INITIAL LUCK, STATUS-SEEKING AND SNOWBALLS LEAD TO CORPORATE SUCCESS AND FAILURE

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Abstract

Corporate success stories often resemble a snowball. We show how initial luck in hiring talented people, the resulting technological advantage, superior corporate culture, and status-seeking by workers and by consumers can make small initial differences generate large differences over time.

Keywords: industry equilibrium, initial luck, status effects, snowball.

JEL classification: L00, L13.

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1 Introduction

The late 1990s were revolutionary in many markets for high-technology products. Companies were created from scratch, with some dramatic successes and failures. In the market for mobile phones, several producers invested heavily in R&D programs to capture the network effects among consumers. But by 2001 only one firm, Nokia, was profitable, with 50% annual growth in some years; its market share reached 39% by 2003. All its competitors, including the well-established Ericsson and Motorola suffered large losses. Thus, corporate success stories often resemble a snowball. Small initial differences may lead firms which produce similar products to end in far different situations. The competition is directed both to the development of new technologies and to the development of products with new features within an existing technology. The span of about 15 years saw four major technologies, $NMT, GSM, 2\frac{1}{2}G$, and $3G$. Innovation was also present within one technology; for example, in 2004 Nokia planned to deliver 40 new varieties of mobile phones using the $2\frac{1}{2}G$ technology. But no firm is guaranteed success. In early 2004 Nokia was losing market share to Sony Ericsson, Siemens, and Samsung.

Among the other examples of a snowball phenomenon is the contest between VHS and Betamax standards for video tapes, with only VHS surviving. The idea that small initial differences can result in vastly differing equilibria is prominent in chaos theory and in macroeconomic models with unstable paths. We show similar outcomes can characterize an industry.

One of the firms may have gained a competitive advantage through luck. For example, it may have been luckier than its competitors in hiring workers who are more talented or better able to work with each other. This could lead to lower costs, or to products which better satisfy consumer desires. If many consumers attach status value to buying the better product, the initially lucky firm may enjoy much higher profits than its competitors. This can generate dynamic repercussions, with the the success of a firm in one period increasing its chances of success in later periods.

Several mechanisms can generate such a snowball effect. For concreteness and for analytical convenience we shall concentrate on two mechanisms. First, we suppose workers gain status from working at a successful firm, allowing the firm to attract better workers at lower pay. Second, we suppose that higher quality of workers generates a superior corporate culture, which improves future performance.

Status. People who care what others think of them may view owning a high-quality product, or working for a firm which has a good reputation, as increasing their esteem. The phenomenon is well known at universities—faculty are attracted to Harvard for its prestige, not only for the salaries or environment it offers. Law school graduates evaluate each other by the prestige of the law firms which offered them jobs, or the prestige of the judge who offered them clerkships. In contrast, working in a prison or in garbage collection offers little prestige, even if the wage is higher than alternatives the workers might find.

Corporate Culture. The corporate culture at a firm may reflect the identity of its workers in the past: the higher the quality of workers in the past, the better its procedures and traditions, and so the more successful it will be in the future.[1] We may also think of current workers hiring new workers, with high-quality workers better able to identify the quality of job applicants. Here again, the past quality of workers at a firm will affect profits in later periods. Moreover, if capital markets are imperfect, a firm that was successful in the past may have sufficient assets to survive periods of low profits, and may therefore be less likely to fire its workers. The increased job security can allow the firm to pay lower wages in the future. At a more psychological level, success can increase the morale and enthusiasm of workers, making them more productive the greater their success has been in the past.

Path dependence. This paper explores the implications of status concerns and corporate culture. A firm which is lucky enough to hire high-quality workers better succeeds in developing technology. This may later benefit the firm in various ways. The firm may enjoy lower costs, or higher productivity from a better corporate culture. Such path dependence may explain the evolution of firms within some industries. Thus, the different fortunes of Nokia and Ericsson may have arisen from small initial differences in the quality of their workers, reflected in small differences in the products. (Casual observation suggests that Nokia's phones were more elegant than Ericsson's, and had longer-lasting batteries). The puzzle is that Nokia increased its dominance under several major technological changes, where its previous technological lead appeared to have little relevance to the new technologies. And we nevertheless wish to allow the dominant firm to falter, as Nokia did in 2003-2004 when it saw its market share decline.

2 Literature

Our assumption that people care about status, rather than exclusively about absolute income, is commonly found in the literature. Rae (1834) and Mill (1847) consider such a motive. The behavior of consumers who signal income is studied by many economists since then, most elegantly in the work of Frank (1984a, 1984b, 1985a, 1985b). Frank also considers workers who care about their prestige within a firm, so that a person at the bottom of the wage scale demands a premium to work with richer people, and a person at the top of the scale is willing to trade off income for status. Our analysis complements

[1] If corporate culture is embodied in the firm's workers (as Jovanovic (1979), Prescott and Visscher (1980), and Becker (1993) suppose), then as Arrow (1974) shows, a firm's culture can be path dependent, and culture can vary across firms. The path dependence can be stronger if management selects workers whose preferences it prefers (Lazear (1995)), or if a worker prefers to work at a firm which has a culture fitting his background. This preference resembles the peer-group effect in schooling, which has been much studied by Epple and Romano (1998). Becker examines discrimination when workers care who their co-workers are. Ma (2001) models the peer-group effect at the workplace.

Frank's by considering status of a worker as viewed by persons outside the firm, rather than by co-workers. In small cities, or in cities with a dominant employer, relative status within a firm may be most important. In large cities with many employers, status as observed by people outside the firm may be more important. The status-effect we model differs from the analysis in Fershtman, Weiss and Hvide (2001), who consider self-esteem which rises with a worker's wage. We see a successful firm as preferring to hire workers with low self-esteem, but who desire approval from others because they work at a successful firm.

Studies of discrimination in the labor market use related ideas. In his classic book, Becker (1957) explores a model where some individuals in a group prefer to work with persons of the same group. Under factor price equalization this leads to segregation in different sectors. Borjas (1982) assumes that white constituents prefer to be served by white clerks in a government agency, and that blacks prefer to be served by blacks. Arrow (1972) supposes that some whites do not like to work with blacks.

The idea that a person's utility varies with the types of persons belonging to the same organization is found in some analyses of clubs. Scotchmer (1992) proves the existence of a unique competitive equilibrium, which is also Pareto optimal. Berglas (1976), Brueckner (1991), and McGuire (1991) study the characteristics of a competitive equilibrium when firms hire workers with different skills. Some attention has also been paid to schooling where the presence of able students improves the performance of less able students (see Arnott and Rowse (1987) and De Bartolome (1990)).

3 Assumptions

There are two firms.[2] Each hires workers to develop new technologies and produce goods with new features. We start with investment in a single period, each firm working on a new technology. We then consider firms which compete in producing additional features within the available technology. Lastly, we consider the fully dynamic problem where firms compete in developing new technologies over an infinite horizon.

Initial luck in R&D. At the beginning of the period, the two firms (A and B) are identical. Each is uncertain about what product features consumers will value. Workers develop a product, with features consumers value at f_i for firm i's product. The features may include ease of operating the product, weight, color, shape, and so on. The outcome of a firm's investment, which we do not model, is random. After the investments are made, nature makes a draw to determine the relative merits of the outcomes, say $f_A - f_B = \delta$. One firm, say A, has a better product than the other; δ is then positive. Features f_A and f_B can be interpreted as the distance to hidden consumer tastes. A natural interpretation for the difference in the outcomes is that some firm is lucky in

[2] The number of firms is fixed because ability to innovate is a scarce resource.

hiring workers who better know consumer preferences than do workers in the other firm.

Consumers: product features and status. In the basic model, the consumers decide once what to buy. Consumers are willing to pay more for the better product, with the premium $\delta = f_A - f_B \geq 0$. Furthermore, consumers value status: a consumer is willing to pay more for the better product, regardless of its absolute quality. This status concern may arise, for example, from the satisfaction of having early identified which product is better or from the information role of the having the product. We index consumers according to the value they place on status, with consumer i placing a value s_i on status.[3] If the two products are of the same quality, status considerations are irrelevant. The mass of consumers is 1, and s_i is uniformly distributed between zero and one.

We suppose that the better product gives a fixed status effect of s, regardless of the difference in quality between the two products. We view this as a simplifying assumption. Suppose s is an increasing, concave, function of δ. If the slope of this function becomes close to zero for all but small values of δ, then we can take status to be s for the better product throughout almost the whole range of δ.

The price of good i is p_i. For any given values of p_A, p_B (with $p_A > p_B$), f_A, and f_B, there exists a critical value of willingness to pay for status, $\widehat{s}$, such that consumers with a higher value buy good A, and others buy good B. If $\widehat{s} \in (0,1)$ sales at both firms are positive, and the following indifference condition for the marginal consumer is satisfied:

$$f_A + \widehat{s} - p_A = f_B - p_B. \tag{1}$$

Consumers with $s < \widehat{s}$ buy product B; the others buy product A. The share of consumers buying product B is

$$\widehat{s} = f_B - f_A + p_A - p_B. \tag{2}$$

4 Market equilibrium

To reflect the importance of fixed costs of R&D, we assume that the marginal cost of production is zero. The two firms engage in Bertrand competition. Firm A's objective is to

$$\max_{p_A} (1 - f_B + f_A - p_A + p_B) p_A, \tag{3}$$

resulting in

$$p_A = \frac{1 + p_B - f_B + f_A}{2}. \tag{4}$$

[3] As an example, grandmothers seldom regard a portable phone as a status symbol. Teenagers do.

Firm B's objective is to

$$\max_{p_B}(f_B - f_A + p_A - p_B)p_B, \tag{5}$$

resulting in

$$p_B = \frac{p_A + f_B - f_A}{2}. \tag{6}$$

Equations (4) and (6) imply that the prices are

$$p_A = \frac{2 - f_B + f_A}{3} \tag{7}$$

and

$$p_B = \frac{1 + f_B - f_A}{3}. \tag{8}$$

For firm B to charge a non-negative price, we must have $f_A - f_B < 1$. The market share of firm B is

$$\widehat{s} = \frac{1 + f_B - f_A}{3}. \tag{9}$$

We see that the market share of firm B cannot exceed $1/3$. Status considerations make the upper limit bind. The profits of the two firms are

$$\Pi_A = \left(\frac{2 - f_B + f_A}{3}\right)^2$$

and

$$\Pi_B = \left(\frac{1 + f_B - f_A}{3}\right)^2.$$

Since $f_A > f_B$, Π_A must be greater than Π_B.

To see how status considerations affect the equilibrium prices, consider the equilibrium when status is irrelevant, that is were $s = 0$ for all consumers. Each consumer is indifferent between the products if the difference in quality is compensated by prices,

$$p_A - p_B = f_A - f_B.$$

Any one firm can capture the whole market by undercutting the price of the competitor. In equilibrium, $p_B = 0$, and firm A can capture the whole market by charging $p_A = f_A - f_B > 0$, which then also is its profit.

Suppose that the beter product now generates status. As firm A can keep the whole market by choosing the price as without status effects, namely $f_A - f_B$, its profits cannot be reduced. It can, however, raise its price at the cost of losing those customers who value status less than $\widehat{s}$ and who switch to firm B. Firm A will find it profitable to raise the price above $f_A - f_B + p_B$ if

$$\left(\frac{2 + (f_A - f_B)^2}{3}\right) > f_A - f_B. \tag{10}$$

With $f_A - f_B < 1$ this always holds.

Proposition 1 *The product of the lucky firm better satisfies consumer tastes. The status effect associated with the better product enhances the quality effect, allowing the firm with the better product to charge a higher price. Consumers who little value status buy the cheaper product.*

Corollary 2 *If consumers value status, the firm with the better product able to raise its profits even when the quality difference is small.*

Corollary 3 *With small initial differences in product quality, the firm with the better product finds it profitable to attract only consumers who highly value status, thus leaving some market share for the losing firm.*

Do consumers who place little value on status gain or lose from the existence of some consumers who highly value status? If both firms are active, the price of the inferior good (bought by consumers who little value status) is $p_B = \frac{1+f_B-f_A}{3}$; a buyer of this good enjoys a consumer surplus of $f_B - p_B = \frac{2f_B+f_A-1}{3}$. If firm A chooses to set a price so that all consumers buy its good, it sells the good at price $f_A - f_B$; a buyer's consumer surplus is $f_A - p_A = f_B$. So the consumer surplus of a person who little values status is larger when both goods are sold if $\frac{2f_B+f_A-1}{3} > f_B$, or if $f_A - f_B > 1$, which can never hold.

Lemma 4 *The presence of consumers who highly value status can hurt consumers who do not.*

Recalling the results from above, we also conclude.

Proposition 5 *The firm that developed a better product always has a larger market share than the other firm.*

4.1 A snowball

To allow for a snowball, that is for initial success to lead to later success, we consider investment in multiple periods. We do so first with a two-period model. We provide two mechanisms which independently can explain a snowball effect. We notice, however, that they may also be mutually reinforcing.

In period 1, as in the previous section, firms develop a new product. In period 2 both firms engage in development effort, further improving the quality of their products. A conservative assumption for our purposes is that at the end of period 1, firm B can imitate firm A's product; therefore the differences between the products produced by the two firms will reflect investments made in period 2.

4.1.1 Status effects among workers

At the end of period 1, each firm has a product with quality f_A^o. Consider competition in period 2. Each firm chooses to invest in developing additional

features, with firm i spending e_i. Then the product quality in period 2 at firm i is

$$f_i = f_A^o + e_i.$$

We now extend the model to allow workers to value status: a person is willing to work at a lower wage at the firm which had the better product in period 1. This difference can arise if a worker's utility from employment derives both from his monetary wage and from the status associated with employment at his firm. Working at a firm known to have high-quality workers could provide utility for the worker because of self-satisfaction. Or the extra utility could appear because outsiders use the quality of a person's employer as a signal of his quality: outsiders could perceive employment in successful firm as a signal indicating that the worker is likely of high quality.

Let the status value of working at the winning firm be s_A, so that if the wage at firm B is w_B, the wage at firm A is $w_A = w_B - s_A$. Normalize the wage at firm B to 1, so that $w_B = 1$, and $0 < w_A = 1 - s_A < 1$. Because of the value a person places on working at the better firm, $w_A \equiv \theta < 1$.

Increased effort or increased employment is subject to increasing costs. In particular, let the cost of developing enhancement e be $\theta e^2/2$. We simplify notation by normalizing quality $f_A = 0$. In period 2, firms play a Cournot game in their R&D, knowing that they engage in Bertrand competition when setting prices. The profits for the two firms are then

$$\Pi_A = \left(\frac{2 + e_A - e_B}{3}\right)^2 - \frac{\theta}{2}(e_A)^2$$

and

$$\Pi_B = \left(\frac{1 + e_B - e_A}{3}\right)^2 - \frac{1}{2}(e_B)^2.$$

The first-order conditions for maximizing profits are

$$\frac{4 + 2(e_A - e_B)}{9} - \theta e_A = 0$$

and

$$\frac{2 + 2(e_B - e_A)}{9} - e_B = 0.$$

These conditions yield

$$e_B = \frac{2 - 2e_A}{7}. \tag{11}$$

and

$$e_A = \frac{8}{21\theta - 6}. \tag{12}$$

so that

$$e_B = \frac{6\theta - 4}{21\theta - 6}. \tag{13}$$

Since $\theta < 1$, it follows that $e_A > e_B$: firm A invests more than firm B does. We also note that for both firms to engage in development, firm A's cost advantage

cannot be too large. Necessary conditions are that $\theta > \frac{2}{7} = 0.29$ and that $\theta > \frac{84}{126} = 0.67$. As the last inequality is a stronger requirement, it is binding for firm B to engage in R&D.

Profits are

$$\Pi_A = \frac{(144\theta - 32)\theta}{(21\theta - 6)^2} \tag{14}$$

and

$$\Pi_B = \left(\frac{27\theta - 18}{3(21\theta - 6)}\right)^2 - \frac{1}{2}(\frac{6\theta - 4}{21\theta - 6})^2. \tag{15}$$

We summarize with

Proposition 6 *(Snowball effect with status concerns). If workers at the better firm enjoy higher status, it can pay a lower wage. This cost advantage enables it to invest more than the other firm in developing new models of the product, and therefore to maintain its lead.*

4.1.2 Corporate Culture

A firm which happened to hire good workers may also develop a better corporate culture, allowing it to produce better products in the future. In other words, for any given labor input e allocated to R&D, firm A's development efforts are more effective the better its early hires, and so the better its corporate culture. The product qualities are then

$$\begin{aligned} f_A &= f_A^o + \gamma e_A, \quad \gamma > 1 \\ f_B &= f_A^o + e_B. \end{aligned}$$

It is now convenient to interpret γ as a measure of corporate culture, and ignore here status effects. As consumers are willing to pay a premium for the better product, $\Pi_A > \Pi_B$ with $\gamma > 1$, the profits are

$$\Pi_A = \left(\frac{2 + \gamma e_A - e_B}{3}\right)^2 - \frac{1}{2}(e_A)^2$$

and

$$\Pi_B = \left(\frac{1 + e_B - \gamma e_A}{3}\right)^2 - \frac{1}{2}(e_B)^2.$$

The first-order conditions for maximizing profits are

$$\frac{2(2 - e_B)\gamma + 2\gamma^2 e_A}{9} - e_A = 0$$

and

$$\frac{2(1 - \gamma e_A) + 2e_B}{9} - e_B = 0$$

Therefore,

$$e_A = \frac{8\gamma}{21 - 6\gamma^2}, \qquad e_B = \frac{6 - 4\gamma^2}{21 - 6\gamma^2}.$$

Clearly, investment incentives depend on the advantage firm A enjoys from its better corporate culture. We have $\partial e_A/\partial\gamma > 0$, and $\partial e_B/\partial\gamma < 0$.The more efficient firm invests more in the next round. With $\gamma > 1$, we have $e_A > e_B$. There is a stronger implication. For firm B to remain in the market and to have an incentive to stay in the innovation race, firm A must not have an overwhelmingly superior corporate culture. The condition for $e_B > 0$ (and hence non-zero price) is that $\gamma \leq \sqrt{\frac{3}{2}}$. If the superior corporate culture at firm A satisfies $\gamma > \sqrt{\frac{3}{2}}$, firm B would be unable to charge a positive price and so would exit. In the next section, however, we see, that since firm B has a chance of developing a superior new technology, it may remain as a potential competitor.

When both firms are active in the current race, the condition for p_B to be positive is that $\gamma e_A - e_B = \frac{12\gamma^2 - 6}{21 - 6\gamma^2} < 1$, which amounts to the condition above. The feasible range for corporate culture which keeps both firms in the R&D race is thus $0 < \gamma < \sqrt{\frac{3}{2}}$. When the inequality is satisfied, $\Pi_B = \frac{7\left(3-2\gamma^2\right)^2}{9(7-2\gamma^2)^2} < \Pi_A$. We have thus established another snowball effect. From another angle, the winning firm pays a lower wage for an efficiency unit of labor.

We summarize with

Proposition 7 *(Snowball effect with corporate culture). If a firm's success is based on better worker quality, the resulting corporate culture provides another and independent reason for further success. The better firm effectively pays a lower wage in efficiency units to its labor. The firm that initially had a better product will therefore also have the better product, and higher profits, in the next period.*

5 Large innovations

The previous sections showed how status concerns of workers and a superior corporate culture of the market leader can generate snowball effects on the leader's profits and market share. In those sections investment by a firm had a deterministic outcome, and in equilibrium the firm which initially had the better product would also have the better product in later periods. We can interpret this as applying to incremental modifications of a known technology. But in developing new technologies (such as in the switch from analog to digital mobile phones or from the GSM to $3G$), the outcomes of investment may be highly uncertain: a firm which had the better product under one technology may invest heavily, and still find that the other firm developed a better technology. In this section we allow for this possibility.

5.1 Status effects among workers

Consider the industry dynamics starting with a given state, when one of the firms, say A, developed the better technology. As before, firm A can engage in R&D effort at lower cost than can firm B. Thus, it is more likely than firm B to develop a superior technology. Investment by firm i is e_i. The probability that firm 1 develops a superior technology is q_i, with

$$q_A = \frac{1}{2} + \varepsilon(e_A - e_B),\ q_B = \frac{1}{2} + \varepsilon(e_B - e_A), \quad \varepsilon > 0. \tag{16}$$

We expect that in equilibrium, $e_A > e_B$, that is, $\frac{1}{2} + \varepsilon(e_A - e_B) > \frac{1}{2}$ making $\frac{1}{2} + \varepsilon(e_B - e_A) < \frac{1}{2}$. A success for firm A means that it earns a higher profit and continues to have the better product. If firm B, however, produces a better technology and hence a better product, the market positions will change. The technology leader becomes the laggard and the laggard becomes the leader in the race for the next variety. The game continues indefinitely. In technical terms, there is a continuous industry dynamics with no stationary state.

To analyze the optimal current R&D, suppose as before that in the current period firm A has the better product. The discounted value of profits for firm i is V_i; the profits in the current period are Π_i. As explained in the previous sections, consumers are willing to pay a premium for the better product, $\Pi_A > \Pi_B$.The quality and hence this premium increases with the efficiency of corporate culture, γ.

Denote the discount rate by r. Recall that the relative success of the firms may change over time. Thus, Π_A is not the profits of a named firm in each period, but rather the profits in any period of the firm which has the better product. Similarly, V_A is the discounted value of profits for the firm which in the period under consideration has the better product. Assume both firms plan to be active, $V_A > 0, V_B > 0$. Then the Bellman equations are

$$rV_A = \max_{e_A} \ [\Pi_A + (\frac{1}{2} - \varepsilon(e_A - e_B))(V_B - V_A) - \frac{\theta}{2}e_A^2] \tag{17}$$

$$rV_B = \max_{e_B} \ [\Pi_B + (\frac{1}{2} - \varepsilon(e_A - e_B))(V_A - V_B) - \frac{1}{2}e_B^2]. \tag{18}$$

They capture the idea that the leading firm experiences a capital loss if it loses its position, while the lagging firm experiences a capital gain if catches up, and passes, the leader. With such forward-looking behavior, solutions for optimal investments are

$$e_A = \frac{\varepsilon}{\theta}(V_A - V_B) \tag{19}$$

and

$$e_B = \varepsilon(V_A - V_B). \tag{20}$$

Then

$$\varepsilon(e_A - e_B) = \varepsilon^2 \frac{1-\theta}{\theta}(V_A - V_B).$$

With $\theta < 1$, we must have $e_A > e_B$: the status effect among workers makes the firm that was better in period 1 invest more in R&D than the other firm.

Inserting (19) and (20) into the Bellman-equations gives

$$rV_A = \Pi_A + (\frac{1}{2} - \varepsilon^2 \frac{1-\theta}{\theta}(V_A - V_B))(V_B - V_A) - \frac{\varepsilon^2}{2\theta}(V_A - V_B)^2$$

$$rV_B = \Pi_B + (\frac{1}{2} - \varepsilon^2 \frac{1-\theta}{\theta}(V_A - V_B))(V_A - V_B) - \frac{\varepsilon^2}{2}(V_A - V_B)^2$$

Subtracting, we get

$$r(V_A - V_B) = \Pi_A - \Pi_B + (2\varepsilon^2 \frac{1-\theta}{\theta}(V_A - V_B) - 1)(V_A - V_B) - \varepsilon^2 \frac{1-\theta}{2\theta}(V_A - V_B)^2.$$

Thus, and denoting $\Delta \equiv V_A - V_B$ we find that Δ follows the dynamics

$$\frac{3}{2}\varepsilon^2 \frac{1-\theta}{\theta}\Delta^2 - (1+r)\Delta + (\Pi_A - \Pi_B) = 0. \tag{21}$$

This equation has two roots. Only one can be relevant, as an increase in current profit $\Pi_A - \Pi_B$ must raise the value differential Δ. We thus have the solution

$$\Delta = \frac{1 + r - \sqrt{(1+r)^2 - 6\varepsilon^2 \frac{1-\theta}{\theta}(\Pi_A - \Pi_B)}}{3\varepsilon^2 \frac{1-\theta}{\theta}}. \tag{22}$$

For the sake of comparison, suppose for the moment that the more successful firm in an initial period maintains a permanent instead of a temporary advantage. Then a steady state equilibrium exists with

$$\widehat{\Delta} = \widehat{V_A} - \widehat{V_B} = \frac{\widehat{\Pi_A} - \widehat{\Pi_B}}{r}. \tag{23}$$

With probabilistic success, however, the better firm in one period must engage in costly investment to maintain its superior technology, reducing its value and facing the risk of falling behind. We thus expect that throughout the dynamic path, $t \geq 1$, $\Delta_t < \widehat{\Delta}$.

As a comparative static result we find that

$$\frac{\partial \Delta}{\partial(\Pi_A - \Pi_B)} > 0 \tag{24}$$

Denoting for a moment $x = 3\varepsilon^2 \frac{1-\theta}{\theta}$ and evaluating $\frac{\partial}{\partial x}\left(\frac{1+r-\sqrt{(1+r)^2 - 2x(\Pi_A - \Pi_B)}}{x}\right) = D$, yields

$$\begin{aligned} D &= \frac{1}{x}\frac{(\Pi_A - \Pi_B)\left(2r + 2x(\Pi_A - \Pi_B) + r^2 + 1\right)}{2r + 2x(\Pi_A - \Pi_B) + r^2 + 1} \\ &\quad + \frac{1}{x^2}\left(\sqrt{2r - 2x(\Pi_A - \Pi_B) + r^2 + 1}\right) - (1+r). \end{aligned}$$

Then $D > 0$ for a whole range of parameter values. For example, it is likely to hold at least when r and $\Pi_A - \Pi_B$ are not too large. In those circumstances, a decrease in θ increases Δ; $\partial\Delta/\partial\theta < 0$.

5.2 Corporate Culture

Above we showed how status concerns of workers can generate a snowball effect when firms develop a new technology. We consider next the effect of superior corporate culture, showing that it can also generate snowball effects.

Introduce then the probabilities of developing a superior technology as

$$q_A = \frac{1}{2} + \varepsilon(\gamma e_A - e_B),\ q_B = \frac{1}{2} + \varepsilon(e_B - \gamma e_A), \quad \varepsilon > 0. \tag{25}$$

with $\gamma > 1$Ṫhe Bellman equations are

$$rV_A = \max_{e_A} \ [\Pi_A + (\frac{1}{2} - \varepsilon(\gamma e_A - e_B))(V_B - V_A) - \frac{1}{2}e_A^2] \tag{26}$$

$$rV_B = \max_{e_B} \ [\Pi_B + (\frac{1}{2} - \varepsilon(\gamma e_A - e_B))(V_A - V_B) - \frac{1}{2}e_B^2]. \tag{27}$$

The optimal R&D efforts satisfy

$$e_A = \gamma\varepsilon\,(V_A - V_B) \tag{28}$$

and

$$e_B = \varepsilon\,(V_A - V_B)\,. \tag{29}$$

Then we find

$$\Delta' = \frac{1 + r - \sqrt{(1+r)^2 - 6\varepsilon^2(\gamma^2 - 1)(\Pi_A - \Pi_B)}}{3\varepsilon^2(\gamma^2 - 1)}.$$

Now $\partial\Delta'/\partial\gamma > 0$. Superior corporate capital operates in a similar way as the status effect among workers of the market leader.

We collect the results above

Proposition 8 *When the industry dynamics are characterized by probabilistic success, the firm with a better product in any period finds it optimal to invest more in R&D than does the other firm. The status effect among its workers reduces the investment cost and gives an incentive to take advantage of the resulting snowball effect. A more efficient corporate capital has similar effects.*

The finding in the previous section (that with overwhelmingly superior technology $\gamma > \sqrt{\frac{3}{2}}$, the losing firm abstains from current development effort and market activity) means that in the dynamic model of the current section, $\Pi_B = 0$. The current model, however, shows that firm B may nevertheless engage in the competition to develop a new technology.

Lastly, we note a possibility for multiple equilibria. Suppose that one firm expects the other to develop the better product. This solidifies the winner's position, and is self-enforcing. A laggard, however, who expects to win the next round with sufficiently high probability, will invest heavily, which makes success more likely.

6 Final remarks

The model above explained corporate success in terms of initial luck in hiring talented workers and the subsequent snowball effect, making evolution of an industry path-dependent. It may also explain some other behavior.

Consider unemployment. The puzzle of unemployment is why people who are willing to work at the market wage are not employed. One potential answer would rest on the reputational externality discussed above. A low-quality worker could increase output, and generate more revenue for firm than his wage. But if he is hired, the reputation of workers in the firm will decline, and other workers will demand a higher wage. The firm may therefore not want to hire additional low-quality workers.

The idea of established corporate culture has another implication worth exploring. Suppose that workers, after developing valuable skills, exploit their bargaining power by seeking competing job offers from the rival firm. The lagging firm, in particular, might seek to attract high-quality workers from the competitor. But since working at the laggard firm confers no favorable status, it must pay a higher wage. Corporate culture, especially when embedded in workers, reduces the inter-firm mobility of workers.

Our model also yields testable implications: 1) The wage distribution differs from the distribution of productivity. 2) In human-capital intensive industries, leading firms pay lower wages for workers of similar talent than do lagging firms. 3) In a market with heterogeneous products, price differences often exceed differences in quality. 4) A firm with a small initial lead may often expand its lead in later periods. 5) Though technological leadership in an industry tends to be maintained at the introduction of new technologies, positions of leadership are lost over time with positive probability.

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