Resistance to change

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Abstract

Established firms often fail to maintain leadership following disruptive market shifts. We argue that such firms are more prone to internal resistance. A radical adjustment of assets affects the distribution of employee rents, creating winners and losers. Losers resist large changes when strong customer goodwill cushions the consequences. Partial adaptation may lead winners to depart to form new firms with no goodwill, but no internal resistance.

1 Introduction

Often leading firms fail to adjust to radical market and technology changes, and new firms emerge to seize the opportunities. This is puzzling. Leading firms should have precisely the human capital, financial resources and brand name necessary to seize the opportunity. Yet evidence from case studies shows a pattern of failure to adapt following radical innovation in the disk drive, steel, and earth excavator industries (Christensen 1997, 1999), the laser industry (Klepper and Sleeper 2005), the photolithographic and pharmaceutical industries (Henderson (1993, 2006), and the post-deregulation US airline and trucking industries (Audia, Locke and Smith 2000). Leading firms seem to struggle to respond to large, disruptive changes. Conventional explanations focus on the reluctance to relinquish strategies which earn rents on sunk investment, such as sales cannibalization (Arrow, 1962). Management scientists argue that '*radical innovations ... destroy the usefulness of the architectural knowledge of established firms... (leading firms) will often be adept at managing a process of incremental improvement, but disruptive technologies which change the rules ... leave established businesses with nowhere to go*' (Clark and Henderson, 1990). But why, if adaptation promises returns that exceed lost rents on sunk investment, should successful organizations fails to adjust?

One explanation involves behavioural biases resulting from past success. Audia, Locke and Smith (2000) cite internal satisfaction with performance levels, confidence in past strategies, and avoidance of unfavourable information. Henderson and Kaplan (2006) cite organizational inertia, procedural rigidity, and the difficulty of making large adjustments to working practices characterized by extensive interdependencies. Several cases studied in the management literature point to resistance within the organization. Harley-Davidson was unable to prevent Honda's entry with smaller motorcycles, even though it made a competing product, because its distributors did not want to market it (Christensen 1999). A leading disk-drive company failed to move to the new generation of 1.8" drives, as there was no incentive for employees to push a disruptive technology (Christensen 1999). Geroski and Markides (2005) explain Xerox's failure to sustain innovation by the difficulty of creating support inside the organization.[1]

Internal opposition to radical change is understandable: major reconfiguration of firm physical and human capital creates winners and losers. For instance, the transition from film to digital photography entailed a switch in production processes away from chemical engineering and towards computer skills. Employees who were chemical engineers stood to lose out in the process. But why is it difficult to promise compensation to those who stand to lose?

We assume that compensation of agents whose skills lose value is not ex-post credible. Therefore losers may try to block, or at least limit, change by refusing to cooperate. Yet this cannot explain resistance if private benefits are also undermined by reduced firm value. Here we show that resistance is credible when the firm has significant intangible capital, or goodwill, arising from a history of success.

We model three typical features of large firms. First, skilled agents perform complex and nonverifiable tasks. This grants them non-contractible private benefits (for example by structuring asset use and tasks to suit themselves).[2] Secondly, owners can rearrange firm assets and strategies by fiat, but cannot force workers to adapt their behaviour to the new strategy. Most tasks require coordination among agents with complementary expertises, so cooperation is essential.[3] Losers can adopt passive resistance, failing to adjust their actions to the new asset configuration, in order to retain a larger share of benefits. Finally, output is noncontractible, so it cannot be pledged to losers.

We show that for small shifts, losers gain from change and do not oppose it. Even with a reduced share, they prefer to share the larger pie. However, when external change calls for a large reconfiguration, losers can credibly oppose change, and force owners to limit adjustment to a compromise solution.[4]

How can a value-destroying threat be credible? In established firms with

[1] Some companies have managed to overcome this difficulty, at the cost of splitting off the new activity into a separate unit. HP did manage to enter the emerging inkjet market, but they achieved this by setting up a completely separate division from laser printers, located hundred of miles away (Christensen 1999). Another example is IBM's choice to set up a separate unit for its PC business (Henderson, 2006).

[2] For instance, the share of surplus enjoyed by computer specialists depends on the quality and importance of hardware equipment and software in the firm.

[3] Actions in a team are hard to measure (Holmstrom, 1982), and lack of cooperation in highly complementary task execution is particularly inefficient.

[4] Control rights over assets could be assigned to the agents with the ex ante critical investment (Grossman-Hart, 1986). Yet since external change alters the relative role of different skills, this may further increase resistance to change.

strong intangible capital (goodwill), suboptimal production reduces profitability less. For example lower quality output may be sold at a high price thanks to the firm's brand name. This leads to destruction of accumulated intangible capital, and ideally it should be avoided by negotiation. Yet when output is not contractible, winners cannot credibly compensate losers, who in turn cannot commit not to oppose resistance ex-post.[5]

In this context, critical employees can force concessions. Resistance is inefficient in terms of overall output, but rational for losers. To avoid passive resistance, the firm will respond by choosing partial adjustment to the changed circumstances: they prefer to make a small adjustment that losers will cooperate with, than to suffer disruption by attempting to force a large adjustment. In the case of a radical change in the firm's environment, this implies a large loss of potential value for winners.

When the change in external opportunities goes beyond a certain threshold, there is a further effect. New firms have no accumulated intangible capital, so they also have no internal resistance: as a result, winners will leave old firms to form new firms better able to adjust and capture market leadership.

To summarize, our analysis can explain why resistance to radical change is greater in successful firms, even by rational agents aware of the consequences of insufficient adaptation. We show that more succesful firms (those with more goodwill) are (i) more likely to make only a partial adaptation to change and (ii) more likely to collapse and be replaced by new firms.

1.1 Related literature

In the property rights view of the firm (Hart, 1995), firm owners control decisions on alienable (physical) assets in response to external opportunities. However, assets such as skilled human capital are inalienable in the sense that control over them cannot be assigned by contract.[6] Inalienable human capital in Hart and Moore (1994) imposes a limit on the value of the firm which may pledged, producing a theoretical explanation for limited borrowing capacity.

In our model resistance to change arises from unavoidable ex-post haggling, as in the rent-seeking view (Williamson 1981). A difference here is that authority does not enable to dictate agents' actions, enabling them to capture some benefits.[7] This is in line with the comment by Hart and Moore (2008) that ex-post efficient renegotiation seems a poor description of what goes on inside large firms.

Critically, we assume output is not verifiable. Since owners cannot promise some fraction of output, they can neither discourage passive resistance by losers nor departure by winners. In our model, owners are unable to resist non-

[5] We do not model how goodwill is formed; it could reflect either human or financial investment.

[6] Thus vertical integration can restrain rent-seeking only in the use of alienable capital, such as physical assets (Gibbons, 2005).

[7] This ex post control, with its associated benefits to employees, may be ex ante efficient to protect rents arising from firm specific investment.

cooperation which takes advantage of intangible capital when non-cooperative employees remain essential to production[8], which allows them to protect existing rents.

In Hart and Moore (2008), a credible threat to resist may arise from a behavioural sense of entitlement, induced by expectations created by initial contracts. It may be driven by beliefs or psychological utility. This leads to non-cooperative behaviour or “shading,” which resembles our notion of passive resistance. Hart and Holmstrom (2009) show how such “shading” undermines cooperation within integrated firms, and not only in market leaders.

A related approach focuses on struggles between divisions over contractible allocation of resources (e.g. Rajan and Zingales, 2001). In Brusco and Panunzi (2005), managers have weaker incentives in conglomerate firms even in the absence of a power struggle, since they have lower private benefits when they retain less of their profits relative to stand alone firms which do not experience ex-post reallocation of surplus.

Our approach is related to issues studied in the political economy literature. Acemoglu (2003) describes how oligarchic elites whose grip on the economy suffocates growth are not able to make credible promises to other social groups to create better incentives, unless they agree to reduce their own political power.[9] Nor can those who stand to gain once they obtain control commit to compensating the previous elite . Thus the inability to share power and commit to agreements undermines any Coasian solution. In Coate and Morris (1999), trade protection leads to investment which in turn leads to increased demand for future protection. This offers an explanation for persistence of inefficient policy, a form of status quo bias.

In a context of voting over policy choices, valuable radical change will be resisted by voters under sufficient uncertainty over the identity of the winners and losers (Dewatripont and Roland (1994), Fernandez and Rodrik (1994)). In such cases, gradual change may be the sole strategy to cope with resistance, leading to delayed reforms and loss of efficiency. In the special case when individual reforms have some positive interaction, partial change below some threshold will not achieve critical mass and will fail (Roland and Verdier (1994), Shleifer, Murphy and Vishny (1992)).

2 The Model

We assume that a firm consists of two workers, with distinct but complementary expertise (such as production and sales) denoted by $\{w, l\}$. Ex-post the owner captures all firm income, which cannot be contracted upon. However, the owner cannot control the output which accrues directly as private benefits to employees.

[8] They may also not be able to intervene when interference with skills undermines incentives (Aghion and Tirole (1997), Gertner et al. (1994).

[9] In this literature there is a weaker presumption of ex-post efficiency, as compared to organisation theory where the Coase theorem operates as a benchmark.

The firm faces a shift in the technological frontier characterized by the parameter $\gamma^{MAX} \in (\frac{1}{2}, 1]$.[10] The higher is γ^{MAX}, the more radical is the potential gain. The firm adjusts its assets in response, choosing a configuration in the newly feasible set $\gamma \in [\frac{1}{2}, \gamma^{MAX}]$ (the status quo should be regarded as $\gamma = \frac{1}{2}$). A shift to $\gamma > \frac{1}{2}$ favours one type of worker, type w ("winner"), who potentially comes to enjoy a fraction γ of total employee surplus. However, this gain is reduced if type l ("loser") chooses not to adapt behaviour to the new asset configuration.

Firm strategy represents the choice of real assets, which have different skill specificity and thus affect the division of private benefits across skills. We assume the asset choice is made by the winner: it is natural to assume that the winner is critical for the new strategy, so his preferences matter more. However, the analysis is very similar if, instead, one assumes asset choice is made by an external owner; the necessary modifications to our results are given in footnotes. If the loser were in charge, he would choose a smaller adjustment.

After the assets are chosen, the loser chooses his action a. Full cooperation where the action adjusts fully to the new asset configuration ($a = \gamma$) ensures maximum productivity. Partial cooperation means not adapting behaviour fully to the new asset configuration, but enables the loser to maintain a share of private benefits equal to a.

Potential output equals γV (V, which measures the value of the new strategy, is scaled up by the degree of adjustment γ chosen) with each agent getting a share of output given by the loser's action a: the winner gets a and loser gets $1 - a$. However, this is reduced by any dissonance between assets and loser action $a \neq \gamma$, which we call disruption. Disruption reduces output by creating a risk of poor product quality. We measure disruption by defining

$$\delta \equiv \frac{\gamma - a}{\gamma - \frac{1}{2}} \tag{1}$$

so that $\delta \in [0, 1]$. Firms with a reputation for high quality suffer less, albeit at the cost of a loss in intangible capital (goodwill). Let G denote the stock of goodwill, which we interpret as customer loyalty.[11] For future reference as a measure of potential damage from resistance, we define $p \equiv \frac{G}{V}$.

2.1 Output with no resistance

$V\gamma$ is the output if no resistance, with shares of output to w and l of γ and $(1 - \gamma)$ respectively. The individual payoffs are

$$\begin{aligned} \text{Winner:} &\quad \gamma V \gamma \\ \text{Loser:} &\quad (1-\gamma) V \gamma \end{aligned}$$

[10] Purely as a reference, we consider that prior firm strategy was based on an equal division of firm specific assets. In the context of Hart and Moore (2007), any departure from this initial equal divisions of rents would produce some irrational resistance (shading) by the loser.

[11] Goodwill may be defined more broadly to include other benefits, such as better access to credit. In the model, establishing new firms requires investing some resources. We assume that any residual intangible capital at the end of the period is dissipated. In a dynamic context owners would have a claim on it.

2.2 Resistance to change

When there is a mismatch δ between asset configuration and actions, there is a probability of "breakdown," in which case the firm's output and sales rely only on goodwill G. So expected sales are a weighted average of $V\gamma$ and G. We use δ directly as the probability of breakdown, so sales are

$$\delta G + (1 - \delta)\gamma V \tag{2}$$

We assume that G is smaller than γV in all relevant outcomes, which requires $V > 2G$ (so $p < \frac{1}{2}$).Substituting for the definition of δ, the payoff to the loser is

$$\begin{aligned} \pi_L(a,\gamma) &= \tfrac{1}{2}\delta G + (1-\delta)(1-a)\gamma V \\ &= \tfrac{1}{2}\tfrac{\gamma-a}{\gamma-\frac{1}{2}}G + \tfrac{a-\frac{1}{2}}{\gamma-\frac{1}{2}}(1-a)\gamma V \\ &= \frac{(\gamma-a)G + (2a-1)(1-a)\gamma V}{2\gamma-1} \end{aligned} \tag{3}$$

while for the winner it is

$$\begin{aligned} \pi_W(a,\gamma) &= \tfrac{1}{2}\delta G + (1-\delta)a\gamma V \\ &= \tfrac{1}{2}\tfrac{\gamma-a}{\gamma-\frac{1}{2}}G + \tfrac{a-\frac{1}{2}}{\gamma-\frac{1}{2}}a\gamma V \\ &= \frac{(\gamma-a)G + (2a-1)a\gamma V}{2\gamma-1} \end{aligned} \tag{4}$$

2.3 Loser's response

After the winner has chosen the new asset configuration γ, the loser chooses whether to cooperate or resist. It turns out this choice depends on the degree of asset change implemented, as well as the value of the potential change V relative to goodwill G (recall that $p = \frac{G}{V}$.) The following Proposition establishes that the loser cooperates for a moderate shift in asset configuration up to a certain threshold, and responds to any further change by partial adaptation at a decreasing rate.

Proposition 1 *The loser cooperates completely with new strategies γ entailing a moderate shift in asset configuration. The loser resists more radical change. It is never optimal for the loser to block all the value gain from change: the action $a(\gamma)$ taken by the loser may be less than the winner's choice of strategy γ, but exceeds the existing benchmark $\frac{1}{2}$. The point where the loser starts to resist is given by:*

$$\gamma^R = \tfrac{1}{8}\left(3 + \sqrt{9-16p}\right) \tag{5}$$

Beyond this point the loser's action $a(\gamma)$ increases with the chosen γ but less than proportionately. The loser's action is given by

$$a(\gamma) = \min(\gamma, \frac{3}{4} - \frac{p}{4\gamma}) \tag{6}$$

The proof is given in the Appendix (as are all proofs). Notice that γ^R is the point at which $\gamma = \frac{3}{4} - \frac{p}{4\gamma}$. This is the point at which resistance starts to occur. γ^R ranges from $\frac{3}{4}$ (when there is no goodwill; $p = 0$) towards $\frac{1}{2}$(very high goodwill, relative to the improvement generated by the new technology), as shown in the figure below.

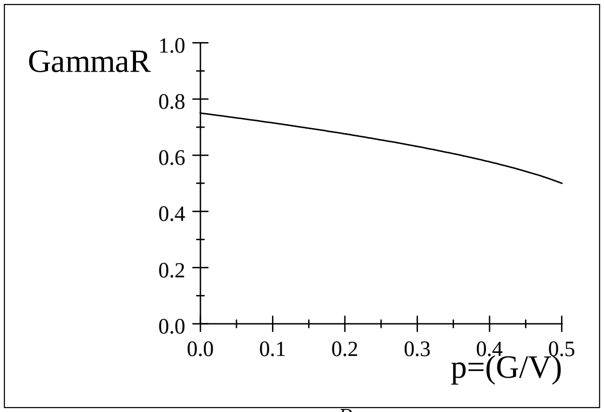

Figure 1: threshold γ^R for resistance

We would expect γ^R to be decreasing in p : more goodwill makes resistance more likely. We can also see that the loser never blocks change completely (it is never optimal for the loser to choose $a = \frac{1}{2}$; even when goodwill is very high, there is a small interval where the new asset configuration is accepted). Also, even when there is no goodwill, the loser always resists a big enough shift in asset configuration (for $a > \frac{3}{4}$, there is always resistance). This is because the loser is willing to accept lower total output, and the risk of loss from disruption, in return for retaining a higher share of output.

Beyond the point where resistance does occur, the loser responds to a higher shift by partial adaptation at a decreasing rate: $a(\gamma)$ is an increasing, concave function with a slope less than 1. The following figure shows the optimal loser response a as a function of the winner's choice of γ (equation (6)) (the figure is drawn for $p = 1/8$).

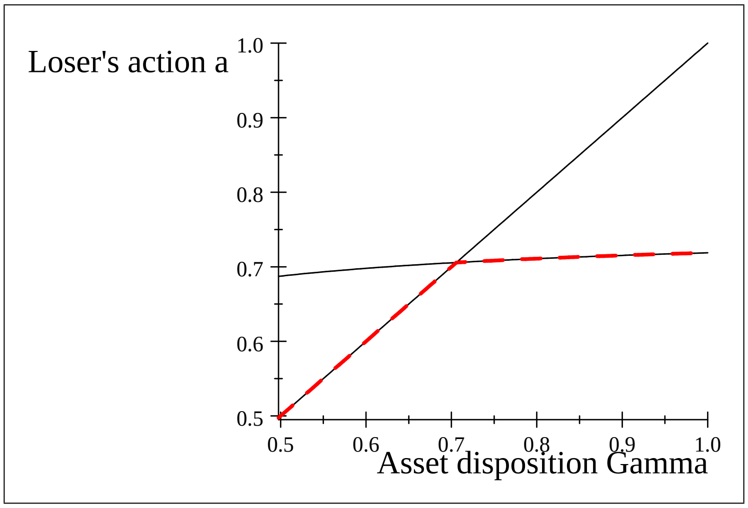

Figure 2: Loser's best response.

2.4 Winner's response

We now consider the winner's decision. Resistance is doubly costly to the winner: it transfers a greater share of benefits to the loser, and creates a risk of poor product quality. The winner must balance these costs against the value gain associated with more change. It turns out in cases where the transformation in external circumstances is large enough to encounter resistance from the loser ($\gamma^{MAX} > \gamma^R$), the winner prefers to scale back the strategy to avoid resistance.[12]

Proposition 2 *The winner chooses the highest possible strategy, $\gamma = \gamma^{MAX}$, in cases where this does not induce the loser to resist ($\gamma^{MAX} \leq \gamma^R$). When $\gamma^{MAX} > \gamma^R$, the winner chooses the maximum adjustment which avoids resistance, so $\gamma = a(\gamma) = \gamma^R$.*

Specifically, the winner chooses

$$\gamma = \min\{\gamma^R, \gamma^{MAX}\} \tag{7}$$

Note that as the largest value of γ^R is $\frac{3}{4}$, the winner will never choose $\gamma > \frac{3}{4}$, as this would always encounter resistance. Also, for small external transformation (small γ^{MAX}), change is implemented in full without resistance from the loser.

This result shows that the winner is better off accepting less radical change which the loser cooperates with, rather than forcing more change which will engender resistance. The loser would not block change completely beyond the

[12] If instead we assume that the decision on γ is made by an external owner of the firm, it is easy to see that the owner would make the same decsion. Beyond γ^R, the owner would face the same trade-off as the winner except that the winner also reduces his output share with a larger γ. Therefore, if the winner prefers to reduce γ back to γ^R, so will the owner.

point γ^R. However, the degree of partial resistance by the loser is severe enough to deter the winner from seeking a larger change in the first place.

We can now state our main comparative static result.

Corollary 3 *A firm with more goodwill (higher p) faces a greater threat by the losing skill to resist change. As a result, it will choose less adaptation to change.*

The payoff for the winner is $W(\gamma) = (\gamma^{MAX})^2 V$ when there is no resistance. Under resistance (when $a = \gamma^R$) it is

$$\begin{aligned}\gamma^R aV &= \frac{V(3+\sqrt{9-16p})^2}{64} \\ &= \frac{V}{64}(18-16p+6\sqrt{9-16p}) \\ &= \frac{9V}{32} - \frac{G}{4} + \frac{3V}{32}\sqrt{9-16\frac{G}{V}} \end{aligned} \tag{8}$$

2.5 New firm creation

Suppose agents can start new firms. We assume that the initiative may be taken only by the winner, as his is now the most scarce talent.[13] Firm creation costs a fixed amount C. As a new firm has no track record, it has no accumulated goodwill. This may impose higher costs (for instance, it may reduce its access to credit), and the parameter C includes these costs as well as other costs of moving and setting up a new firm. However, it also implies that the resistance payoff to the losers is lower. In a new firm, the loser will agree with any asset configuration in the range $\gamma \in (\frac{1}{2}, \frac{3}{4})$. This can be seen by setting $G = p = 0$ in the solution for γ^R given in the previous section. For any γ larger than $\frac{3}{4}$ the loser would resist: the winner, anticipating this, prefers not to set $\gamma > \frac{3}{4}$. This implies that the highest value of the firm is for $\gamma^{MAX} = \frac{3}{4}$, and equals $(\gamma^R)^2 V = (\frac{3}{4})^2 V = \frac{9V}{16}$. More generally, and defining

$$\overline{\gamma}^{MAX} = \min\{\gamma^{MAX}, \tfrac{3}{4}\}, \tag{9}$$

the winner's payoff in the new firm is:

$$W^{NEW} \equiv (\overline{\gamma}^{MAX})^2 V - C \tag{10}$$

Proposition 4 *There is a threshold γ^{New} defined by*

$$\gamma^{New} \equiv \sqrt{\left(\frac{18V-16G+6\sqrt{9V^2-16VG}}{64V} + C/V\right)} \tag{11}$$

When $\overline{\gamma}^{MAX} > \gamma^{New}$, then winner leaves the firm and starts a new firm. As a result, the established firm collapses.

[13] It is straightforward to assume instead that an external owner makes the decision. Details are given in a subsequent footnote.

Note that $\gamma^{New} > \gamma^R$. Also, γ^{New} is strictly decreasing in G and increasing in C. This is intuitive because goodwill makes the existing firm less profitable for the winner, so lowers the threshold at which he leaves to start a new firm. On the other hand a higher cost of starting a new firm makes starting a new firm less attractive and raises this threshold. Note that in the range $\gamma^{MAX} > \gamma^{New}$, it would be in the interests of the loser to commit not to oppose as much resistance. However, following any asset shift larger than γ^R, he will ex-post find it optimal to choose an action a lower than γ.

Note also that lack of goodwill does not eliminate the power of weaker skill. As long as the loser remains indispensable to the production process, some rents have to be left to it. Furthermore, a very high reconfiguration $\gamma > \frac{3}{4}$ which shifts almost all surplus to the winning skill is impossible.

Indeed, the winner's return may be higher if he is able to demand up front some of the value of the ex-post benefits enjoyed by the employee with the loser skill. We could assume that this is so, and that they have some bargaining power β.[14] If $\beta \in (0,1]$ they can extract a fraction of the loser's surplus by requiring them to pay an up-front fee.[15] We could modify the above analysis to allow for this possibility. The winner's payoff in the new firm would then be:

$$W^{NEW} \equiv (\overline{\gamma}^{MAX})^2 V - C + \beta(1 - \overline{\gamma}^{MAX})\overline{\gamma}^{MAX} V. \tag{12}$$

and the statement of Proposition (4) could be modifed accordingly.

As in the previous analysis, Proposition (4) can readily adapted if we assume instead that the decision to start a new firm is made by an external owner.[16]

To summarize the results, the best firms will collapse in the face of radical change, because they face an upper bound on the degree of adaptation that is feasible. Winners then leave established firms, where limited adjustment reduces their own return, and start new firms.

3 Conclusions

Adjustment to radical change requires major reconfiguration of firm strategies, and redeployment of assets dedicated to different skills. Goodwill, a measure of accumulated intangible capital, increases the bargaining power of the losing skill by scaling up what they receive if they refuse to cooperate. The higher goodwill is, the harder it is to achieve an efficient level of change.[17] Thus, a

[14] It would be reasonable to assume that this bargaining power reflects the degree of relative skill scarcity, presumably increasing in the industry shift γ^{MAX}. For simplicity, we assume β is exogenous.

[15] Ex- ante, before they have joined the firm, there are many losers in competition to join the firm. However, ex-post, once they have joined, the losers are able to extract a share of the surplus.

[16] If instead we assume the decision to start a new firm is made an external owner, the analysis is modified as follows. The owner's payoff in the old firm is $\gamma^R V = \frac{V(3+\sqrt{9-16p})}{8}$. In the new firm it is $\overline{\gamma}^{MAX} V - C$ Therefore, the new firm is started when $\overline{\gamma}^{MAX} > \frac{V(3+\sqrt{9-16p})}{8V} + \frac{C}{V}$.

[17] This mirrors Acemoglu's (2003) analysis of the level of investment when neither rulers nor citizens can commit to a compensation scheme.

critical weakness of leading firms in the face of *radical* change (not change per se) is precisely the stock of intangible capital, which keeps up the value of firm output upon resistance.

Compromise change implies a loss of productive opportunity but it is 'politically feasible' because it leaves enough benefits to the losing skill. As it reduces the surplus available to those whose skills have become more valuable, they may leave to set up new ventures, where resistance is weaker because failure to cooperate produces less value. A leading firm may thus collapse as new firms are set up, creating discontinuity in industry dynamics.

Our notion of resistance is related to the notion of shading in Hart and Moore (2008), though it is based on a rational choice when output is verifiable. As actions in a team are hard to measure (Holmstrom, 1982), in our approach this grants significant bargaining power to employees with highly complementary expertise.

An interesting question for future research is what gives rise to goodwill. Goodwill is related to the past success of the firm at pleasing its consumers. While owners in principle own the firm's intangible assets, its future value is at the mercy of hard-to-replace employees. Yet if goodwill reflects value accumulated from intangible human capital dedicated to the firm, as when it reflects quality and knowledge of workers, its value is correlated with past sunk investment by employees. The question of intangible capital seems thus to deserve more attention by researchers.

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5 Appendix

5.1 Proof of Proposition 1

Proof. The loser chooses $a \in [\frac{1}{2}, \gamma]$ to maximize his payoff $\pi_L(a,\gamma)$. Note from (3) that $\pi_L(a,\gamma)$ is quadratic and concave in a. The derivative with respect to a is:

$$\frac{\partial \pi_L(a,\gamma)}{\partial a} = -\frac{G - 3V\gamma + 4Va\gamma}{2\gamma - 1}. \tag{13}$$

First we check that it is not optimal for the loser to offer maximal resistance $a = \frac{1}{2}$ by examining $\frac{\partial \pi_L(a,\gamma)}{\partial a}$ evaluated at this point. Since $V > 2G$, $\frac{\partial \pi_L(a,\gamma)}{\partial a} \mid_{a=\frac{1}{2}} = \frac{V\gamma - G}{2\gamma - 1} > 0$. Thus $a = \frac{1}{2}$ (maximal resistance) is never an optimal choice for the loser. Next we study when some resistance is optimal for the loser by examining $\frac{\partial \pi_L(a,\gamma)}{\partial a}$ evaluated at the point $a = \gamma$:

$$\frac{\partial \pi_L(a,\gamma)}{\partial a} \mid_{a=\gamma} = -\frac{G - 3V\gamma + 4V\gamma^2}{2\gamma - 1} \tag{14}$$

which is negative if some resistance is optimal ($a < \gamma$). If is positive, the constraint $a \leq \gamma$ binds and the loser chooses not to resist.. This occurs when $G - 3V\gamma + 4V\gamma^2 < 0$; equivalently $\gamma(4\gamma - 3) < -p$. Define γ^R as the solution to $\gamma(4\gamma - 3) = -p$:

$$\gamma^R \equiv \tfrac{1}{8}\left(3 + \sqrt{9 - 16p}\right). \tag{15}$$

As $\gamma(4\gamma - 3)$ is increasing, for $\gamma < \gamma^R$ the loser does not resist and for $\gamma > \gamma^R$ there is resistance. Next consider the first order condition for an interior solution (i.e. $\gamma > \gamma^R$) by setting $\frac{\partial \pi_L(a,\gamma)}{\partial a} = 0$ which implies

$$a = \frac{3}{4} - \frac{G}{4V\gamma}$$

Note that $\frac{\partial a}{\partial \gamma} = \frac{G}{4V\gamma^2}$,which is positive, less than $\frac{1}{2}$and decreasing in γ over $(\frac{1}{2}, 1)$. This implies that the loser response to more change in this range is partial adaptation at a decreasing rate. To summarize we have

$$\begin{aligned} a(\gamma) &= \min(\gamma, \frac{3}{4} - \frac{G}{4V\gamma}) \\ &= \min(\gamma, \frac{3}{4} - \frac{p}{4\gamma}) \end{aligned} \tag{16}$$

■

5.2 Proof of Proposition 2

Proof. The winner's payoff is

$$\pi_W(a,\gamma) = \frac{(\gamma - a)G + (2a - 1)a\gamma V}{2\gamma - 1}$$

where $\gamma = \min(\gamma, \frac{3}{4} - \frac{p}{4\gamma})$.

Full Cooperation: Plainly, for $\gamma^{MAX} \leq \gamma^R$, the winner should choose $\gamma = \gamma^{MAX}$ because there will be no resistance.

Potential Resistance: When $\gamma^{MAX} > \gamma^R$, the winner's payoff changes if he chooses $\gamma > \gamma^R$. As the loser will respond with $a(\gamma) = (\frac{3}{4} - \frac{p}{4\gamma})$, the winner's payoff becomes

$$\pi_W(a(\gamma), \gamma) = \frac{(\gamma - a(\gamma))G + (2a(\gamma) - 1)a(\gamma)\gamma V}{2\gamma - 1}$$

Consider the marginal gain to the winner for a further increase in γ in this range:

$$\begin{aligned}
\frac{d\pi_W(a(\gamma), \gamma)}{d\gamma} &= \frac{\partial \pi_W(a(\gamma), \gamma)}{\partial \gamma} + \frac{\partial \pi_W(a(\gamma), \gamma)}{\partial a} . \frac{da(\gamma)}{d\gamma} \\
&= (1 - 2a)\frac{Va - G}{(2\gamma - 1)^2} - \frac{G}{4V\gamma^2(2\gamma - 1)}(G + V\gamma - 4Va\gamma) \\
&= \frac{4V\gamma^2(1 - 2a)(Va - G) - G(2\gamma - 1)(G + V\gamma - 4Va\gamma)}{4V\gamma^2(2\gamma - 1)^2} \\
&= -\frac{3(4\gamma + 1)(8\gamma - 1)}{8V\gamma^2(2\gamma - 1)^2}.
\end{aligned}$$

It is easy to see that it is negative, so the winner chooses not to force change in excess of $\gamma = \gamma^R$. ■

5.3 Proof of Proposition 3

Proof. As the winner payoff in a new firm is $(\overline{\gamma}^{MAX})^2 V - C$, the winner leaves when

$$\begin{aligned}
(\overline{\gamma}^{MAX})^2 V - C &\geq \frac{V}{64}(18 - 16p + 6\sqrt{9 - 16p}) \\
&= \frac{18V - 16G + 6\sqrt{9V^2 - 16VG}}{64} \\
&= \sqrt{\left(\frac{18V - 16G + 6\sqrt{9V^2 - 16VG}}{64V} + C/V\right)}
\end{aligned}$$

■