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Watercooler chat, organizational structure and corporate culture ☆

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ABSTRACT

Modeling firms as networks of employees, occasional collaborative decision making around the office watercooler changes long run employee behavior (corporate culture). The culture that emerges in a given team of employees depends on team size and on how the team is connected to the wider firm. The implications of the model for organizational structure are explored and related to trends in the design of hierarchies.

Apple is a very disciplined company, and we have great processes. But that's not what it's about. Process makes you more efficient. But innovation comes from people meeting up in the hallways or calling each other at 10.30 at night with a new idea...

–Steve Jobs, founder of Apple Inc.[1]

1. Introduction

People talk, share ideas, and collaborate when it is mutually advantageous to do so. Workers bring their collaborative nature with them to the workplace and to their dealings with their colleagues, with whom they interact on shopfloors, in meetings, on production lines and during coffee and lunch breaks. In this paper we consider collaborative decision making

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[1] "The seed of Apple's innovation" - BusinessWeek, October 12th, 2004.

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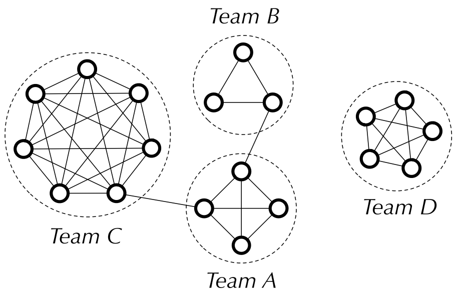


Fig. 1. Firms are represented by networks of employees. A line between two employees (vertices) indicates that they interact with some considerable frequency. Every employee interacts with all members of his own team. Some employees in Teams B and C interact with employees in Team A. In contrast, Team D is isolated from the rest of the firm.

in the social environment of the workplace and, using a simple model of adaptive decision making, show that this can have dramatic and far reaching effects on corporate culture and the optimal internal structure of organizations.

Our model takes the well documented fact that humans are particularly good at mutually beneficial collaboration (Tomasello, 2014), and incorporates this fact into a noisy variant (Young, 1998) of the best response dynamic that has been the bread and butter of economic modeling since Cournot (1838). We model firms as networks of employees, each of whom can choose a 'safe' action or a 'risky' action. The risky action represents innovative, even speculative, behavior within the firm. An employee will only find it in his interest to take the risky action if enough of his neighbors in the network do likewise. Within firms, employees are divided into teams. A team is a group of employees who interact together, although they may also interact with others outside of the team. The team represents an employee's work group, department, or even a corporate board or senior management committee (Fig. 1).

The ability of employees to engage in collaborative action choice is modeled by the idea of a watercooler, around which small groups of employees within a team can chat and form collaborative intentions. If there are no watercoolers, so that employees cannot share intentions, the model reduces to the canonical model of Young, for which the action profile in which every player chooses the safe action is always a long run equilibrium (Peski, 2010). This result no longer holds when small groups of players can occasionally meet at the watercooler to form shared intentions, coordinating their action choice to their mutual benefit. Instead, by incorporating this basic facet of human nature into the model, we obtain a diversity of behavior, dependent on network topology.

We find that in order for members of a given team to play the risky action in long run equilibrium, some conditions must be satisfied. (i) Firstly, the team must not be too large. The larger a team is, the less likely that a fixed amount of collaborative decision making around the watercooler will have an impact on long run behavior. (ii) Secondly, sufficient numbers of employees must be able to coordinate their strategic choice at the watercooler; that is, communication within the team must be strong enough to generate enough collaboration to overcome the systemic bias in favor of the safe action. (iii) Thirdly, the team must not be so small that the influence of its members' external connections can cause them to play the safe action, or, if the team is indeed that small, then all members' connections outside of the team must be to teams that play the risky action. In other words, the external influence from those outside of the team who play it safe must be limited. These conditions provide guidance for organizational design: they can be used to promote or prevent different behaviors in different parts of an organization. Section 5 provides examples related to delayering and job rotation.

Each of these conditions helps to explain empirical facts. Condition (i) provides an explanation for why companies seeking to promote innovation create organizational structures based around small teams (Cook, 2012; Stross, 1996). Condition (ii) helps explain the efforts that firms take to increase spontaneous interaction and facilitate informal communication between workers; that is, to create larger watercoolers (Evans, 2015). Condition (iii) helps explain why organizations seek to foster independence within teams and even isolate research units from other parts of the organization (Sloan, 1964).

The paper is organized as follows. Section 2 discusses some related literature. Section 3 gives the model. Section 4 studies isolated teams of different sizes. Section 5 studies firm structure and design. Section 6 concludes. All proofs are relegated to the Appendix.

2. Related literature

This paper contributes to several strands of literature. The practical contribution is to the literature on the importance of the workplace social environment – the nature and patterns of interaction between workers in a firm (see, for example Bandiera et al., 2005; Gibbons and Henderson, 2013; Kandel and Lazear, 1992). We demonstrate how the facilitation of collective agency by the workplace social environment can have a significant effect on corporate culture. Like Kreps (1990) and Hermalin (2001), we model corporate culture as an equilibrium outcome played in a coordination game. To do this we turn to the literature on adaptive decision making and evolution, which allows us to develop a simple explanation of some aspects of corporate culture, providing an alternative, even complementary, theory to the shared beliefs model of Van Den Steen (2010). Evolutionary models often focus on long run equilibria. This is similar to how the relational-contracting literature adapts long run folk theorems to study firms (Baker et al., 1999; Levin, 2003; Li et al., 2017), the difference being that evolutionary models impose very low rationality requirements on agents. Such low rationality models have had success at explaining laboratory data (Chong et al., 2006) as well as empirical phenomena as diverse as crop-sharing norms (Young and Burke, 2001) and the wearing of the Islamic veil (Carvalho, 2013). The current paper shows how the incorporation of collective agency into such models can lead to even richer empirical predictions whilst retaining the simplicity and elegance of evolutionary methodology.

The incorporation of collective agency into perturbed evolutionary dynamics is a relatively new and rapidly growing literature (Newton, 2012a,b; Newton and Angus, 2015; Sawa, 2014; Serrano and Volij, 2008), although considerable work has been done in the context of matching, where pairwise deviations represent intentional behavior by coalitions of size two (Jackson and Watts, 2002; Klaus et al., 2010; Klaus and Newton, 2016; Nax and Pradelski, 2014; Newton and Sawa, 2015). The proclivity of humans to engage in collective agency is well documented[2] and recent research in developmental psychology has shown that the urge to collaborate is a primal one, manifesting itself from ages as young as 14 months (Tomasello, 2014; Tomasello et al., 2005; Tomasello and Rakoczy, 2003). Recent theoretical work has shown that the ability to act as a plural agent will evolve in a wide variety of situations (Angus and Newton, 2015; Newton, 2017; Rusch, 2019). The authors of the current paper believe that the evidence in favor of the incorporation of collective agency into models of human behavior is overwhelming. Furthermore, adaptive/evolutionary frameworks are ideal for this as, in contrast to static analyses, they explicitly model behavior both in and out of equilibrium.

Finally, we note that work on collective agency in evolutionary dynamics builds on a broader literature on coalitional behavior in game-theoretic models. The concept of joint optimization underpins cooperative game theory (see Peleg and Sudholter, 2003, for a survey) and also motivates a small but established literature at the intersection of noncooperative and cooperative game theory (see, for example Ambrus, 2009; Aumann, 1959; Bernheim et al., 1987; Konishi and Ray, 2003). However, despite the noted limitations of methodological individualism in economics (Arrow, 1994), the use of coalitional concepts in economics has not attained the same level of popularity as, for example, the use of the concept of beliefs, except insofar as the concepts of the household and the firm assume a sharing of intentions on the part of the individuals within those structures. The contrast is interesting, as developmental studies of children indicate that they collaborate at earlier ages than they can understand beliefs.[3] One of the goals of the current paper is to show how a weakening of methodological individualism can lead to simple and striking economic predictions that flow from some of the deepest currents of human nature.

3. Model

Let N be a finite set of employees partitioned into disjoint teams T_m, $m = 1, \dots, \bar{m}$. Let $m(i)$ denote the team to which employee $i \in N$ belongs. Each employee, $i \in N$, has a set of colleagues with whom he interacts, denoted by $\Delta_i \subseteq N \setminus \{i\}$, and any interaction is mutual $j \in \Delta_i \Leftrightarrow i \in \Delta_j$. This means that the interaction structure can be depicted as an undirected network. If $j \in \Delta_i$ (equivalently $i \in \Delta_j$), then we say that j is a neighbor of i (and i is a neighbor of j). Assume that each employee $i \in N$ interacts with every member of his own team, $(T_{m(i)} \setminus \{i\}) \subseteq \Delta_i$, and with at most a single employee outside of his team, $|\Delta_i \setminus T_{m(i)}| \leq 1$. That is, we consider interaction structures similar to that depicted in Fig. 1.

Employees have two possible modes of behavior, either taking a *safe* or a *risky* action. Let $X^t \subseteq N$ denote the set of employees who take the risky action at time t. When a time is not specified, we denote this set by X. When an employee takes the safe action, he receives a fixed utility that is independent of the actions of others.[4] The risky action is risky in that when an employee takes this action, his utility depends on the actions of others. Specifically, utility from taking the risky action increases in the share of one's neighbors who take it, so that each employee prefers to take the risky action if and only if at least a proportion $q \in (0, 1]$ of his neighbors also take the risky action. Our primary interest will be in values of $q > 1/2$, for reasons that will become apparent later.[5] For $i \in N$, let $q_i(X)$ be the proportion of employee i's neighbors who are in set $X \subseteq N$.

Just like in many real workplaces, groups of employees occasionally meet at a watercooler. Time is continuous and any given set of employees $C \subseteq N$ meets at the watercooler with Poisson arrival rate $\lambda_C \in \mathbb{R}_{\geq 0}$. When $\lambda_C = 0$, the set of employees C never meet at the watercooler. This could be because they work in different areas of the organization, or because there are too many employees in C for them to comfortably fit around a watercooler at the same time. Let $\mathcal{C}$ denote the set of all groups of employees who meet from time to time:

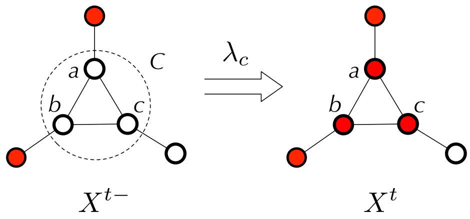
$$\mathcal{C} := \{C \subseteq N : \lambda_C > 0\}.$$

[2] In the words of Tomasello (2014): "...humans are able to coordinate with others, in a way that other primates seemingly are not, to form a "we" that acts as a kind of plural agent to create everything from a collaborative hunting party to a cultural institution."

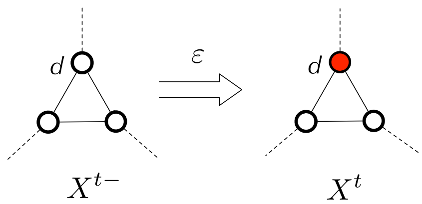
[3] See Baron-Cohen (1994); Call and Tomasello (1999); Carpenter et al. (1998a,b); Wellman and Bartsch (1994); Wellman et al. (2001).

[4] This assumption would have no effect in an individualistic model but in the current setting ensures that if an individual cannot gain from switching to the safe action on his own, then he cannot gain from doing so as part of a coalition. For an analysis of the links between individual incentives and collective agency via the payoffs of coordination games, see Newton and Sercombe (2017).

[5] Early work in this area has players choosing a single action to play against each of their neighbors in identical symmetric two action games in which the safe action corresponds to a risk dominant Nash equilibrium and the risky action corresponds to a Pareto efficient Nash equilibrium (Kandori et al., 1993). A threshold $q > 1/2$ then arises from the payoffs of such a game.



(a) $C = \{a, b, c\}$ meet at the watercooler and $\bar{C}(X^{t-}, C) = \{a, b, c\}$ adopt the risky action.



(b) Employee d is hit by a random shock and switches his action.

Fig. 2. The strategy updating process. It is assumed that $q = 3/5$. Filled (red) vertices (employees) are playing the risky action. The remaining employees are playing the safe action. Note that the updating process can easily be applied to interaction structures beyond the ones considered in the current paper. For example, if we were to give individual c an additional neighbor outside of C who is playing the safe action, then individual c would no longer wish to participate in a switch to the risky action and we would have $\bar{C}(X^{t-}, C) = \{a, b\}$. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

We assume that each team has its own watercooler and we limit the number of employees who can fit around the watercooler to a maximum of k. Any set of no more than k employees within a team has some opportunity to form shared intentions at the watercooler.

$$\mathcal{C} = \bigcup_{m=1}^{\bar{m}} \{C \subseteq T_m : |C| \le k\} \text{ for some } k \in \mathbb{N}_+.$$

Note that standard *individualistic* dynamics, for example Young (1993) and Kandori et al. (1993), correspond to the restriction that $k = 1$; that is to say, there is no watercooler. In this case, individuals make their decisions in isolation, as if everyone is "working from home" and no one ever interacts in a common workspace or in an office.

When employees meet at the watercooler, they have the opportunity to coordinate a change in action. Specifically, when set C meets at the watercooler, subsets of C can adopt the risky action if it is in their mutual best interests to do so. Let $\bar{C}(X, C)$ be the maximal $\hat{C} \subseteq C$ such that $q_i((X \setminus C) \cup \hat{C}) \ge q$ for all $i \in \hat{C}$. That is, $\bar{C}(X, C)$ is the largest set of employees within C who, fixing the actions of those outside of C, will each obtain a higher utility when every employee in $\bar{C}(X, C)$ takes the risky action than they would from taking the safe action. In the example of Fig. 2(a), from state X^{t-}, if we assume that $q = 3/5$, then when the set of employees $C = \{a, b, c\}$ meet at the watercooler, we have that $\bar{C}(X^{t-}, C) = \{a, b, c\}$.

If X^{t-} is the state immediately preceding an updating opportunity for some group of employees C at time t, let $X^t = (X^{t-} \setminus C) \cup \bar{C}(X^{t-}, C)$. In other words, the employees in C agree to update their actions in such a way that no subset of employees within C could do better than by following this plan, given that the others within the group also do so.[6] For the example of Fig. 2(a), as $C = \{a, b, c\}$ and $\bar{C}(X^{t-}, C) = \{a, b, c\}$, we have that $a, b, c \in X^t$. Individuals a, b and c have coordinated a mutually beneficial switch to the risky action. Note that none of these individuals would wish to switch to the risky action if the others were not also switching.

Employee behavior is perturbed by random shocks. With Poisson arrival rate ε, shocks hit the organization. When such a shock occurs, an employee $i \in N$ is selected uniformly at random and his action is flipped to the alternative action. This means that if $i \in X^{t-}$, then $X^t = X^{t-} \setminus \{i\}$, and if $i \notin X^{t-}$, then $X^t = X^{t-} \cup \{i\}$.[7] This captures employee mistakes, randomness in the translation between intent and action, or simply exogenous influences on behavior. Such a shock is illustrated in Fig. 2(b), where employee d is hit by a random shock, causing him to switch from the safe action to the risky action.

Employee behavior is thus determined by a continuous-time Markov process on state space $\mathcal{P}(N)$, with transition probabilities derived from the above description of the process. Note that for $\varepsilon > 0$, the process is irreducible and therefore has

6 That is, fix the actions of players outside of C and consider the induced game with player set C. The actions chosen by players in C are a strong equilibrium (Aumann, 1959) of the induced game.

7 This perfect symmetry between shocks in either direction is not necessary for our results. All that is required is that the rate of each kind of shock is of the same order of magnitude as ε.

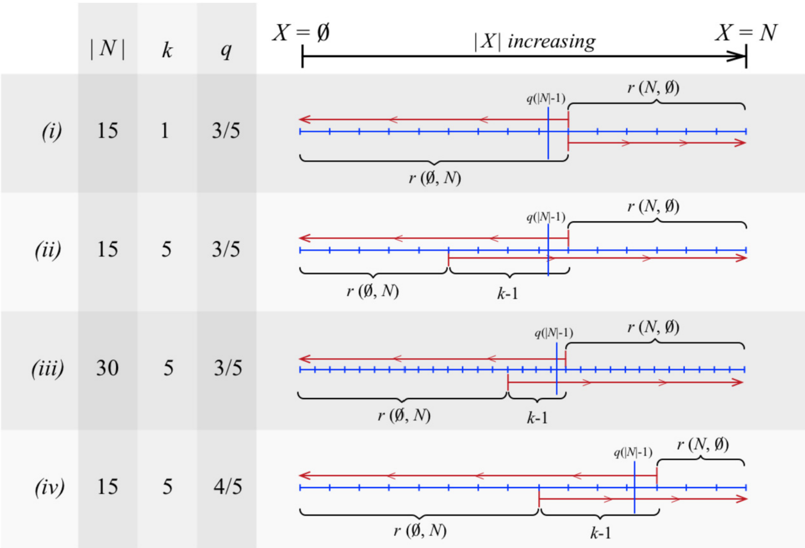


Fig. 3. Red arrows indicate states from which $X = \emptyset$, $X = N$ can be reached without random shocks. Therefore, $r(\emptyset, N)$ is the number of shocks required to reach $X = N$ from $X = \emptyset$; $r(N, \emptyset)$ is the number of shocks required to reach $X = \emptyset$ from $X = N$. If $r(\emptyset, N) > r(N, \emptyset)$ then $X = \emptyset$ at long run equilibrium. If $r(\emptyset, N) < r(N, \emptyset)$ then $X = N$ at long run equilibrium. Comparing (i), (ii), we see that $r(\emptyset, N)$ decreases in k and $r(N, \emptyset)$ is unaffected, giving Corollary 2. Comparing (ii), (iii), we see that $r(\emptyset,N)/|N|$ increases in $|N|$ and $r(N,\emptyset)/|N|$ remains approximately the same, giving Corollary 1. Comparing (ii), (iv), we see that $r(\emptyset, N)$ increases in q and $r(N, \emptyset)$ decreases, giving Corollary 3.

a unique invariant measure π_ε. We are interested in the long run behavior of the process for small values of ε. By standard arguments, as $\varepsilon \to 0$, π_ε approaches a limiting measure π_0. States with strictly positive weight under π_0 are known as *stochastically stable* states (Foster and Young, 1990), or *long run equilibria* (Kandori et al., 1993) of the process. For small values of ε, the process will spend the vast majority of time at such states.

The model above gives an explicit behavioral rule composed of three components. Firstly, employees update their actions in a way that is consistent with their individual incentives (Cournot, 1838). Secondly, they may do this in a coalitional manner (Neumann J, 1928). Thirdly, behavior is subject to random perturbations. This third aspect was foreseen by Cournot (1838) and our formal implementation follows Young (1993). We make no assumptions of equilibrium. Instead, equilibria emerge as conventions (regularities in behavior) as described by Lewis (1969).

4. Independent teams and corporate culture

We start by analyzing the behavior of a single team in isolation. That is, we are interested in a team like Team D in Fig. 1, in which no employee interacts with anyone from outside of their own team. This is an appropriate assumption for autonomous work groups, senior management teams or corporate boards, where bonds within the group are much stronger than connections to outsiders. Analytically, this is equivalent to the entire population being a single team, $N = T_1$, and the interaction structure being the complete network. In such a setting, when $q > 1/2$, if $k = 1$, then $X = \emptyset$ will always be a long run equilibrium, regardless of the size of the team (Kandori et al., 1993; Young, 1993). However, humans are naturally social and collaborative creatures, and when these instincts are brought into the work environment, risky behavior can be selected as the unique long run equilibrium.[8]

Theorem 1. *If $N = T_1$, $q > 1/2$, then in any long run equilibrium X,*

$$\begin{aligned} |N| - 1 > \tfrac{k}{2q-1} \quad &\implies \quad X = \emptyset, \\ |N| - 1 \le \tfrac{k-2}{2q-1} \quad &\implies \quad X = N. \end{aligned}$$

Theorem 1 arises from the interaction of two effects. The first effect is similar to risk dominance of the safe action. Specifically, given $q > 1/2$, if exactly half of an employee's neighbors take the safe action, then the employee prefers to take the safe action. The second effect is the effect of collaborative decision making. This enables employees to coordinate their switches to the risky action, making it easier to attain the required threshold q. These two effects are illustrated in Fig. 3.

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[8] The reader will note that there is a gap between the two thresholds on $|N| - 1$ in the theorem. This is because integer considerations mean that, for fixed $N, k < N$, there is an interval of values of q over which both $X = \emptyset$ and $X = N$ are long run equilibria.

The above explanation clarifies why our analysis focuses on $q > 1/2$. If $q \leq 1/2$, then the direction of the risk dominance effect switches, so that both effects work towards the adoption of the risky action.[9]

Remark 1. *If $N = T_1$ and $q \leq 1/2$, then $X = N$ is a long run equilibrium. If, in addition, $k \geq 2$, then $X = N$ is the unique long run equilibrium.*

The first part of Remark 1 states that when both the risk dominance effect and collaborative decision making work towards the adoption of the risky action, then the state at which all employees take the risky action is a long run equilibrium.[10] The second part states that the existence of a watercooler ($k \geq 2$) suffices to exclude the possibility of multiplicity of equilibria due to integer considerations.

Three comparative statics regarding behavior of agents within firms arise naturally out of Theorem 1. The first relates to team size.

Corollary 1. *All else equal, large teams are less likely to engage in risky behavior than small teams.*

Evidence from case studies suggests that companies that place a high value on innovation indeed try to create a work environment based around interaction within small teams. Stross (1996) notes that Microsoft, “even as it grew large, was deliberately fashioned to perpetuate the identity of small groups”. Cook (2012) notes that Google, Cisco and Wholefoods have organizational structures founded on small entrepreneurial groups. In particular, the cited study notes that at Google

> “they focus on multiple smaller workgroups that may have a project manager overseen by committees. They are very independent. The basic concept inspired by the founders is to maintain an entrepreneurial culture.”

The second comparative static relates to the number of employees who can meet and jointly determine their actions.

Corollary 2. *All else equal, risky behavior is more likely at higher k.*

Thus, if a firm values the risky behavior, then it will attempt to create an environment that is conducive to spontaneous interactions between colleagues. Firms sometimes make great efforts to bring employees to the same physical space so as to facilitate informal communication. Tech firms invest in campuses, cafes and hangouts, and the professional services firm KPMG has recently piloted collaborative work areas in some of its offices (Evans, 2015). Organizations can foster informal discussion, increasing k, by sponsoring social activities and corporate retreats, or by establishing consultative working groups to broaden employees’ networks with their co-workers.[11]

The third comparative static arising from Theorem 1 relates to q, the share of an employee’s colleagues with whom he interacts who must take the risky action in order for the employee in question to have a preference for taking the risky action over the safe action.

Corollary 3. *All else equal, risky behavior is less likely at higher q.*

Factors that determine q include the apportionment of reward and blame within the firm when things go right and when things go wrong. If the risky action carries a potential downside and the possibility of blame, then an employee may not want to take this action unless a high proportion of his colleagues do likewise. This corresponds to a high q. Conversely, if management accepts failure as a necessary side-effect of innovation, then q may be relatively low. As Garry Ridge, the CEO of lubricant manufacturer WD-40 says: “Why waste getting old if you can’t get wise? We have no mistakes here, we have learning moments.”[12]

5. Firm structure and design

As a quick glance at any corporate annual report indicates, organizational structures in firms are typically more complex than a single team with everyone working together. In this section we show that hierarchical structures can significantly

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[9] In the two player, two strategy game interpretation described in Footnote 5, $q \leq 1/2$ implies that the Pareto efficient Nash equilibrium is also risk dominant.

[10] This part of the result can be proven for any interaction structure using results from Peski (2010) and Newton (2019). These results relate to a concept of *asymmetry* that is beyond the scope of the current study. Hence we only state and prove the result under the restriction that $N = T_1$.

[11] It is conceivable that the value of k within a firm could vary over time, either due to the actions of managers or because of exogenous changes in the environment. Corollary 2 suggests that employees should be more likely to switch to a risky action following periods when the watercooler is ‘large’ (high k). Social or cultural events might provide a catalyst for informal discussions between employees; the Monday following the Super Bowl or the final game in the World Series might create an opportunity for conversations between employees to start, conversations that can lead onto work-related topics.

[12] “Leadership Lessons From WD-40’s CEO, Garry Ridge” – Forbes Magazine, June 28th, 2011.

affect the actions adopted by different departments/divisions/teams in an organization; the actions of a team depend on the balance of external and internal influence. Teams that are large enough are unaffected by external influence. Specifically, if a team is large enough that its members *cannot* all fit around the watercooler ($|T| > k$), then a similar result to Theorem 1 applies, with the conditions on the inequalities strengthened so that k becomes $k+1$ and $k-2$ becomes $k-3$ in the numerators of the relevant fractions.

Theorem 2. *If $q > 1/2$, then for a given team T, $|T| > k$, in any long run equilibrium X:*

$$
\begin{aligned}
|T| > \tfrac{k+1}{2q-1} &\implies T \subseteq N \setminus X,\\
|T| \le \tfrac{k-3}{2q-1} &\implies T \subseteq X.
\end{aligned}
$$
[13]

Now, consider small teams such that the whole team can meet at the watercooler ($|T| \le k$). If such a team is large enough, it ignores whatever its neighbors are doing and coordinates on the risky action in any long run equilibrium. If the team is smaller still, then its actions in long run equilibrium will depend on those of its neighbors. If no employee in such a team has a neighbor outside of the team who plays the safe action, then all members of the team will play the risky action. However, if even a single member of the team has a neighbor outside of the team who plays the safe action, then members of the team are driven to do likewise. For a set of employees $C \subseteq N$, we let $\triangle_C$ denote the set of employees outside of C who are neighbors of an employee in C, that is $\triangle_C := \bigcup_{i\in C} \triangle_i \setminus C$.

Theorem 3. *For a given team T, $|T| \le k$, in any long run equilibrium X:*

$$
\begin{aligned}
|T| \ge \tfrac{1}{1-q} &\implies T \subseteq X,\\
|T| < \tfrac{1}{1-q},\ \Delta_T \subseteq X &\implies T \subseteq X,\\
|T| < \tfrac{1}{1-q},\ \Delta_T \nsubseteq X &\implies T \subseteq N \setminus X.
\end{aligned}
$$

So coalitional behavior can lead to heterogeneous choices by teams within a firm depending on their size. This effect is not necessarily monotonic. Large teams play the safe action, medium-size teams the risky action. In the absence of neighbors, small teams can easily solve the coordination problem and play the risky action, but the presence of neighbors playing safe is enough incentive for very small teams to choose the safe action.

By exploiting the internal and external pressures that drive these results, a firm owner or manager can manipulate the structure of the firm to achieve desired outcomes. If the manager would like the safe action to be taken by a small workgroup, she will ensure it has strong links to a division that will definitely be playing the safe action – typically a large department.[14] On the other hand, if the manager would like a team to play the risky action – this group could be the firm's research group – this team should be small and either have limited links to the rest of the firm, or only link to other teams that play the risky action.[15]

Entrepreneurs do indeed realize the potential cost of too much communication. As Slone (2013) records, the founder of Amazon.com, Jeff Bezos, has suggested

> "We should be trying to figure out a way for teams to communicate less with each other, not more".

An example of this maxim being put into practice is the Palo Alto Research Center (PARC), established by Xerox to create the innovations of the future. The PARC was deliberately geographically isolated from Xerox's headquarters and existing research laboratory in New York. Given its intended role, it was important that the PARC was separated from the main bureaucratic processes and culture of Xerox, which was conservative and focused on its traditional copier business (Regani, 2005).[16]

[13] For the case $q \le 1/2$, we noted in Footnote 10 that the first part of Remark 1 still applies, so that $X = N$ is a long run equilibrium and $T \subseteq X$. Various conditions for $T \subseteq X$ at all long run equilibria can be determined, but in the interests of brevity and clarity, we omit any such determination here.

[14] There may be times when a firm owner wants a small team to avoid the risky action. A particularly egregious example of this would be when the risky action is a form of shirking or work avoidance that employees can only get away with if a sufficiently high proportion of their colleagues do likewise.

[15] Note that for sets of very small teams connected to one another, long run behavior can be ambiguous. For example, if a firm consists of two teams T_1, T_2, $|T_1|, |T_2| \le k$, $|T_1|, |T_2| < \frac{1}{1-q}$, with an edge between the teams, then both $X = \emptyset$ and $X = N$ are long run equilibria. This multiplicity follows from integer considerations when considering sparse networks and was remarked for individualistic dynamics by Blume (1996).

[16] In 1970 Xerox Inc. established the PARC with the objective that it develop 'future technologies'. In an extremely innovative environment, PARC was responsible for many fundamental computing innovations such as developing the prototype PC, the ethernet, the what-you-see-is-what-you-get computer screen, the graphical user interface, the commercial application of the mouse, page description languages and the laser printer (Kovar, 1999; Regani, 2005). The isolation from the rest of the company was intentional and lay at the heart of the laboratory's success: Charles Geschke, a researcher at PARC from 1972 until 1982 suggested that 'When George Pake ... started the lab, he realized that if he simply put a building next to the research lab in Webster [N.Y.], it would very likely [be] sort of sucked into the kind of research that Xerox had been doing historically' (Kovar, 1999). More recently, in 2002 PARC was formally separated from Xerox and incorporated as a stand-alone research entity, wholly owned by Xerox Inc. (Regani, 2005).

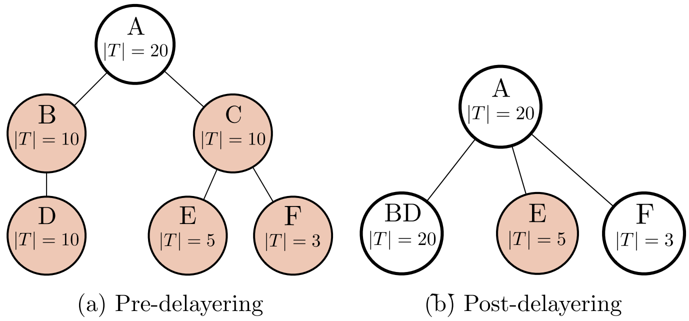

Fig. 4. A line between two teams indicates a link between a member of each team. Teams filled by red play the risky action in long run equilibrium. The remaining teams play the safe action in long run equilibrium.

5.1. Example: delayering

There has been a trend in recent decades for organizations to shorten the lengths of their hierarchies. Moreover, many of these firms have also increased the span of control of the senior management group; there has been a notable increase in the number of individuals who directly report to the CEO. While there can be other drivers for such changes – Guadalupe and Wulf (2010) emphasize the impact of product-market competition from internationalization – here we use Theorems 2 and 3 to look at a possible relationship between watercooler chat and delayering.

For this purpose, let $q = 3/4$ and $k = 8$. Consider the fragment of a corporate hierarchy in Fig. 4(a) that includes six teams labeled A to F. Teams A, B, C and D are all larger than k, meaning that it is not possible for all of the members of these teams to fit around the watercooler at once. Theorem 2 then implies that in any long run equilibrium, Team A will take the safe action and Teams B, C, D will take the risky action. Teams E and F are smaller than k, so that the whole team can fit around the watercooler. Each of these two teams contains a member who is connected to some member of Team C. Team E is of size 5, larger than $1/(1-q) = 4$, so the first statement of Theorem 3 implies that in any long run equilibrium, Team E will take the risky action. Team F, on the other hand, is smaller than $1/(1-q)$, but as it does not have any neighboring teams who take the safe action, the second statement of Theorem 3 implies that it will also play the risky action.

Now, consider the delayering of the firm, leading to the hierarchy in Fig. 4(b). Two things have changed. Teams B and D have been merged into a single team – Team BD – and Team C (middle management) has been eliminated, so that Teams E and F are now directly connected to Team A. These changes affect the culture of the employees in the surviving teams. The merging of B and D, two teams that previously played the risky action, has created Team BD, which Theorem 2 implies will play the safe action in any long run equilibrium. Delayering, in the case of Team BD, has created a work unit of sufficient scale such that it will play the safe action. Moreover, its size makes it immune to external pressures from Head Office in that Team BD would play safe regardless of the action taken by Team A.

The elimination of Team C does not affect Team E, which is large enough that its decision to play the risky action cannot be outweighed by external influence (first statement of Theorem 3). However, Team F is now in direct contact with Head Office, which plays the safe action. It follows from the third statement of Theorem 3 that all employees in Team F will also now play the safe action. The external contact here is crucial as it allows the senior manager to switch the behavior of a small unit.

The analysis of this section shows how delayering can create opportunities for a principal to exercise her influence by creating different sized teams in her organization and linking them to create the right balance between external and internal pressures. In this way, different behavior can be generated in separate parts of an organization, whenever this is a required component of the organization's strategy.

5.2. Example: job rotation

Firms might choose to rotate workers through tasks for a variety of reasons.[17] Here we show that rotation can act as a mechanism to allow the culture of one part of an organization to contage another part of the organization. Specifically, we show how even relatively short spans of time spent working in a small team can shape an employee's behavior. When rotated back to a larger team, the employee will, for a while, retain the behavior to which he became accustomed in the small team. The periodic arrival of such employees is enough to change the long run culture of the large team from safe to risky.

If $q = 9/10$, $k = 5$ and there are two independent teams of size 4 and 8, then these teams play the risky and safe actions respectively in long run equilibrium (by Theorems 3 and 2 respectively). Here, we amend the model so that with probability

[17] Arya and Mittendorf (2004) note that rotation can aid in information collection from agents. Choi and Thum (2003) argue that it can help overcome boredom and reduce corruption.

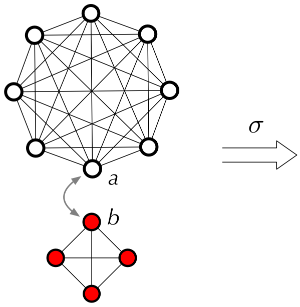

Fig. 5. Two employees exchange places. Filled (red) vertices (employees) are playing the risky action. The remaining employees are playing the safe action.

given by the Poisson rate σ, two employees, one from each team, exchange places. That is, they switch teams whilst leaving their action unchanged. Fig. 5 gives an example of such a switch.

Now, from any state, the state $X = N$ can be reached without random shocks. To see this, consider that the following sequence of events will occur with positive probability. First, all current members of the small team meet at the small team's watercooler, where they will agree to play the risky action. Second, the members of the small team switch places, one by one, with members of the large team. This gives at least four members of the large team who are now playing the risky action. Third, the other four members of the large team meet at the large team's watercooler and agree to switch to the risky action. They are happy to do this as the remaining four members of the team are already playing the risky action. Finally, the new members of the small team all meet at the small team's watercooler and switch to the risky action. We have reached the state $X = N$. All employees are playing the risky action.

Furthermore, from $X = N$, any group of employees who meet at a watercooler will agree to continue playing the risky action. That is, random shocks are required to leave this state. Therefore, when the shock probability ε is low, all employees will take the risky action almost all of the time. That is, $X = N$ is the unique long run equilibrium.

6. Concluding comments

While the boundaries of a firm are defined by its physical assets (Hart and Moore, 1990), social interactions between workers characterize the way things get done in an organization. Workers idly sharing scuttlebutt around the watercooler might seem like the bane of an employer's life, but these informal interactions could engender collective actions that enhance firm productivity. This paper has examined how a manager can tinker with an organization's structure and the physical work environment to harness workers' informal interactions for the firm's advantage.

Although the direct application considered in this paper is the design of a firm, it is clear that adaptive/evolutionary models that incorporate some degree of collective agency should also be applicable to other problems in applied economics. In particular, the implications of collective agency may be of particular importance whenever formal structures in an organization can facilitate informal interactions. This is true for academic conferences, where informal interactions are typically of more import than organized presentations, and also for diplomacy, where formal meetings are accompanied by informal, less structured, discussions in which parties are often more able to find common ground and create shared intentions.

Appendix A. Proofs

Consider the discrete time *skeleton chain* derived from observing the process at $t \in \mathbb{N}_0$. Under both the continuous process and the skeleton chain, from any state X^t, there is strictly positive probability that $X^{t+1} = Y$ for any $Y \subseteq N$, so both processes are positive Harris recurrent and irreducible. Applying Theorem 6.1 of Meyn and Tweedie (1993), the continuous process is ergodic with invariant measure equal to that of the skeleton chain. By finding the stochastically stable states of the skeleton chain we shall thus find the stochastically stable states of the continuous process.

Note that for the skeleton chain, any transition probability is of the order of ε^r for some $r \in \mathbb{N}_0$, with r being equal to the lowest number of random shocks required to effect the transition under the original process. We denote the t-period Markov transition probability from state S to state T by $P^t_{k,q,\varepsilon}(S,T)$. We apply the results of Freidlin and Wentzell (1988) as adapted by Foster and Young (1990); Kandori et al. (1993); Young (1993). For $S, T \subseteq N$, define the resistance $r(S,T)$ so that the most probable transition from state S to state T occurs with probability of order $\varepsilon^{r(S,T)}$.

$$r(S,T) = \min\left\{ r \in \mathbb{R}_+ : \exists t \in \mathbb{N}_+ : \lim_{\varepsilon \to 0} \frac{P^t_{k,q,\varepsilon}(S,T)}{\varepsilon^r} > 0 \right\}.$$

Note that strategic complementarity, the fixed utility of the safe action, and the absence of ties imply that any communicating class $\{S\}$ of the process with $\varepsilon = 0$ is a singleton. Therefore, if $\{S\}$ is such a communicating class, then S is a rest point, $P_{k,q,0}(S,S) = 1$.

Proof of Theorem 1. Consider the communicating classes of the process with $\varepsilon = 0$. $\{N\}$ is trivially a communicating class. $\{\emptyset\}$ is a communicating class if and only if $(k-1)/(|N|-1) < q$, so that no updating set of players can gain from switching to the risky action.

Let $\{S\}$, $S \neq \emptyset$, $S \neq N$, be a communicating class. This implies that when $i \in S$ updates as a singleton (i.e. $C = \{i\}$), he will continue to play the risky action. Hence $q_i(S) \geq q$. However, if $j \notin S$, then $q_j(S) > q_i(S) \geq q$, so when j updates as a singleton (i.e. $C = \{j\}$), he will switch to the risky action. This contradicts S being a communicating class.

So we have at most two communicating classes, $\{N\}$ and possibly $\{\emptyset\}$.

By Young (1993), any long run equilibrium must be part of a communicating class of the chain with $\varepsilon = 0$. Furthermore, if $r(N, \emptyset) > r(\emptyset, N)$, then N is the unique long run equilibrium. If $r(\emptyset, N) > r(N, \emptyset)$, then $\emptyset$ is the unique long run equilibrium.

The number of shocks $r(N, \emptyset)$ required to transit from N to $\emptyset$ is the lowest nonnegative integer satisfying

$$\frac{|N| - 1 - r(N, \emptyset)}{|N| - 1} < q$$

which rearranges to $r(N, \emptyset) > (1 - q)(|N| - 1)$, so

$$r(N, \emptyset) = \lfloor (1 - q)(|N| - 1) + 1 \rfloor > 0. \tag{A.1}$$

The number of shocks $r(N, \emptyset)$ required to transit from $\emptyset$ to N is the lowest nonnegative integer satisfying

$$\frac{(k - 1) + r(\emptyset, N)}{|N| - 1} \geq q$$

which rearranges to $r(\emptyset, N) \geq q\,(|N| - 1) - k + 1$, so

$$r(\emptyset, N) = \max\left\{0, \lceil q\,(|N| - 1) - k + 1 \rceil\right\}. \tag{A.2}$$

As $q > 1/2$, if $|N| - 1 > \frac{k}{2q-1}$, then $k < (|N| - 1)(2q - 1)$ and we have

$$r(\emptyset, N) \underbrace{\geq}_{\text{by (A.2)}} q\,(|N| - 1) - k + 1 \underbrace{>}_{\substack{\text{substituting}\\ \text{for } k}} (1 - q)(|N| - 1) + 1$$
$$\underbrace{\geq}_{\text{by (A.1)}} r(N, \emptyset).$$

Now consider $|N| - 1 \leq \frac{k-2}{2q-1}$, so that $k \geq (|N| - 1)(2q - 1) + 2$. If $r(\emptyset, N) = 0$, then (A.1) implies that $r(\emptyset, N) < r(N, \emptyset)$. If $r(\emptyset, N) > 0$, then

$$r(\emptyset, N) \underbrace{=}_{\text{by (A.2)}} \lceil q\,(|N| - 1) - k + 1 \rceil \underbrace{\leq}_{\substack{\text{substituting}\\ \text{for } k}} \lceil (1 - q)(|N| - 1) - 1 \rceil$$
$$\underbrace{<}_{\substack{\text{by defn}\\ \text{of } \lceil\cdot\rceil \text{ and } \lfloor\cdot\rfloor}} \lfloor (1 - q)(|N| - 1) + 1 \rfloor \underbrace{=}_{\text{by (A.1)}} r(N, \emptyset). \quad \square$$

Proof of Remark 1. If $r(\emptyset, N) = 0$, then as $r(N, \emptyset) > 0$ by (A.1), we have $r(N, \emptyset) > r(\emptyset, N)$.

If $r(\emptyset, N) > 0$, then using (A.1) and (A.2), we have

$$r(N, \emptyset) = \lfloor (1 - q)(|N| - 1) + 1 \rfloor \underbrace{\geq}_{\text{as } q \leq 1/2} \lfloor q(|N| - 1) + 1 \rfloor$$
$$\underbrace{\geq}_{\substack{\text{by defn}\\ \text{of } \lceil\cdot\rceil \text{ and } \lfloor\cdot\rfloor}} \lceil q\,(|N| - 1) \rceil \underbrace{\geq}_{\text{as } k \geq 1} \lceil q\,(|N| - 1) - k + 1 \rceil = r(\emptyset, N),$$

where the third inequality is strict if $k \geq 2$. $\square$

Proof of Theorem 2. For any communicating class $\{X\}$, consider any two employees in the same team, $i, j \in T$. Note that i and j are neighbors and i shares all of his other neighbors, except possibly one, with j (and vice versa). Therefore, it cannot be that $i \in X$ and $j \notin X$, as this would then imply that $q_j(X) \geq q_i(X)$ and as $i \in X$ implies $q_i(X) \geq q$, we have that $q_j(X) \geq q$, so that when j gets the opportunity to update his strategy he will switch to the risky action, contradicting $\{X\}$ being a communicating class. So in any communicating class, and hence in any long run equilibrium, members of the same team play the same action.

Similar manipulation to that in the proof of Theorem 1 gives

$$|T| > \frac{k+1}{2q-1} \implies \min_{Y:T\subseteq N\setminus Y}\ \min_{Z:T\subseteq Z} r(Y,Z) > \max_{Y:T\subseteq Y}\ \min_{Z:T\subseteq N\setminus Z} r(Y,Z)$$
$$|T| \leq \frac{k-3}{2q-1} \implies \min_{Y:T\subseteq Y}\ \min_{Z:T\subseteq N\setminus Z} r(Y,Z) > \max_{Y:T\subseteq N\setminus Y}\ \min_{Z:T\subseteq Z} r(Y,Z)$$

In words, $|T| > {}^{(k+1)}/_{(2q-1)}$ implies that the least resistance in moving from any state at which T plays the safe action to some state at which T plays the risky action is greater than the maximum resistance of any move in the opposite direction. By Freidlin and Wentzell (1988); Young (1993), this implies that at any long run equilibrium X, we have $T \subseteq N \setminus X$. Similarly, $|T| \leq {}^{(k-3)}/_{(2q-1)}$ implies that at any long run equilibrium X, we have $T \subseteq X$. □

Proof of Theorem 3. Consider the chain with $\varepsilon = 0$, starting from a conjectured long run equilibrium state X.

Assume $T \nsubseteq X$. If $|T| \geq {}^{1}/_{(1-q)}$, then ${}^{(|T|-1)}/_{|T|} \geq q$, so when T gets an opportunity to update as a coalition, all members would adopt the risky action. So X is not part of any communicating class of the chain with $\varepsilon = 0$ and is therefore not a long run equilibrium.

Again, assume $T \nsubseteq X$. If $|T| < {}^{1}/_{(1-q)}$ and $\Delta_T \subseteq X$, then when T gets an opportunity to update as a coalition, all members would adopt the risky action. So X cannot be a long run equilibrium.

Assume $T \cap X \neq \emptyset$. If $|T| < {}^{1}/_{(1-q)}$ and $\Delta_T \nsubseteq X$, then there exists $i \in T$ for whom $\Delta_i \setminus T \nsubseteq X$. When T gets an opportunity to update as a coalition, as ${}^{(|T|-1)}/_{|T|} < q$, player i will adopt the safe action. Given this, all remaining $j \in T$ must also adopt the safe action. Consequently, X cannot be a long run equilibrium. □

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