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Myopic selection

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MYOPIC SELECTION*

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Abstract:

The severity of selection mechanisms and the myopia of selection are explored through a duopoly model where one firm tries to move down a learning curve in which costs are initially higher than its rival's but ultimately much lower. A trade-off is found between catch-up time and asymptotic market share: the more severe are selection pressures, the less likely is it that the learning technology will survive, however if it does survive, the learning technology will in the limit be more competitive the more severe are selection pressures. We explore the dynamics of the model under unit cost and strategic pricing and find that the optimal pricing rule depends on the parameters governing firm learning and market selection.

Key Words: learning by doing, selection, strategic pricing, capital markets.

JEL Classification: L1 (market structure, firm strategy and market performance), D4 (market structure and pricing).

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I.   INTRODUCTION

The analogy between natural and market selection that underlies popular (and some scholarly) notions of "*competition*" has inclined many to believe that an increase in the severity of selection pressures will inhibit the willingness of firms to invest and innovate in new technologies. The problem arises because selection based on current fitness is myopic, and, in a market context, this means that only current performance matters. In these circumstances, anything that increases selection pressures will concentrate attention on current fitness, discouraging behaviour that sacrifices current performance for enhanced future performance. In a market context, this means that increasing selection pressures will diminish incentives to invest (e.g. in technological change).

Actually, things are not quite this simple. There are two levels of selection through which a firm must pass if it is to survive: product market selection and capital market selection. Product market selection operates through the mechanism of consumer choice. Firms whose products are of good value attract customers, earn profits and use them to expand. Although some customers take a long-sighted view and support innovative firms with temporarily high prices, this is definitely not the general rule (particularly in consumer markets). Capital market selection is, in principle, different. Banks and other financial institutions will often make loans to firms who seek to improve their future competitiveness at the risk of weakening their current financial position, and they will also loan to firms whose current activities are unprofitable if they believe that improvements will be made in the near future. In this sense, capital market selection may midigate some of the effects of product market selection, making current fitness much less important in determining an enterprise's future growth and development than would be the case if product market selection were the only force operating in markets.

In this paper, we explore the relationship between the severity of selection mechanisms and the myopia of selection processes using a simple simulation model of a duopoly in which one firm tries to move down a learning curve in which costs are initially higher than its rival's but ultimately much lower. The intensity of product market selection is studied by varying a parameter which denotes the degree of consumer price sensitivity: the more price sensitive are consumers the more severe is selection. In the absence of capital market selection, increases in market selection pressures have two opposing effects on the decision to invest in the learning technology. On the one hand, the more severe are selection pressures, the less likely is it that the learning technology will survive due to its higher initial costs (and prices). On the other hand, if it does survive, the learning technology will be more competitive the more severe are selection pressures. This second effect means that a long-sighted lender may be willing to support such investments, particularly when product market selection pressures are particularly strong. As a consequence, the addition of capital market selection completely confounds the common presumption: as product market selection pressures become more severe, the ability of the learning firm to borrow against future performance increases and this facilitates the introduction of the learning technology. That is, increases in the severity of product market competition increase the likelihood that the new technology will be introduced when capital market agents are prepared to lend against future performance.

The structure of the paper is as follows. In Section II, we introduce the model. The main modelling challenges are the need to parameterize the severity of product market selection pressures in a manner which makes comparative static exercises fairly transparent, and the need to introduce a simple and tractable extension of the model to allow for capital

market selection. Our basic results are summarized in the form of four propositions, and these are discussed in Section III, and Section IV contains a few concluding observations.

II.   THE MODEL

We suppose that there are two firms, $i = 1,2$, that there exist exogenous entry barriers which mean that there will always only be two firms, and that the two firms price non-cooperatively and do not collude. Firm 1 operates with a "*traditional technology*" which enables it to produce output $x_1(t)$ at constant unit costs c_1. Firm 2 invests in a "*learning technology*" in which unit costs are initially $c_0 > c_1$, but fall with cumulative output, $Q \equiv \Sigma_\tau$ $\{x_2(\tau) + 1\}$:

$$c_2(t) = c_0 Q(t)^\lambda. \tag{1}$$

λ is the learning index and is equal to $\log\beta/\log 2$ where β is the rate of learning and $1-\beta$ is the progress ratio.[1] If we want to set our learning index close to the empirically relevant progress ratio of .20 then we must set λ close to $\log.80/\log 2 = -.32$. In the simulation exercise below we perform comparative static exercizes using values of λ close to .3.

Since, in principle, firm 2 could have opted to use the traditional technology, the difference between the two firms' initial costs, $\Delta \equiv \{c_0 - c_1\}$, can be thought of as the per period fixed (licensing) cost that firm 2 has to pay to get access to the learning technology. In the model we use the parameter δ to denote the percentage difference in initial costs between the two firms ($\delta=.4$ means that there is a 40% initial cost difference). Clearly, if learning is

slow and set up costs are high (i.e. if λ is small and δ is large), then the learning technology is unlikely to displace the traditional technology. Finally, we define t* as the time when the two technologies achieve parity; i.e. t* satisfies $c_1 = c_2(t*)$. This "*switch-over point*" identifies the earliest time at which the learning technology can survive the most severe product market selection pressures.

Since we have assumed the existence of exogenous entry barriers, selection in product markets operates only through price competition between the two established players. Hence, the severity of selection depends on how sensitive consumers are to price differences between firms. There are several ways to model this. One is to suppose that all consumers are the same, and to allow parametric variations in their elasticity of demand (or some such parameter) to reflect variations in the intensity of selection. Another is to suppose that there are different types of consumers, some more price sensitive than others. In this case, the intensity of market selection pressures will reflect differences in the population mix. We have opted for this second course. We suppose that there are a fixed number, N, consumers, and that θ% of them are sensitive to prices (i.e. they always buy from the low priced firm). The remaining $(1 - \theta)N$ "*noisy consumers*" choose randomly between the two firms regardless of the sign or size of the price difference between them. If both firms change the same price, the "*price sensitive consumers*" choose randomly between them.

This specification of demand produces a 'kink' in the demand facing the two firms. In particular, if:

$$p_1 > p_2, \quad x_1 = (1 - \theta)N/2 \quad \text{and} \quad x_2 = \theta N + (1 - \theta)N/2; \quad\quad (2)$$

$$p_1 = p_2, \quad x_1 = x_2 = N/2; \quad \text{and}$$

$$p_1 < p_2, \quad x_1 = \theta N + (1 - \theta)N/2 \quad \text{and} \quad x_2 = (1 - \theta)N/2.$$

Clearly, when $\theta = 1$, only price sensitive consumers are present in the market, and selection pressures are as severe as they can be. When $\theta = 0$, on the other hand, consumers are all noisy and they choose randomly between the two firms. In this case, no effective selection occurs.

We assume that firms do not know the value of θ and cannot identify "price sensitive" or "noisy" consumers or discriminate between them. If this market were monopolized recognized and θ were known to be small (i.e. when most consumers are noisy), the monopolist will be tempted to set $P \rightarrow \infty$, driving price sensitive consumers out of the market and taking full advantage of the rest. To rule this out, we would have to suppose that (2) is an approximation to true demand behaviour which is accurate only in the neighbourhood of c_1. Alternatively, we could suppose that there is a large queue of potential entrants who will enter if price exceeds some limit, $p_1 > c_1$. The duopolists in our model set prices non-cooperatively, so there will be a strong tendency for prices to fall to the level of costs. Still if the duopolists know that θ is small, they might price above costs. To keep the analysis tractable, we rule this out.

It is worth making four observations on our specification of consumer price sensitivity. First, market demand has no elasticity in this model, but the demand facing individual firms is elastic (at least in the neighbourhood of the point at which their prices are equal). Aside from basic tractability, this specification has the virtue of concentrating attention on competitive pressures. Market growth is something which benefits all firms and it also facilitates the introduction of new technologies (whose fixed costs can be spread over a larger output or whose per unit cost savings increase with market size). Ruling out

exogenously or endogenously generated market growth helps to make market selection more difficult than it might otherwise be, and it is easy to see how the results will be affected by a generalization along these lines.

Second, although consumers base their choice solely on price (product quality is not introduced in the model), there are different ways that the 'noise' embodied in θ can be interpreted. For example, θ can be interpreted as reflecting the degree of brand loyalty in the market in a way that is similar to the 'preference parameter' used in Cabral and Riordan (1994). In a model of a price-setting, differentiated duopoly selling to a sequence of heterogeneous buyers with uncertain demands, they define the preference parameter as the variance of the distribution of consumer preferences for a particular firm's product. Consumers buy from that firm only if the degree to which they like its product is larger than the degree to which its price is larger than the other firm's price. They find that the higher is the variance of the distribution, the larger is this firm's asymptotic market share. This is similar to our result (below) that the lower is the degree of consumer price sensitivity, θ (i.e. the more random is selection), the higher is the asymptotic market share of the learning firm.

The third observation relates (2) to the literature on evolutionary dynamics[2]. These models often represent the selection mechanism by using a "*replicator*" function which relates fitness (e.g. the difference between a firms costs and those of its rivals) to reproductive success (e.g. changes in the firm's market share). Since prices are related to costs (see below) and N is fixed, it is clear that (2) is just a very specific type of replicator function linking cost differences to market shares. Its virtue in our eyes is that it displays the mechanics of how selection rewards fitness in a way which can be related to basic features of consumer behaviour.

Finally, although we look at θ in a comparative statics framework, there are several ways θ can be made to evolve endogenously. The degree of consumer price sensitivity could, for example, depend on the degree to which prices differ between the two firms: when price differences are small consumers are less price sensitive. Or it could also depend on more local consumer behavior such as that described in Cowan et al. (1997) where consumers are influenced by the consumption behavior of others. This can take the form of buying what the 'best' people bought (a group to which the individual aspires to be similar) not buying what the 'worst' people bought (a group from which the individual seeks to differentiate him/herself), or copying the buying behavior of their closest peers (Cowan et al. 1997). We choose to keep θ exogenous for the use of clarity in the comparative statics and also because our experiments with an endogenous θ do not significantly alter the results found. We discuss this further below.

Capital market selection pressures describe the ability of firms to finance current costs incurred to generate future profits. The effects of capital market selection are reflected in the amount of money that firms can borrow, and on what terms. Our interest here is in trying to parameterize the constraints imposed by the capital market in as simple a manner as possible. Suppose that firm 2 incurs losses to travel down its learning curve as fast as possible. Once it has reached unit cost parity with firm 1 (which occurs at t* and is endogenous to the model), it can begin to earn profits to pay these losses back. If t0 is the time at which these (total) losses are offset by subsequent profits, then $T \equiv t_0 - t^* > 0$ is the pay-back period. If the capital market refuses loans with a pay-back period longer than φ, then increases in φ correspond to a weakening in capital market selection pressures. In the limit as $\varphi \rightarrow 0$, we revert to a situation in which only product market selection pressures matter for firms. Put another way, the size of

φ is a simple measure of the extent to which capital markets alleviate (myopic) product market selection pressures.

The final aspect of model specification is pricing. In the absence of a capital market, firms cannot make losses and survive, and, when firms choose prices non-cooperatively, this means that prices will be driven down to costs. In a "*no-loss pricing regime*", prices will, therefore, be given by:

$$p_1 = c_1 \quad \text{and} \quad p_2(t) = c_2(t\text{-}1). \tag{3}$$

where we have introduced a lag to simplify our computations. If firms can borrow on the capital market, then firm 2 can price more aggressively, setting current losses against the future profits which will appear when it has become more efficient than firm 1.[3] For firm 2, this means undercutting firm 1 in order to build up experience (through cumulative sales). The very specific nature of (2) makes this "*strategic pricing regime*" very simple to describe.[4] In particular, what matters from the point of view of attracting consumers is that p_2 is less than p_1. Since θ is exogenous, the absolute size of this difference has no effect on the demand for firm 2's product, and this means that all it needs to do is to slightly undercut firm 1 both before and after t*. Hence, in this regime, prices will be given by:

$$p_1 = c_1 \quad \text{and} \quad p_2 = c_1 - \xi, \quad \text{for some } \xi > 0.[5] \tag{4}$$

By way of summary, then, the model determines values of three variables of interest: t*, the switch point at which the new learning technology becomes cost competitive with the established, traditional technology; s*, the long run market share achieved by the learning

technology; and $T \equiv t_0 - t^*$, the pay-back period when firms are allowed to price strategically. The exogenous parameters of the model are: θ, the degree of product market selection pressure; N, the market size; λ, the learning rate (or index); δ, the licensing cost of the learning technology (described by the percentage difference in initial costs); ξ, the price discount used in the strategic pricing regime; and the pricing rule used (no-loss or strategic). In the simulations we experiment with different values of these parameters except in the case of ξ (arbitrarily set at .005) due to the fact that the structure of (1) makes the exact value of this parameter irrelevant.

III.   THE RESULTS

Using simulation techniques we explore the types of market structures which emerge under different parameter conditions, where by market structure we mean the values of s* and t*. For each set of initial conditions, we first solve for output via (2) (based on the initial prices in [3] and [4], then for the costs (and prices) of the learning firm via (1), and then again for output via (2) etc. In the case of strategic pricing, we also calculate the time period t_0 at which the learning firm is able to fully pay back its debt accrued by pricing above cost.

Our results can be summarized in the form of four propositions. We start by examining the 'no-loss' pricing regime where firms are forced to price in a way which enables them to break even period by period.

Proposition #1*: Long run market shares, s*, and the time at which the new technology becomes established, t*, increase in* θ*.*

The first part of this proposition follows directly from (2) without the need for any simulation. Given the nature of demand in (2), firm 2's market share is either equal to 0, or it

is somewhere between 50% and 100%. If $\theta = 1$, all consumers are price sensitive and, since firm 2 is the high priced firm initially, it never attracts any customers. However, once θ falls slightly below unity (i.e. some noisy consumers are present), firm 2 will attract some customers. This, of course, happens every period, and since nothing in the model limits the ability of firm 2 to go down the learning curve (as long as $\theta<1$), all of this means that firm 2 will eventually become cost competitive with firm 1. The smaller is θ, the more sales it enjoys period by period (and, therefore, cumulatively at any time t) and, when $\theta = 0$, it captures 50% of the market initially and in every period up until t*. In the long run when $c_2 < c_1$, and, as a consequence, $p_2 < p_1$, the market share of firm 2 is $s* = (1 + \theta)/2$.[6] Columns 1 and 2 in Table 1 illustrate this result.

The fact that t* increases with θ is intuitively obvious as well. When θ is just slightly below unity, firm 2 attracts only a few noisy customers per period, and, regardless of the learning rate, this means that it will take a long time for it to accumulate enough experience, Q, to get far enough down the learning curve to achieve cost parity with firm 1. However, the lower is θ, the more noisy customers there are, and, consequently, the more sales firm 2 will enjoy. All of this means that it will learn much faster than would otherwise have been the case had θ been larger. The net effect is that t* is brought forward; i.e. as θ decreases, t* falls. This holds for any parameter values as long as the learning firm prices at unit costs (the case of strategic pricing is reviewed later). Columns 3-6 in Table I show this result with different market sizes and initial cost differences and columns 3-5 in Table II with different learning indices: in each case as θ increases, t* falls. When $\theta = 1$, firm 2 never emerges.

TABLE I

The substance of Proposition #1 is that increases in selection pressure slow the arrival of the new technology, making it harder for it to become established. This, of course, appears to be an instance of myopic selection, and it appears to work to the disadvantage of consumers. However, if and when the new technology becomes established, then increases in selection pressure bring larger gains to firm 2, since stronger selection gives an increasingly large reward to the cost efficiencies which have accompanied the introduction of the new technology. This too reflects the workings of myopic selection, since, once again, selection is merely rewarding superior current performance. In this case, however, myopic selection appears to work in consumers' interests. The bottom line, then, is that the common presumption is (roughly) right: product market selection is myopic in the sense that it discourages the emergence of new, superior technologies. However, myopic selection based only on current performance differences at least has the virtue of rewarding firms who have somehow managed to establish superior technologies on the market.

Proposition #2: The time it takes the learning technology to become established, t*, increases in its licensing costs, δ, market size, N, and decreases in the learning index, λ.

Columns 3-6 in Table I and columns 3-5 in Table II contain a range of simulations which document the assertions in Proposition #2. Table I indicates that with a given θ, an increase in market size (N=50$\Rightarrow$100) and a decrease in the initial cost difference (from δ=.5 to δ=.4) allow firm 2 to proceed more quickly down the learning curve, causing t* to fall. Table II indicates that this also occurs through an increase in the learning index (from λ = -.1 to λ = -.5). Column 4 in Table II indicates that when the rate of learning is relatively high (λ=.5) it almost doesn't matter what the value of θ is since cost convergence occurs very quickly. Column 5 indicates that this is less true when the initial cost difference is very large (from δ=.4 to δ=.9). The relatively high δ and λ in column 5 of Table II can be interpreted as

follows: if the learning firm wants to obtain a fast rate of learning (to reach t* more quickly) it

will have to make a large initial investment reflected in a high δ.

TABLE II

Intuitively, these propositions are fairly easy to grasp. Licensing costs are just another

way of referring to the initial investment which firm 2 must make in the learning technology:

δ is the initial unit cost disadvantage which it accepts in order to have access to the lower

costs in the future available through learning. The higher is this initial cost penalty, the longer

it takes (ceteris paribus) to establish cost parity. Market size matters to firm 2 because the

number of consumers it serves when its price is higher than that of firm 1 is (1 - θ)N. Clearly,

the larger is the market, the more (noisy) consumers it attracts period by period for a given θ.

This enables it to build up experience more quickly, and (ceteris paribus) accelerated learning

rates mean a short time taken to reach cost parity. Similarly, decreases in λ mean faster

learning rates (ceteris paribus), and that clearly serves to bring t* forward.

Figure I illustrates Proposition #1 and #2 simultaneously by looking at the relationship

between t* and θ with different initial cost differences, δ. Although in both cases t*

increases with θ (Proposition 1), in the case with a higher initial disadvantage for the

learning firm (δ=.5), t* is higher for each value of θ. We do not include in Fig. I the plot for

θ = 1 or θ = .99 because, as indicated in Table I and II, in the former the learning firm *never*

emerges, and in the latter it is so large that it distorts the graph (t*= 4149 for δ=.5 and

t*=659 for δ=.4). Each θ represents a unique s* (Table I, column 2). A similar figure could

have been drawn for the case with different N and λ.

FIGURE I

It is worth noting that in Table I and II t* seems rather large in many cases. The

values of λ which we are using are drawn from the empirical literature describing annual

learning rates, θ is unit free, while one unit of N could describe any multiple of a basic

product unit. This gives one an inclination to interpret t* as measuring "years" and, supposing

this to be reasonable, Table I paints a rather dire story. Except in the most favourable

circumstances (e.g. N =100, $\delta \leq$ .4 and λ = -.5), it might take more than a decade for the new

learning technology to become established (even when selection pressures are not very

severe). In the most unfavourable circumstances (e.g. N =50, δ =.5 and λ = -.1), it might take

as long as 83 years *even with a relatively low degree of product market selection* (e.g. θ = .5).

***Proposition #3: When firm 2 can price strategically, t* decreases in θ, and both t_0 and T
also decrease in θ.***

The essence of strategic pricing as we have modelled it here is that firm 2 undercuts

firm 1 by an amount ξ. Prior to t*, this generates losses (since firm 2's costs are higher than

firm 1's), but these losses are compensated by the profits made after t* when firm 2's costs

are below firm 1's costs.[7] It takes T periods of profit making after t* for the firm to break

even. Intuitively, it is clear that t* must fall with increases in θ in this case, since a firm that

prices strategically benefits from having price sensitive consumers: the more sales it captures,

the faster it learns. By contrast, in the case of no-loss pricing, firm 2 benefited from having a

relatively high population of noisy consumers in the market, since they are the source of its

sales when it cannot undercut firm 1 (i.e. there is a trade-off between s* and t* with increases

in θ). Recall also that an increase in θ increases s* in all pricing regimes. It follows, then, that

when capital markets allow firm 2 to price strategically, increases in product market selection

pressure unambiguously facilitate the introduction of the new, learning technology: it comes

sooner, and with a bigger market share reward for its sponsor. Figure II illustrates the

different relationship between θ and t* under the two pricing regimes, with a given set of parameters.

FIGURE II

Table III repeats the calculations in Table I with strategic pricing. Columns 3 and 6 indicate the t* which arises with strategic pricing under different initial costs. Comparing these values to those in columns 3 and 5 in Table I we see that under strategic pricing as θ increases t* decreases. Columns 4 and 6 show T: the amount of time after t* that it takes the learning firm to fully pay back its debt accrued by pricing below cost prior to t*. T decreases as θ increases since the quicker the firm learns the quicker it is able to reach t* and hence begin making profits to pay back its debt. As with no-loss pricing, increases in N and λ decrease t* while increases in δ increase t*.

TABLE III

It is interesting to note that capital market selection does not necessarily loosen the effects of product market selection all that much. If capital markets insist on a pay-back period of φ (meaning that the learning technology only emerges $T < φ$) and if, as seems casually plausible, this is some number less than 10 years, then Table III indicates that the learning firm will only be able to payback the loan within that period if it already begins in a relatively favorable position (low initial cost difference, high learning rate, large market size). Yet it is precisely in these conditions that the learning firm could have probably gone down the learning curve quickly enough without the help of capital markets. It is possible to identify those conditions under which the learning firms should/not take out a loan by looking at whether it is able to pay back the debt within a 'reasonable' payback period, φ. For

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example, when there is a 50% initial cost difference, even with low product market selection $\theta = .4$, the payback period will unlikely satisfy banks (T =30).[8] One is tempted to conclude that while the introduction of capital market selection does in principle facilitate the introduction of new technologies, in practice relaxation of product market selection pressures may not have much practical effect.[9] This brings us to Proposition # 4 which establishes the precise conditions under which it is worth it for the learning firm to price strategically (hence take out a loan).

***Proposition #4**: The profitability of strategic pricing increases in θ, but no- loss pricing may be more profitable than strategic pricing at low values of θ and when learning is very slow.*

Proposition #4 identifies the basic determinants of firm 2's optimal pricing strategy conditional on θ, N, λ and δ. The surprising feature of this proposition is that it may pay firm 2 not to price strategically.[10] In Table IV and Fig. III we calculate the total profits earned by the learning firm at $t=100$ under different parameter conditions.[11] Since we know that the no-loss pricing regime generates neither losses nor profits, as long as profits are positive at $t=100$ we assume it is better for the learning firm to price strategically. To capture changes in the speed of learning we vary market size but could have shown the same result by varying either δ or λ.

FIGURE III

We see that when market size is very small (e.g. N=10), no matter what the value of θ is at $t=100$, the learning firm makes negative profits (losses) and hence strategic pricing is not recommended. When market size is intermediate (e.g. N=40) strategic pricing is better only for values of $\theta > .4$. Only with relatively large market sizes (e.g. N=60-100) is strategic pricing better than no loss pricing for all values of θ. Figure IV below indicates the optimal

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pricing strategy to pursue under different parameter conditions. The speed of learning is

determined by all three parameters: δ, λ and N.

Figure IV: O*ptimal pricing strategy grid*

	Very slow learning	Intermediate learning	Very fast learning
Low θ	*No-loss*	*No-loss*	*Strategic*
High θ	*No-loss*	*Strategic*	*Strategic*

Intuitively, this result follows from the observation that no-loss pricing works best

when most consumers are noisy, since the price disadvantage which firm 2 initially suffers is

not penalized when consumers do not care about prices. Hence when θ is low, it is not

necessary for firm 2 to borrow from the capital market to compete. When, in addition,

markets are *very* small, and/or learning rates are *very* slow and and/or licensing fees are *very*

high, then firm 2 will learn so slowly that it will incur a debt that is too large to pay back in an

acceptable time period. When instead firm 2 learns relatively quickly (independent of the

value for θ) and when the degree of consumer price sensitivity is high combined with an

intermediate speed of learning, then it is better for the learning firm to employ strategic

pricing. Hence, strategic pricing brings benefits only when consumers are price sensitive, and

when learning is not too slow (i.e. when N and λ are small and δ is large). This result is of

interest since common intuition might suggest the opposite: it is when learning is very fast

that no-loss pricing might have an advantage since the learning firm could potentially reach t*

relatively quickly even without borrowing.

One of the limitations faced by the model is the simplicity of our specification of

demand in (2). One way to improve this is to make the degree of consumer price sensitivity,

θ, endogenous. This would not only make the demand curve smoother (hence more realistic) but also allow the pricing strategy employed by firms to evolve with the degree of consumer price sensitivity. A simple way to make the degree of consumer price sensitivity endogenous is to postulate that consumers care more about prices the more prices actually differ between firms (for a homogeneous product). In the no-loss case, this would cause θ to first begin very high (due to δ), then fall as firm 2 moves down its learning, and then rise again as firm 2 produces past t*. Instead of making price constant in the strategic pricing case, ξ in (4) could be made to decrease as c_2 falls (the lower is firm 2's cost, the more it can afford to undercut firm 1's price). Since our results in proposition #4 show that the optimal pricing strategy depends on both θ and the speed of learning, making θ endogenous would cause the optimal pricing strategy to evolve. This type of feedback could create interesting dynamics to be explored via simulation. Nevertheless, our exploration with endogenous θ indicates that the only real difference is that unlike in the comparative statics excercises with an exogenous θ, there is no longer a unique s* since s* depends on the value of θ at each time period and hence at the particular time period market shares are observed. Increases in the speed of learning cause s* to increase but all the dynamics relating to t* in propositions 1-4 do not change.[12]

V. CONCLUSIONS

Studies addressing reasons why best practice techniques do not always become dominant have focused on the role of positive feedback and network externalities in causing inefficient techniques to get 'locked into'. This occurs due to the processes which *block* selection from rewarding higher fitness. Here we have looked at another angle of this issue: what are the problems that can arise when selection rewards fitness *too strongly*? We explored

the effect of myopic selection in industrial markets on product market performance. On the face of it, a simple minded application of the natural selection/market competition analogy would suggest that firms operating in very competitive product markets would not by very innovative. In particular, an innovation whose introduction incurs costs in the short run will be a risky proposition for a firm whose performance is judged only on its current activities.

We have argued, however, that this argument is too simple. In the first place, very competitive markets reward innovations which somehow make it on the market, and the rewards are more than commensurate with the importance of the innovation (at least for the kinds of process which our model describes). More fundamentally, the simple analogy between natural selection and market competition breaks down. This occurs because firms typically face two different types of selection pressures[13]. In addition to normal product market selection forces (driven by consumer behaviour), firms are also selected by the capital market which governs the conditions under which they can borrow or raise funds. In our model, it turns out that these two sets of selection pressures do not reinforce each other. Instead, capital market selection eases constraints on firms in precisely those circumstances where they are most constrained by product market selection pressures. The fact that product market selection is myopic means that successful innovations will be well rewarded, and these, in turn, are the kinds of innovations which capital market agents are most likely to want to support. As a consequence, when capital markets are not too myopic, the myopia of product market selection can actually facilitate the introduction of new technologies.

Table I: t* with λ=.1 and different initial costs and market sizes

1	2	3	4	5	6
		δ=.4	δ=.4	δ=.5	δ=.5
θ	s*	t* N=50	t* N=100	t* N=50	t* N=100
1	0%	never	never	never	never
0.99	99.50%	659	230	4149	1932
0.9	95%	66	34	411	206
0.8	90%	34	18	206	104
0.7	85%	23	12	138	70
0.6	80%	18	10	104	53
0.5	75%	15	8	83	42
0.4	70%	12	7	70	36
0.3	65%	11	6	60	31
0.2	60%	10	6	53	27
0.1	55%	9	5	47	24
0.001	50.05%	8	4	42	22
0	50%	7	4	41	21

Table II: t* with N=100 , different learning indices and initial costs

1	2	3	4	5
θ	s*	λ=.1, δ=.4	λ=.5, δ=.4	λ=.5, δ=.9
1	0%	never	never	never
0.99	99.50%	230	5	199
0.9	95%	34	2	21
0.8	90%	18	2	11
0.7	85%	12	2	8
0.6	80%	10	2	6
0.5	75%	8	2	5
0.4	70%	7	2	5
0.3	65%	6	2	4
0.2	60%	6	2	4
0.1	55%	5	2	4
0.001	50.05%	5	2	3
0	50%	4	1	2

Table III: t* with strategic pricing and N=50, λ=.1 and different initial costs (δ)

1	2	3	4	5	6
		δ=.4	δ=.4	δ=.5	δ=.5
θ	s*	t*	T	t*	T
1	0%	4	3	21	34
0.99	99.50%	4	3	21	35
0.9	95%	4	4	22	36
0.8	90%	4	4	23	39
0.7	65%	4	5	25	41
0.6	80%	5	5	26	44
0.5	75%	5	5	28	47
0.4	70%	5	6	30	50
0.3	65%	6	6	32	55
0.2	60%	6	7	35	59
0.1	55%	6	9	38	65
0.001	50%	7	9	41	72
0	50%	7	9	41	73

Table IV: θ vs. profits (π) under strategic pricing with different market sizes

(N), λ=-.1 and δ = .5 (numerical values for Figure III)

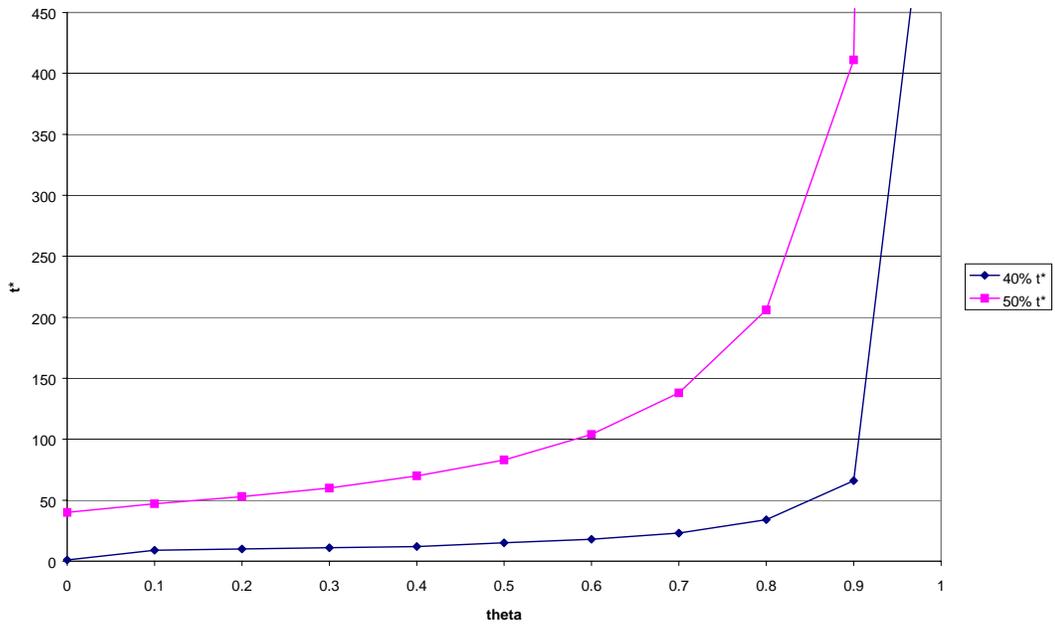| 1	2	3	4	5	6
	N=100	N=60	N=50	N=40	N=10
θ	π	π	π	π	π
0	139	9.6	-14	-34	-46
0.1	178	26	-3	-27	-48
0.2	218	43	9	-19	-49
0.3	260	62	23	-10	-50
0.4	304	82	37	-0.61	-51
0.5	349	103	53	9.6	-52
0.6	396	124	69	20	-53
0.7	444	147	85	31	-53
0.8	493	170	103	43	-54
0.9	543	194	121	56	-54
1	595	218	139	70	-54

Figure I: effect of initial cost difference on t*, with: λ=-.1, N=50

Figure II: relationship between t* and θ under different pricing strategies

(N=100, λ=.1, and δ=.5)
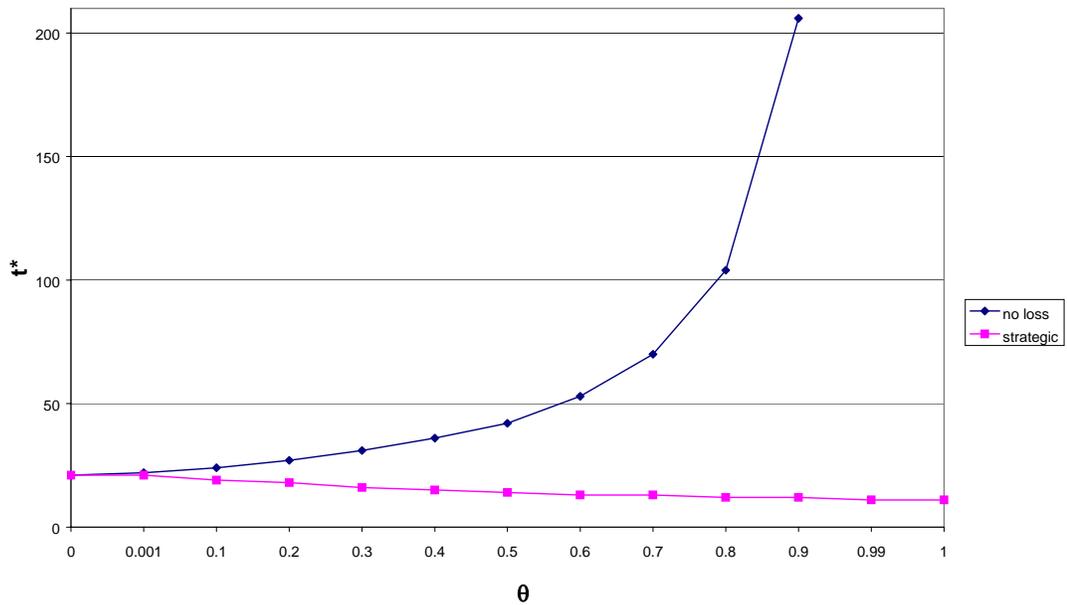
Figure III: θ vs. profits (π) under strategic pricing with different market sizes (N), λ=-.1 and δ = .5
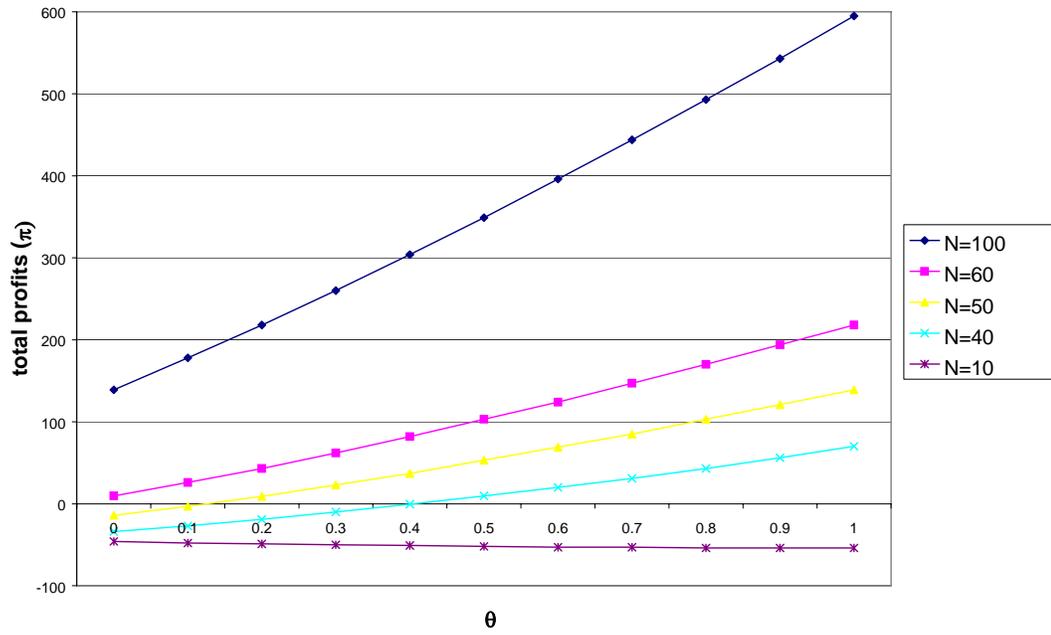
NOTES

[1] Empirical estimates of learning curves often produce estimates in the region of a 25-30% progress ratio. For example, the B-29 bomber have a progress ratio of 29.5% and large-scale integrated circuits 20% (Scherer and Ross, 1990, p. 98; see also Asher, 1956; Boston Consulting Group, 1972).

[2] See, for example, Silverberg et al. (1988) and Metcalfe (1997).

[3] For simplicity, we neglect discounting. Clearly, the higher is the discount rate, the longer it will take to pay back any initially incurred loss caused by investments in learning.

[4] For more general treatments of optimal pricing when learning by doing is present, see Cabral and Riordan (1994) and Spence (1981).

[5] Notice that we are not allowing firm 1 to borrow in order to match firm 2's strategic pricing. The only possible way that firm 1 could generate future profits to offset current losses incurred in this way would be if it were able to drive firm 2 (and all subsequent entrants) out of the market, and set monopoly prices. However, once it tries to do this, firm 2 can re-enter and begin learning. In the absence of a long run permanent cost advantage over firm 2, it is hard to see how it would be in firm 1's advantage to prey on firm 2 in this way.

[6] This result is also reported by Cabral and Riordan (1994) who observe that the higher is the variance of the distribution of consumer tastes, the higher is the market share of the learning firm.

[7] Recall that the special structure of the demand function that we are using mean that all that matters is whether firm 1's price is above or below firm 2's: the amount of extra sales that the low price firm gets depends only on the fact that it has a lower price and not on the size of the price difference. With more subtle characterizations of demand, the optimal discount (prior to t*) and mark-up (after t*) become interesting choice variables.

[8] Notice that the introduction of any amount of discounting would increase both t* and T, making the introduction of the learning technology even less likely.

[9] This is, of course, consistent with a large but not always satisfactory literature which asserts that many capital markets (and particularly those in the US and the UK) suffer from "short-termism".

[10] For example, Cabral and Riordan (1994) argue that it is always better for the learning firm to price strategically.

[11] Although one could argue with the arbitrary time (t=100) period chosen to record the results, by choosing a rather high time period, we are giving the strategic pricing case an easier chance to win.

[12] In those excercises, we used Eq. (5) below to explore endogenous θ:

$$\theta_t = \gamma\theta_{t-1} + (1-\gamma)\{|p_1 - p_2|\} \quad \text{where } 0 \leq \gamma \leq 1 \tag{5}$$

where if γ is close to 0 consumers' degree of price sensitivity (θ) evolves with price differences and the higher is the price difference the more θ changes, while if γ is close to 1 price sensitivity does not change much.

[13] This is also true for the reasons identified in Gould and Lewontin (1979): evolution is not always progressive (fitness enhancing) due to the existence of inertia, non-linearities and random mutations.

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