generations of users and providers are generated in the following way; at T_1 'dead' providers and 'dead' user types are replaced by new generations of providers and user types. A provider is treated as 'dead' if its market share has fallen below a cut-off value and a user type is 'dead' if its share of the user population has fallen below a cut-off value. The new providers created at time T_1 must provide designs in D_2. New user types place positive weight on IS application characteristics h_2 to h and zero weight on characteristics 1 to h_1-1. Third, picking up on the earlier discussion of the possible importance of the relative rate of falling unit costs due to static and dynamic economies of scale, the cost of production for new technologies is reduced by a factor θ, i.e. after T_1 all γ_k are reduced by a factor θ.

4.5 Implementation details

The current model uses three independent random number generators, *RC*, *RF* and *RM*, which are used to initialise and modify the users, providers and the market respectively. These are independent in the sense that each has its own set of seeds. In a run of the model these generators are used as follows,

i. *RC* is used to assign values for parameters α, β in the utility functions both at the start of the model and for new user groups at T_1. All values lie between 0.0 and 1.0.

ii. *RF* is used to assign initial designs and cost parameters γ_k as well as control the mutations and transfers. Apart from initial designs before T_1 all values lie between 0.0 and 1.0. Initial designs before T_1 are truncated at x_{max}.

iii. *RM* is used to randomly shuffle the order in which user groups arrive at the market.

A batch job is used to control multiple runs of the model. This batch job has its own random number generator *RB*.

5. Results

The first step is to establish whether the model is capable of producing technological successions, illustrated in Figure 1 above. In the tests conducted it is found that the model does indeed produce the patterns are associated with technological successions within a market niche. As illustrated in Figure 2 below, the envelope of aggregate utility is raised as the new IS technology displaces the old technology in the market niche. A succession occurs when a new, ‘fitter’ technology (i.e. one offering higher levels of welfare) displaces an older, ‘less fit’ technology (i.e. one offering lower levels of welfare).

Successions are found to occur under a number of different circumstances. As the model is rich in terms of parameters, we report a series of experiments that explore the dimensions of application characteristics h_1, the upper bound on the values of characteristics offered by the old IS technology application x_{max}, time T_1, and the cost reduction factor θ as potential explanatory variables for a technological succession occurring. To this end, we constructed a logit model of the probability of succession P. To estimate the models we take the 400 simulations as observations on the model.

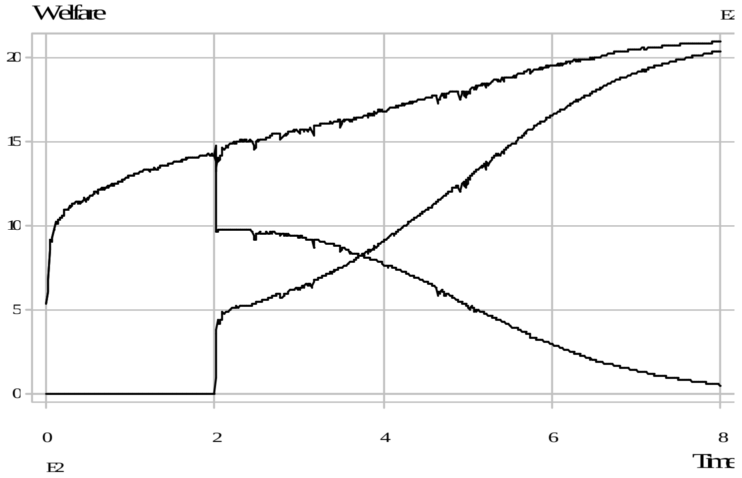

Figure 2. Succession by a new IS technology providing higher welfare

In order to discuss scenarios under which there is a shift to B2B or, alternatively, B2C outcomes we need to distinguish between what the 'full succession' and the 'partial succession' categories discussed in section 2. A 'full succession' occurs when, at the end of a simulation run, a Two provider-user coupling has displaced a Type One provider-user coupling, i.e. only new IS technology providers remain and these sell all their output to new user types. By contrast, a partial succession occurs when Type Two providers displace Type One providers but sell their output to Type One users or a combination of Type One and Type Two users. For each simulation we can use the observed values of sales and user population to classify the outcome as 'full succession', 'partial succession' or 'no succession' (Table 1).

Summary Statistics	**Value**
In Sample Full Successions	111
In Sample Partial Successions	160
In Sample Total	360
Out of Sample Full Succession	16
Out of Sample Partial Successions	21
Out of Sample Total	40

Table 1. Summary statistics for occurrence of full and partial successions

Here we present the logit model that considers the factors influencing a full succession. The model sets the dependent variable to one if there is full succession and to zero otherwise. When estimating the model we used 360 'in sample' observations to select and estimate the models and 40 'out of sample' observations to test the prediction capacity of the selected logit model. Before selecting variables and estimating model the explanatory variables are normalised as follows. For each variable we subtract the in-sample mean and divide by the in-sample standard deviation. Variable selection involves a stepwise elimination of variables in an attempt to minimise SIC (Schwartz Information Criterion) which is a form of Penalised Maximum Likelihood Model Selection (PMLMS) (Birchenhall *et al.*, 1999). Sin and White (1996) show that PMLMS leads asymptotically to the selection of the 'best' model, i.e. the model with the smallest Kullback-Liebler Distance from the true model even if all models are mis-specified.

Using this method of variable selection for the full succession model, the variables are eliminated in the following order: θ, x_{max}, T_1 and h_1. The best model includes T_1 and h_1, the estimated model being (Table 2).

$$P = \text{logit}(1.01 + 0.82\, h_1 + 0.72\, T_1) .$$

Summary Statistics	Value
SIC	383.9
Log Likelihood	180.2
In Sample Succession Errors	26%
In Sample No Succession Errors	18%
In Sample Total	21%
Out of Sample Succession Errors	19%
Out of Sample No Succession Errors	5%
Out of Sample Total	12%

Table 2. Summary statistics for best fit model of full successions

6. Conclusion

The simulation model presented in this paper marks a first attempt to develop a systematic modelling of the probability of IS successions occurring in e-commerce. What is more, we are able to distinguish between those factors influencing a shift to a B2B scenario from those influencing a shift to a B2C scenario. As a consequence, it comes as no surprise that the vast majority of e-commerce trade is currently B2B with very little development of radically new ‘internet’ goods and services. The estimated logit model is statistically respectable and conforms to a number of intuitive expectations. Given the fixed mark-up, providers will happily adjust to a demonstrable demand for their design and price combinations. Hence the key to succession is the replicator dynamics and the utility of the targeted user group. A full succession tends to occur if a new Type Two provider can quickly generate a design and price combination that will make its targeted Type Two user better-off than the current dominant Type One provider-user alliance. This highlights the co-evolutionary interaction between the applications of providers and user preferences that drive emergent market structures. A necessary condition for an IS succession in this model is new market entrants, offering previously unavailable IS performance characteristics, *and* a new user group that is willing to experiment with these new characteristics. It therefore comes as no surprise that the vast majority of e-commerce trade is currently B2B with very little development of radically new B2C goods and services.

Four explanatory variables have been explored in the paper: the new characteristics offered by new IS technology systems, improved performance in one or more characteristics commonly offered by both new and old IS technology designs, differential production costs, and time. In the estimated logit model, the availability of new IS application characteristics has a higher significance than the ability to offer improved performances over existing application characteristics. Given diminishing marginal utility over the entire characteristic space, the initial gain arising from consumption of a new characteristic is likely to be greater than that arising though an incremental improvement of an existing characteristic. This issue is not considered in the Shy model. Indeed, as far as we are aware, the issue has not been considered by previous formal models. Neither does the Shy model consider the likely implications of relative production costs. Interestingly, costs do not appear as a significant factor in he estimated full succession logit model. It may well be that relative costs prove to be a key factor in partial successions, where new IS technology providers are selling to established Type One user groups. This is exactly the driver which appears to be driving the bulk of e-commerce transactions. As a consequence, it comes as no surprise that the vast majority of e-commerce trade is currently B2B with very little development of radically new ‘internet’ goods and services.

The estimated model also considers time as a possible explanatory variable. By varying T_1 one can alter the time allowed for a new IS technology to become established in a market niche. Time T_1 was found to be the second most important explanatory variable in the estimated logit model. Finally, the results generated by the simulation model support a number of aspects of Shy’s earlier analysis of technological successions. Notably, it highlights the importance of a co-existence of new technological products, championed by new market entrants, and one or more user groups that are willing to experiment with these new products. Additionally, it supports Shy’s (previously untested) hypothesis that technological successions can occur in the presence of heterogeneous user preferences.

To conclude, the simulation model developed in this paper complements and extends, Shy's analysis of technological successions, focussing on a number of potentially important variables not considered in that earlier work. The current analysis represents a first effort in an ongoing research programme that seeks to re-open the research agenda on technological successions, and to frame the discussion in meaningful way, through the development of agent-based models that can assist in the analysis of this complex phenomenon.

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