ÁREA CIENTÍFICA: INOVAÇÃO E TECNOLOGIA

COMPUTER TECHNOLOGICAL LOCK IN OR FIRMS' STRATEGY?

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ABSTRACT
Based on empirical evidence of the evolution of the computing capacity of x86 CPU (Computer Processor Unit), this paper provides a new rationale for the persistence of duopolistic positions. Since 1960's computing capacity of x86 CPU increased rapidly but it cut short in 2003. We proved that stagnation is an outcome resulting not from technological lock-ins but instead from incumbent firm's strategic decisions; in concrete, stagnation derives from the fact that the leader firm quits from her intention of expelling the rival out of the market due to her believe (expectation) that this would be unfeasible. This outcome might occur in products which price is independent of the quality.

KEYWORDS: Innovation, Market Structure, Limit strategy

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1. Introduction

Technological changes have resulted in dramatic improvements in our standard of living. The recent and far-ranging developments in computers and communications have spurred new products whose widespread proliferation no one contemplated even a decade ago (Carlton, 1995).

Overwhelming evidence tells us that incumbent monopolists/duopolists do a lot of research and their leadership persists through a number of innovations (Etro, 2004). This persistence of the monopolistic/duopolistic position drives the incentives to invest in Research & Development and indirectly enhances aggregate growth. Nevertheless the industrial organisation theory of innovation since the pathbreaking contribution of Arrow (1962) and the macroeconomic theory of Schumpeterian growth started by Aghion and Howitt (1992) do not provide clear arguments as to why leaders should innovate.

The debate on the effect of competitiveness on innovation and social welfare is going back to Schumpeter (1943) and Arrow (1962). In a seminal work Schumpeter (1943) argued that market concentration is a stimulus to the innovation. So, a society might prefer to sacrifice 'static' efficiency for the 'dynamic' efficiency. The work by Arrow (1962) challenged this view. In his work Arrow (1962) argued that the incentive for innovation would be stronger for competitive industry than a monopolist.

Detailing a bit further the two lines of argument, the so-called Schumpeterian hypothesis maintains that there exists an inverse relationship between the intensity of competition and the pace of technical progress. That is, according to Schumpeter, monopoly is the market structure that should ensure the fastest and largest technical progress. This relies upon the idea that monopoly ensures the highest profit level and therefore the larger internal sources for funding R&D activities. Arrow expresses exactly the opposite view since he focuses upon the replacement effect, according to which a monopolist should be induced to rest on his laurels, while a firm operating in a competitive environment should strive for new technologies or new products, in order to throw her rivals out of business. A subset of this debate is the literature, stemming from the seminal contribution of Gilbert and Newbery (1982) and Reinganum (1983), on the persistence of monopoly when firms compete for a cost-reducing innovation. The persistence result obtained by Gilbert and Newbery (1982) relies on the fact that, when only strict profit maximizing behaviour is accounted for, a monopolist gains larger profits than the whole industry would do under oligopoly, if all firms avail of the same technology. Hence, the same must hold, a fortiori, in the case where the monopolist operates with the most efficient technology around.

Thus, under free competition, the theory implies that leaders do not invest at all and a process of continuous leapfrogging between firms should characterise markets with technological progress.

Based on empirical evidence of the evolution of the computing capacity of x86 CPU (Computer Processor Unit), this paper provides a new rationale for the persistence of duopolistic positions.

In the twenty years ranging from 1982 up to 2002, computing capacity of x86 CPU (Computer Processor Unit) increased approximately 60% per year [cf. Moore's Law, Moore, (1965)]. This evidence seems to be, at first glance, in accordance with Schumpeter (1942) as he claimed that more concentrated market structures would be more beneficial for innovation. However, quite unexpectedly, x86 CPU having reached in the begging of 2003 a speed of 3.2 GHz and duopoly market structure, progress was cut short, which seems to be in line with Arrow's concerns.

In the present work, we demonstrate that this halt does not necessarily translate a technological limit or block but rather that might be the outcome of firms' competitive strategy. In the line of this reasoning, the evidence presented above does not enforce Schumpeter's view but derives from the fact that in the twenty-year period, the dominant firm had an aggressive innovation strategy as it considered that this behavior would lead competitors out of the market. As time went on, however, the leader stopped believing that aggressive innovation behavior could expel all the rivals. Thus she accommodated the existing competitor and stopped implementing innovations. This outcome is in the line of Arrow's thesis, which argued that more concentrated market structures were detrimental for innovation [Arrow (1962)].

In what follows a game theoretical model is presented which includes incumbent's expectation concerning her capacity to push competitors out of the market based on aggressive innovation strategies (i.e., R&D decisions).
It must be noticed that in the x86 CPU market the price of a new product, although with higher velocity, it is the same as previously was the price of the old product.

2. Assumptions of the theoretical model

A1. Goods are characterized by a quality, the velocity.

A2. There are two firms in the market, E_1 e E_2.

A3. Firms E_1 e E_2 produce goods with velocities q_1 e q_2, respectively.

A4. The velocity of good produced by firm E_1 is higher than that of firm E_2.

A5. The price of the highest velocity product is normalized to unit, $p_1 = 1$, being the lowest velocity product proportional to the velocity ratio $p_2 = q_2/q_1$ (respecting the price, market is perfectly competitive)

A6. Market demand is unit.

A7. Firms' market share is proportional its products velocity, thus the quantity sold by firm E_i is: $D(q_i, q_{-i}) = q_i/(q_i+q_{-i})$.

A8. Firms investigate ways of increasing velocity, which is a stochastic variable. A successful invention permits to increase product velocity to $(1+?q)\, q_i$, being $?q$ constant and equal for both firms.

A9. When a firm makes an invention does not need to promptly implement it, accumulating instead Ki innovations.

A10. Product production marginal cost is é c, independent of its velocity.

A11. At any time a firm can implement $k_i \leq Ki$ innovations with a cost C; at this stage product velocity goes up to $(1+?q)\, k_i\, q_i$.

A12. Inventions cannot be imitated. Nevertheless, there is knowledge diffusion being the probability of firm E_2 to innovate is increasing with her distance to the technological frontier (q_1 / q_2).

A13. The probability to innovate is increasing with R&D investment and the distance to the technological frontier.

A14. There are unknown credit constraints.

A15. Firms maximize expected profits.

3. Theory formalisation

Expected profit function is giving by the following recursive function (Stokey et al, 1989), in which the decision variable is whether to increase product quality and in which proportion:

$$\begin{aligned}
&Ep\left(q_i, k_i\right) = \max\{NotInnov; Innov\} \\
&NotInnov = \left[D(q_i, q_{-i})(p_i - c) - RD_i\right] + b\left\{Ep\left(q_i, k_i\right)(1-e) + Ep\left(q_i, k_i + 1\right)e\right\} \\
&Innov = \left[D(q_i(1+\Delta q)k_i, q_{-i})(p_i - c) - RD_i\right] + \\
&\qquad + b\left\{Ep\left(q_i, K_i - k_i\right)(1-e) + Ep\left(q_i, K_i - k_i + 1\right)e\right\} - C \\
&with\ e = e\left(RD_i, q_i / q_1\right), K_i - k_i \geq 0
\end{aligned} \tag{1}$$

4. Main outcomes

Lema 1. *If firm E_1 is the monopolist, she does not implement innovations and does not invest in R&D.*

Proof: Being monopolist, expression (1) can be simplified to

$$\begin{aligned}
&Ep\left(q, k\right) = \max\{NotInnov; Innov\} \\
&NotInnov = \left[(1-c) - RD\right] + b\left\{Ep\left(q, k\right)(1-e) + Ep\left(q, k+1\right)e\right\} \\
&Innov = \left[(1-c) - RD\right] + b\left\{Ep\left(q, K-k\right)(1-e) + Ep\left(q, K-k+1\right)e\right\} - C \\
&with\ e = e\left(RD, 1\right), K - k \geq 0
\end{aligned} \tag{2}$$

In this expression, we see that each period profit is independent of product velocity. As the firm needs to invest C to implement the innovation, thus her expected profit is higher if she implements no innovation. In this vein, it is also non profitable for the firm to invest in R&D. QED

Lema 2. *If the firm E_2 enters into the market and firm E_1 believes to be possible expel her from the market, then she will take an aggressive strategy, strongly investing in R&D and innovating in order to return to be the monopolist. Firm E_2 responds with an innovating strategy in order to i) proof that it will not leave the market and ii) maintain the price well above its marginal cost.*

Proof: It is clear that if firm E_1 implements an aggressive strategy, innovating continuously and investing strongly in *R&D*, then firm E_2 has to have and innovating strategy to maintain her market share and price well above its cost. As firm E_1 has a higher market share, she can invest resources in R&D and implement innovations, sustaining positive profits until firm E_2's expected profit becomes negative. Being credit constraints binding, firm E_2 ends up bankrupted, exiting the market, and firm E_1 recovers her monopolistic position. QED

Lema 3. *If firm E_1 believes that it would not be possible to expel firm E_1 out of the market, then none of the firms will implement innovations. Notwithstanding, firms invest in R&D to avoid the other firm implementing innovations.*

Proof: Firms expected profit can be translated into the following matrix of strategic interaction where [A, B] represents firms E_1 e E_2 pay-off, respectively:

	E_1 does not innovate	E_1 Innovates
E_2 does not innovate	[100, 10]	[100 + $\phi(k_1)$ – C, 10 – $\phi(k_1)$]
E_2 Innovates	[100 – $\phi(k_2)$, 10 + $\phi(k_2) - C$]	[100 + $\phi(k_1) - \phi(k_2) - C$, 10 – $\phi(k_1) + \phi(k_2) - C$]

If a firm implements an innovation, it is optimal that the other firm also implements an innovation as long as $\phi(k_i) - C$ be higher than zero. Thus, the former firm only implements the innovation if $\phi(k_i) - \phi(k_{-i}) - C > 0$. In this way, a firm accumulates innovations in order to simultaneously be profitable to innovate and disincentive the other firm to innovate. Therefore, firms invest in *R&D* to maintain the *status quo*. QED

5. Conclusion

In this work we justify, on theoretical grounds, why during twenty years computers (x86 CPU) velocity increased rapidly and by 2003 it stagnated. We proved that stagnation is an outcome resulting not from technological lock-ins but instead from incumbent firm's strategic decisions; in concrete, stagnation derives from the fact that the leader firm quits from her intention of expelling the rival out of the market due to her believe (expectation) that this would be unfeasible.

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References

Aghion, P. and Howitt, P. (1992). 'A model of growth through creative destruction', *Econometrica*, vol. 60, (March), pp. 323–51.

Arrow, K. J., (1962), "Economic welfare and the allocation of resources for innovation", in R. Nelson (Ed.), *The rate and direction of inventive activity: economic and social factors*, Princeton University Press, Princeton.

Carlton, Dennis (1995), "Antitrust policy toward mergers when firms innovate: should antitrust recognize the doctrine of innovation markets?", University of Chicago, *National Bureau of Economic Research*, Lexecon Inc.W. in http://www.ftc.gov/opp/global/carlton.htm.

Dasgupta, P., Stiglitz, J. (1980) "Uncertainty, Industrial Structure, and the Speed of R&D". Bell Journal of Economics 11: 1–28.

Etro, Federico (2004), "Innovation by leaders". *The Economic Journal* 114 (495), 281-303.

Gilbert, R., Newbery, D. (1982) "Preemptive Patenting and the Persistence of Monopoly". American Economic Review 72: 514–526.

Moore, G. E., (1965), "Cramming More Components Onto Integrated Circuits", *Electronics*, vol. 38, nº 8.

Reinganum, J. (1983) "Uncertain Innovation and the Persistence of Monopoly". American Economic Review 73: 741–748.

Schumpeter, J., (1942), *Capitalism, Socialism, and Democracy*, Harper, New York, USA.

Stokey, N. L., Robert E. L. Jr. and E. C. Prescott, (1989), *Recursive Methods in Economic Dynamics*, Harvard University Press, New York.