Online Appendix
Rational Inattention and Organizational Focus

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Appendix A contains the proof of Lemma A, which is used to prove Proposition 4 in the paper. Appendix B endogenizes the size of the organization. Appendix C extends the analysis to different models of communication. Appendix D discusses our communication technology and relates it to the literature on Rational Inattention. Appendix E shows that our insights are robust to an alternative model of production that has been widely used in the literature on organizational economics. Appendix F takes the case of tasks that have different coordination costs. Appendix G endogenizes attention capacity. The extensions presented in Appendix E-F-G are developed, for simplicity, for the case of an organization with two agents. Appendix H discusses three examples of organizational change through the lens of our model.

Appendix A: Proof of Lemma A

Lemma A: *There exist* $0 < \bar{\beta}(n) < ... < \bar{\beta}(k+1) < \bar{\beta}(k) < ... < \bar{\beta}(2)$ *such that the optimal organization has:* $k^* = n$ *focal tasks if* $\beta/\phi < \bar{\beta}(n)$, $k^* \in \{2, ..., n-1\}$ *focal tasks if* $\beta/\phi \in (\bar{\beta}(k^*+1), \bar{\beta}(k^*))$, *and* $k^* = 1$ *if* $\beta/\phi > \bar{\beta}(2)$. *Furthermore*

$$\bar{\beta}(k+1) = \frac{1}{n-1}\left[\frac{e^{\frac{\lambda\tau}{k+1}} + ke^{-\frac{\lambda\tau}{k(k+1)}} - (k+1)}{k + e^{-\frac{\lambda\tau}{k}} - (1+k)e^{-\frac{\lambda\tau}{k(k+1)}}}\right]. \tag{13}$$

Proof of Lemma A. Recall that expected payoffs of an organization with k focal tasks is

$$E(\pi\left(\mathbf{q}, \mathbf{t}|\boldsymbol{\theta}\right)) = nP - n\sigma_\theta^2\phi + \sigma_\theta^2\left[\frac{k\phi}{\phi + \beta(n-1)(1 - r(\tau/k))} + \frac{(n-k)\phi}{\phi + \beta(n-1)}\right].$$

Denote by $\gamma = \beta/\phi$. Then, we write

$$E(\pi\left(\mathbf{q}, \mathbf{t}|\boldsymbol{\theta}\right)) = nP - n\sigma_\theta^2\phi + \sigma_\theta^2\left[\frac{k}{1 + \gamma(n-1)(1 - r(\tau/k))} + \frac{(n-k)}{1 + \gamma(n-1)}\right].$$

We obtain that

$$\frac{dE\left[\pi\left(\mathbf{q}, \mathbf{t}|\boldsymbol{\theta}\right)\right]}{dk} = \frac{\lambda\gamma}{(1+\gamma(n-1))k\left(1 + \gamma(n-1)e^{-\frac{\lambda\tau}{k}}\right)^2}\Phi(k, \gamma, \tau, n),$$

where

$$\Phi(k,\gamma,\tau,n) = k\left[1-e^{-\frac{\lambda\tau}{k}}\right]\left[1+\gamma(n-1)e^{-\frac{\lambda\tau}{k}}\right] - \lambda\tau(\gamma(n-1)+1)e^{-\frac{\lambda\tau}{k}},$$

and that

$$\frac{d^2E\left[\pi\left(\mathbf{q},\mathbf{t}|\boldsymbol{\theta}\right)\right]}{dkdk} = -\frac{\lambda^2\gamma(n-1)\tau^2e^{-\frac{\lambda\tau}{k}}}{k^3\left(1+\gamma(n-1)e^{-\frac{\lambda\tau}{k}}\right)^3}\left[1-\gamma(n-1)e^{-\frac{\lambda\tau}{k}}\right].$$

Observation 1. By direct verification, the function $\Phi(k,\gamma,\tau,n)$ is decreasing in γ for all k,τ,n. Note also that the sign of $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$ is the same as the sign of $\Phi(k,\gamma,\tau,n)$.

Denote by $\tilde{\beta}$ the solution to $1-\tilde{\beta}(n-1)e^{-\frac{\lambda\tau}{n}}=0$. Also, denote by $\hat{\beta}$ the solution to $1-\hat{\beta}(n-1)e^{-\lambda\tau}=0$. Since $1-\beta(n-1)e^{-\frac{\lambda\tau}{k}}$ is decreasing in β and decreasing in k, the following observation follows:

Observation 2. (2a) $\tilde{\beta}<\hat{\beta}$ for all τ,n; (2b) If $\gamma<\tilde{\beta}$ then $\frac{d^2E[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dkdk}<0$ for all k; (2c) If $\gamma>\hat{\beta}$ then $\frac{d^2E[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dkdk}>0$ for all k.

We now show that there exists a $\underline{\beta}(\tau,n)>0$ such that for all $\gamma<\underline{\beta}(\tau,n)$ the number of focal tasks is $k=n$. Denote by $\underline{\beta}(\tau,n)$ the solution to $\Phi(n,\underline{\beta}(\tau,n),x,n)=0$. Explicitly,

$$\underline{\beta}(\tau,n) = \frac{n\left(1-e^{-\frac{\lambda\tau}{n}}\right)-\lambda\tau e^{-\frac{\lambda\tau}{n}}}{\lambda\tau-n\left(1-e^{-\frac{\lambda\tau}{n}}\right)}\tilde{\beta}.$$

Observation 3. Direct verification implies (3a) $\underline{\beta}(\tau,n)<\tilde{\beta}$ for all τ,n; (3b) $\underline{\beta}(\tau,n)$ is increasing in τ.

Observation 3a together with observation 2b imply that $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$ is declining in k for all $\gamma<\underline{\beta}(\tau,n)$. So, for all $\gamma<\underline{\beta}(\tau,n)$, the lower value of $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$ is obtained when $k=n$, and, at $k=n$ we have

$$\frac{dE\left[\pi\left(\mathbf{q},\mathbf{t}|\boldsymbol{\theta}\right)\right]}{dk}|_{k=n} = \frac{\gamma}{(1+\gamma(n-1))n\left(1+\gamma(n-1)e^{-\frac{\lambda\tau}{n}}\right)^2}\Phi(n,\gamma,\tau,n)>0,$$

because, by observation 1, $\Phi(n,\gamma,\tau,n)>\Phi(n,\underline{\beta}(\tau,n),\tau,n)$, and, by definition, $\Phi(n,\underline{\beta}(\tau,n),\tau,n)=0$. Hence, for all $\gamma<\underline{\beta}(\tau,n)$ the expected returns of an organization with k focal tasks are increasing in k, which implies that the optimal organization has $k^*=n$.

We now show that there exists a $\bar{\beta}(\tau, n) > \underline{\beta}(\tau, n)$ such that for all $\gamma > \bar{\beta}(\tau, n)$ in the optimal organization the number of focal tasks is $k^* = 1$. Denote by $\bar{\beta}(\tau, n)$ the solution to $\Phi(1, \bar{\beta}(\tau, n), \tau, n) = 0$. Explicitly

$$\bar{\beta}(\tau, n) = \frac{1 - e^{-\lambda\tau} - \lambda\tau e^{-\lambda\tau}}{\lambda\tau - 1 + e^{-\lambda\tau}} \hat{\beta}.$$

Observation 4. Direct verification shows that: 4a. $\tilde{\beta} < \bar{\beta}(\tau, n) < \hat{\beta}$, for all τ and n; 4b. $\bar{\beta}(\tau, n)$ is increasing in τ.

Observation 1 together with $\Phi(1, \bar{\beta}(\tau, n), \tau, n) = 0$ imply that $\Phi(1, \gamma, \tau, n) < 0$ for all $\gamma > \bar{\beta}(\tau, n)$. Similarly, observation 1 together with $\Phi(n, \underline{\beta}(\tau, n), \tau, n) = 0$ and observation 4a, imply that $\Phi(n, \gamma, \tau, n) < 0$ for all $\gamma > \bar{\beta}(\tau, n)$. So, $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$ is negative at $k = 1$ and at $k = n$. Observation 4a and observation 2b implies that $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$ is either first decreasing in k and then increasing in k (when $\gamma \in [\bar{\beta}(\tau, n), \hat{\beta}]$) or it is always increasing in k (when $\gamma > \hat{\beta}]$). Hence, the profits of the organization are decreasing in k for all $\gamma > \bar{\beta}(\tau)$ and therefore the optimal organization has $k^* = 1$.

We now conclude by considering the case where $\gamma \in (\underline{\beta}(\tau, n), \bar{\beta}(\tau, n))$. From the analysis above we infer that the marginal expected profits to k of the organization around $k = 1$ are positive, because $\Phi(1, \gamma, \tau, n) > 0$, and that the marginal expected profits of the organization around $k = n$ are negative, because $\Phi(n, \gamma, \tau, n) < 0$. Furthermore, observation 2b implies that, for all $\gamma \in (\underline{\beta}(\tau, n), \bar{\beta}(\tau, n))$, the marginal expected profits of the organization, $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}$, are either always decreasing in k (when $\gamma \in [\underline{\beta}(\tau, n), \tilde{\beta}]$) or they are first decreasing in k and then increasing in k (when $\gamma \in [\tilde{\beta}, \bar{\beta}(\tau, n)]$). Hence, there exists a unique $k^* \in [1, n]$ such that $\frac{dE[\pi(\mathbf{q},\mathbf{t}|\boldsymbol{\theta})]}{dk}|_{k=k^*} = 0$; such value of k^* is the solution to $\Phi(k^*, \gamma, x, n) = 0$ and, k^* maximizes the expected profit of the organization. Finally, by applying the implicit function theorem, $dk^*/d\gamma < 0$ if and only if $d\Phi(k^*, \gamma, \tau, n)/dk < 0$. Note that this last inequality holds because the fact that there exists a unique k^* in which $\Phi(k^*, \gamma, \tau, n) = 0$ and the fact that $\Phi(1, \gamma, \tau, n) > 0$ and $\Phi(n, \gamma, \tau, n) < 0$, assure that for all $\gamma \in (\underline{\beta}(\tau, n), \bar{\beta}(\tau, n))$ the function $\Phi(k, \gamma, \tau, n)$ is decreasing around k^*.

We have therefore shown that for every $k \in \{1, ..., n-1\}$ there exists a $\beta(k+1) < \beta(k)$ such that: a. if $\gamma = \beta(k+1)$ the optimal organization has $k^* = k+1$; b. if $\gamma \in (\beta(k+1), \beta(k))$ the optimal organization has either $k^* = k$ or $k^* = k+1$, and c. if $\gamma = \beta(k)$ the optimal organization has $k^* = k$.

We now show that for every $k \in \{1, ..., n-1\}$ there exists a unique value of $\gamma \in (\beta(k+1), \beta(k))$, say $\bar{\beta}(k)$, such that at $\gamma = \bar{\beta}(k)$ the expected profit of the organization with k focal tasks is the same as the expected profit of the organization with $k+1$ focal tasks. For brevity define $G(x) = e^{-\frac{\lambda\tau}{x}}$ and denote by $\Delta(k,\gamma)$ the difference between the expected profit generated by $k+1$ focal tasks and the expected profit generated by the organization with k focal tasks. We obtain

$$\Delta(k,\gamma) = \sigma_\theta^2 \left[\frac{k+1}{1+\gamma(n-1)G(k+1)} - \frac{k}{1+\gamma(n-1)G(k)} - \frac{1}{1+\gamma(n-1)} \right].$$

Taking the minimum common denominator, we have that $\Delta(k,\gamma) = 0$ if, and only if,

$$\begin{aligned} (1+\gamma(n-1))\left[(k+1)(1+\gamma(n-1)G(k)) - k(1+\gamma(n-1)G(k+1))\right] - & \\ -[1+\gamma(n-1)G(k)][1+\gamma(n-1)G(k+1)] &= 0. \end{aligned}$$

This is a quadratic equation in γ and therefore there are only two solutions of γ. Moreover, it is immediate to check that $\gamma = 0$ is one of the solution. Hence, there is only one non-zero solution. Simple algebra shows that the non-zero solution is given by expression 13. This completes the proof of Lemma A. ■

Appendix B: Endogenous Organizational Size

We endogenize organizational size n^*. A possible interpretation of our model is that each task corresponds to a different type of product or service that is produced by a multi-product firm. By engaging in multiple tasks, firms can spread out some fixed costs $F > 0$ and realize scope economies (Panzar and Willig, 1981). Doing so, however, increases coordination costs as now more tasks need to be coordinated. We maintain the assumption of our base line model that each agent i has an attention capacity τ to participate in public meetings.[13]

Let $\phi_i = \phi$ for all $i \in \mathcal{N}$ and let $k^*(n)$ is the optimal number of focused tasks given size n (Proposition 2). We assume that pay-offs of an organization of size n are given by

$$\tilde{\Pi}(n) = \Pi(k^*(n)) - F$$

where organizational size is chosen to maximize profits per product-line, i.e.,

$$n^* = \arg\max_n \frac{1}{n} E[\tilde{\Pi}(n)]$$

Our underlying assumption is that firms, whenever profitable, have the option to operate a set of product lines independently as a separate organization. Note that splitting up a single firm, with $n^* = m$ agents participating in one meeting, into two independent firms, each with $n^* = m/2$ agents participating in two different meetings, does not create additional communication capacity. Total agent time

[13] Further, agent i needs to be present in a public meeting with agent j both to learn about agent $j's$ primary action and for agent j to learn about agent $i's$ primary action.

spent in meetings remains $m\tau$.

Management scholars have cited many reasons for the rise of new organizational forms, but there are two prominent lines of explanation. The first is the "increased turbulence" that managers face because of rapid technological changes, deregulation, and globalization (Siggelkow and Rivkin, 2005; Roberts and Saloner, 2013). In our model this corresponds to an increase in the volatility of the environment σ_θ^2.

Proposition 6: *Assume $\phi_i = \phi$ for all $i \in \mathcal{N}$. The optimal organization size n^* is decreasing in σ_θ^2. Furthermore, $k^*(n^*)/n^*$ is increasing in σ_θ^2. If $k^*(n^*) < n^*$, the number of focal tasks is increasing in σ_θ^2.*

As σ_θ^2 increases, so do the incentives to adapt, which in turn bring coordination costs. By narrowing firm scope (reducing n^*), and increasing the number of focused tasks, organizations partially reduce these coordination costs, allowing for a better adaptation. Proposition 6 therefore reflects the common idea that smaller organizations are more "nimble" and "flexible".[14] Note while organizational scope n^* depends on the variance σ_θ^2, the decision on how many tasks to focus given n, that is $k^*(n)$, is independent of σ_θ^2 if n is fixed. Intuitively, an increase in the variance does not change the trade-off between adaptation and coordination, but it does affects the benefits of resolving this trade-off (for example by reducing size). Thus, for a given level of adaptiveness to local shocks α_i, an increase in the variance increases both expected adaptation losses (as primary actions are then, on average, further away from the realized shock) and expected coordination losses (as primary actions are then, on average, further away from the uninformed coordinating actions). The optimal level of adaptiveness, however, is not affected and neither is the optimal level of organizational focus. But since coordination and adaptation losses are larger with a larger σ_θ^2, it pays for the organization to invest more in communication technology (as in online Appendix G) or to reduce organizational size and incur higher fixed costs (as in this Appendix). Note, finally, that while $k^*(n)$ does not depend on the variance σ_θ^2 of shocks, $k^*(n)$ is decreasing in the importance of adaptation to those shocks, ϕ.

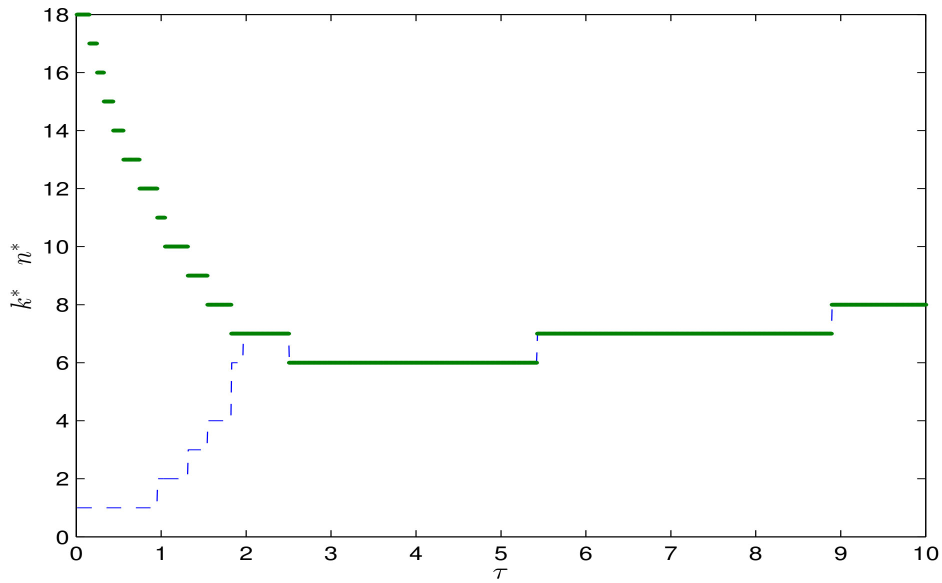
The other prominent line of explanation is improvements in information and communication technology. In our model this corresponds to an increase in $\lambda\tau$. One may conjecture that an increase in the effective communication capacity always results in (weakly) larger organizations. The next proposition states that this is not necessarily the case

Proposition 7: *Organizational size n^* may be decreasing in communication capacity $\lambda\tau$ when $\lambda\tau$ is small.*

[14] Rantakari (2013) obtains a related result in a different setting. He shows how firms operating in more volatile environments decentralize decision-making and reduce task-interdependence, whereas in our model, firms become more balanced and reduce firm scope.

FIGURE 1. **Endogenous organizational size and focus as a function of τ**

Optimal organizational size, n^* (continuous line), and focal tasks, k^* (dashed line), as a function of τ. In this example the maximum number of tasks is $\overline{n} = 18$, $\sigma_\theta^2 = 1$, $\beta = .25$ and $F = 3$.



Intuitively, what restricts organizational size, is the adaptiveness of the organization, not communication capacity. When the communication capacity ($\lambda\tau$) is very limited, organizations often give up on adapting to local shocks, and choose n^* large in order to minimize average fixed costs/maximize economies of scope. As $\lambda\tau$ becomes larger, the organization then uses the extra communication capacity to become more adaptive. Doing so without incurring substantial coordination costs, however, requires reducing organizational size n^*, often substantially. As a result of an increase in $\lambda\tau$ the organization then moves from a "large, rigid bureaucracy" into a "nimble, adaptive democracy". For larger values of $\lambda\tau$, organizational size slowly increases again with τ. Figure 1 illustrates changes in organizational size and on the number of focal tasks in response to changes in communication capacity τ. For simplicity, it is assumed that n^* is constrained to $n^* \leq \overline{n} = 18$. For τ very small, the organization size is set at the maximum, $n^* = \overline{n}$. As communication capacity τ increases, the organization is transformed from a "large, rigid bureaucracy" with eighteen tasks but only one focused task into a "nimble, adaptive democracy" with six tasks which share the attention evenly. For larger values of τ, organizational size slowly increases again with τ and attention remains evenly distributed.

Our model thus predicts that improvements in ICT may result in a shift from large inflexible organizations emphasizing economies of scale and scope, towards smaller, more balanced organizations, which are focused on being adaptive to external shocks and emphasize horizontal communication linkages.[15] This is consistent with recent trends in organization design, as described by Whittington et al. (1999) and Roberts and Saloner (2013). According to our model, only organizations that are already very adaptive, respond to ICT improvements by increasing organizational scope. Alternatively, observed trends toward de-sizing and de-scoping may have been a response to an increased variability in the environment (Proposition 6), for example because of globalization and increased competition (Siggelkow and Rivkin, 2005; Roberts and Saloner, 2013).

Proof of Proposition 6. We prove that the optimal organization size is decreasing in σ_θ^2. Recall that k_{n+1}^* is the optimal number of focal tasks given $n+1$ tasks and k_n^* is the optimal number of focal tasks given n tasks. Then

$$\frac{E[\tilde{\Pi}(n)]}{n} = P - \sigma_\theta^2 - F/n + \frac{1}{n}\left(k_n^* \frac{1}{1+(n-1)\beta e^{-\lambda\tau/k_n^*}} + (n-k_n^*)\frac{1}{1+(n-1)\beta}\right)\sigma_\theta^2 \tag{14}$$

whereas

$$\begin{aligned} \frac{E[\tilde{\Pi}(n+1)]}{n+1} &= P - \sigma_\theta^2 - F/(n+1) \\ &+ \frac{1}{n+1}\left[\frac{k_{n+1}^*}{1+(n-1)\hat{\beta}e^{-\lambda\tau/k_{n+1}^*}} + \frac{(n-k_{n+1}^*)}{1+(n-1)\hat{\beta}} + \frac{1}{1+(n-1)\hat{\beta}}\right]\sigma_\theta^2, \end{aligned} \tag{15}$$

where $\hat{\beta} = \frac{n}{(n-1)}\beta > \beta$.

Suppose first that $k_{n+1}^* \leq n$. Then, Proposition 3 implies that $k_n^* \geq k_{n+1}^*$. To prove the proposition is then sufficient to show that

$$\Delta \equiv \frac{E[\tilde{\Pi}(n+1)]}{n+1} - \frac{E[\tilde{\Pi}(n)]}{n}$$

is decreasing in σ_θ^2. Since $\hat{\beta} > \hat{\beta}e^{-\lambda\tau/k^*}$, a sufficient condition for Δ to be decreasing in σ_θ^2 is that

$$\frac{k_n}{1+(n-1)\beta e^{-\lambda\tau/k_n^*}} + \frac{n-k_n^*}{1+(n-1)\beta} > \frac{k_{n+1}^*}{1+(n-1)\hat{\beta}e^{-\lambda\tau/k_{n+1}^*}} + \frac{n-k_{n+1}^*}{1+(n-1)\hat{\beta}}$$

Since $k_n^* \geq k^*$ and $\hat{\beta} > \beta$,this is indeed satisfied.

[15]This prediction stands in contrast with those of obtained in recent team-theory models that model organizations as information-processing (Bolton and Dewatripont, 1994) or problem-solving institutions (Garicano, 2000; Garicano and Rossi-Hansberg, 2006). While these papers also characterize optimal information flows in organizations, improvements in communication technology unambiguously result in larger and more centralized organizations.

Next, assume that $k^*_{n+1} = n+1$; We then have hat $k^*_n = n$. Hence

$$\Delta = \left[\frac{1}{1+(n-1)\hat{\beta}e^{-\lambda\tau/(n+1)}} - \frac{1}{1+(n-1)\beta e^{-\lambda\tau/n}}\right]\sigma^2_\theta + F/n - F/(n+1).$$

Since $\hat{\beta} > \beta$, it follows that Δ is decreasing in σ^2_θ. The second part of the proposition follows from this result and Proposition 3. ■

Appendix C: Alternative Communication Models

This Appendix extends the result of Proposition 2 and Proposition 3 to alternative models of communication. Without loss of generality we set, hereafter, $\phi = 1$.

C.1. Bilateral communication with aggregate organizational constraints.

We now consider that communication is bilateral and that the constraint is at the organizational level. Formally, the allocation of attention is $\mathbf{t} = \{t_{ji}\}_{ji\in\mathcal{N}}$, where t_{ji} denotes the amount of communication between agent i and agent j about local information θ_i. Let τ be the total communication capacity of the organization. Then, we require that $\mathbf{t}$ satisfies

$$\sum_i \sum_j t_{ij} \leq \tau.$$

We maintain the assumption that $r(t_{ij}) = 1 - e^{-\lambda t_{ij}}$. The following equivalent result obtains:

Result 1. In an optimal organization under bilateral communication and constraint τ, the allocation of attention $\mathbf{t} = \{t_{ji}\}$ satisfies

$$t_{ji} = t^P_i \text{ for all } i, j \in \mathcal{N},$$

where $\mathbf{t}^P = \{t^P_1, ..., t^P_n\}$ is the allocation of attention in an optimal organization under public communication and constraint $\tau^P = \tau/(n-1)$.

Proof of Result 1. The key step for this equivalence result is the proof of the following Lemma

Lemma B: *Consider bilateral communication and constraint τ. In an optimal organization all agents devote the same attention to a particular agent, that is, for all $i \in \mathcal{N}$, $t_{ji} = t_{ki}$ for all $j, k \in \mathcal{N} \setminus \{i\}$.*

Proof of Lemma B. Suppose that $\mathbf{t}$ is optimal and, for a contradiction, assume that there exists some agent i such that $t_{ji} > t_{ki} \geq 0$. Define a new organization

$\mathbf{t}'$, which is the same as $\mathbf{t}$ with the exception that $t'_{ji} = t_{ji} - \epsilon$ and $t'_{ki} = t_{ki} + \epsilon$, for some small and positive ϵ. Using the expression for expected payoffs, it is easy to verify that

$$E\left[\pi\left(\mathbf{q}, \mathbf{t}|\boldsymbol{\theta}\right)\right] - E\left[\pi\left(\mathbf{q}, \mathbf{t}'|\boldsymbol{\theta}\right)\right] \geq 0,$$

if, and only if,

$$e^{-\lambda t'_{ji}} + e^{-\lambda t'_{ki}} \geq e^{-\lambda t_{ji}} + e^{-\lambda t_{ki}}. \tag{16}$$

Since $t'_{ji} = t_{ji} - \epsilon$ and $t'_{ki} = t_{ki} + \epsilon$, after some algebra we obtain that condition 16 is equivalent to

$$e^{-\lambda t_{ki}} \leq e^{-\lambda(t_{ji}-\epsilon)} \Longleftrightarrow t_{ki} \geq t_{ji} - \epsilon,$$

which, for ϵ sufficiently small, contradicts our initial hypothesis that $t_{ji} > t_{ki}$. This completes the proof of Lemma B. ■

Note that under bilateral communication and arbitrary capacity τ, Lemma B implies that the optimal allocation of attention $\mathbf{t}$ satisfies $t_{ji} = t_{li}$ for all $j, l \neq i$. Hence, in the optimal organization every agent $j \neq i$ devotes the same attention to agent i, that is the restriction imposed by public communication. It is immediate to see the relation between τ and τ^P. ■

C.2. Individual Communication Constraints.

So far we have assumed that the communication constraint is determined at the organizational level. Alternatively, each agent may have a limited communication capacity τ^I. Formally, let each agent have access to an individual communication channel, whose finite capacity τ^I can be used to broadcast information to all other agents and/or to process information broadcasted by others. Each agent i then optimally decides on a vector $\mathbf{t}_i = \{t_{i1}, t_{i2}, ..., t_{ii}, ..., t_{in}\}$, where

$$\sum_{j \in N} t_{ij} \leq \tau^I \qquad \forall i \in \mathcal{N}, \tag{17}$$

and where t_{ii} is the capacity devoted to broadcast information about θ_i, and t_{ij} is the capacity devoted to listen to the information broadcasted by agent $j \neq i$. We maintain the assumption that $1 - r(t_{ij}, t_{jj}) = e^{-\lambda \max\{t_{ij}, t_{ii}\}}$ We now proof the following equivalence result, which again implies that the optimal organization is focused on k^* tasks with $k \in \{1, 2, \cdots, n\}$ and that the same comparative statics hold as in Proposition 3.

Result 2. Under individual communication and individual capacity constraint τ^I, in the optimal organization the allocation of attention $\mathbf{t} = \{t_{ij}\}_{i,j}$ satisfies

$$t_{jj} = t_{ij} = t^b_{ij} \qquad \forall i, j \in \mathcal{N}$$

where $\mathbf{t}^b = \{t_{ij}^b\}_{i \neq j}$ is the allocation of attention in the optimal organization under bilateral communication and capacity constraint $\tau = (n-1)\tau^I$.

Proof of Result 2. Consider the case of individual communication with individual capacity constraint τ^I. Suppose that $\mathbf{t}$ is an optimal organization. It is immediate to see that $\mathbf{t}$ satisfies: a. $t_{ji} \leq t_{ii}$ for all $i, j \in \mathcal{N}$ and b. $\sum_j t_{ji} = \tau^I$ for all $ij \in \mathcal{N}$. Now note that if $\mathbf{t}^b$ is an optimal organization under bilateral communication and constraint $\tau = (n-1)\tau^I$, then organization $\mathbf{t}^*$ with $t_{ji}^* = t_{ii}^* = t_{ji}^b$ is a feasible organization under individual communication and satisfies property a. and b. above. We now claim that $\mathbf{t}^*$ is optimal under individual communication and individual capacity constraint τ^I. Suppose there is another organization $\mathbf{t}$ that does strictly better than $\mathbf{t}^*$. First, note that the expected profit of an organization, for a given $\mathbf{t}$, can be written in terms of residual variances as follows

$$E[\pi(\mathbf{t}|\boldsymbol{\theta})] = -n\sigma_\theta^2 + \sum_{i=1}^{n} \frac{\sigma_\theta^2}{\sigma_\theta^2 + \beta(n-1)\sum_{j=1}^{n} \mathsf{RV}(t_{ji}, t_{ii})},$$

where $\mathsf{RV}(t_{ji}, t_{ii}) = \sigma_\theta^2(1 - r(t_{ji}, t_{ii}))$. Second, $\mathbf{t}$ must satisfy property a and property b and therefore $\min\{t_{ji}, t_{ii}\} = t_{ji}$, and so the residual variance that agent j has about task i is $\mathsf{RV}(t_{ji})$. Since $\mathbf{t}$ is strictly better than $\mathbf{t}^*$ is follows that the profile of residual variances $\{\mathsf{RV}(t_{ji})\}_{ji}$ is better than $\{\mathsf{RV}(t_{ji}^*)\}_{ji}$. But then, construct $\hat{\mathbf{t}}^b$ as follows: $\hat{t}_{ji}^b = t_{ji}$. Note that $\hat{\mathbf{t}}^b$ is feasible under bilateral communication and capacity τ. Furthermore since the profile of residual variances $\{\mathsf{RV}(t_{ji})\}_{ji}$ is better than $\{\mathsf{RV}(t_{ji}^*)\}_{ji}$, it must also be true that profile of residual variances $\{\mathsf{RV}(\hat{t}_{ji}^b)\}_{ji}$ is better than $\{\mathsf{RV}(t_{ji}^b)\}_{ji}$, and so $\hat{\mathbf{t}}^b$ must be strictly better than $\mathbf{t}^b$, which contradicts our initial hypothesis that $\mathbf{t}^b$ is optimal. ■

Appendix D: Information Theory

While we posit a specific binary communication technology, this Appendix shows that identical results obtain if communication is noisy instead and, following the literature of Rational Inattention, entropy is used to model the cost of more precise information.

In particular, we now consider that messages m_{ji} and local information θ_i are normally distributed and the attention constraint $\sum_i t_i \leq \tau$ is modelled as a constraint on the total reduction in entropy, as in Information Theory (Cover and Thomas, 1991) and the literature on Rational Inattention (Sims, 2003). This specification leads to the same residual variance that is obtained in the binary communication technology adopted in the paper. Since, in an equilibrium with linear strategies, the expected profits for a given attention allocation $\mathbf{t}$ can be written as a function of the residual variance, identical results obtain with this alternative communication technology. We now develop these arguments formally.

For simplicity, we focus on the two-task case. Let m_i be a message about

θ_i and let $\mathbf{m} = (m_1, m_2)$. The mutual information between $\mathbf{m}$ and $\boldsymbol{\theta}$, denoted by $I(\boldsymbol{\theta}; \mathbf{m})$, equals the average amount by which the observation of $\mathbf{m}$ reduces uncertainty about the state $\boldsymbol{\theta}$, where the ex ante uncertainty is measured by the (differential) *entropy* of $\boldsymbol{\theta}$,

$$H(\boldsymbol{\theta}) = -\int f(\boldsymbol{\theta}) \log f(\boldsymbol{\theta}) d\boldsymbol{\theta},$$

and the uncertainty after observing $\mathbf{m}$ is measured by the corresponding entropy

$$H(\boldsymbol{\theta}|\mathbf{m}) = -\int f(\boldsymbol{\theta}|\mathbf{m}) \log f(\boldsymbol{\theta}|\mathbf{m}) d\boldsymbol{\theta}.$$

Denoting by τ the (Shannon) capacity of the communication channel, the constraint on information conveyed by $\mathbf{m}$ about $\boldsymbol{\theta}$ is given by [16]

$$I(\boldsymbol{\theta}; \mathbf{m}) = H(\boldsymbol{\theta}) - H(\boldsymbol{\theta}|\mathbf{m}) \leq \tau. \tag{18}$$

Following Sims (2003) and the subsequent literature on rational inattention, we assume that θ_1 and θ_2 are (independently) normally distributed, and communicated through a Gaussian communication channel which contaminates its inputs with independent normally distributed noise, e.g., $m_i = \theta_i + \epsilon_i$, where ϵ_i is normally distributed. As a result, also m_1 and m_2 and the conditional distributions $F(\theta_1|m_1)$ and $F(\theta_2|m_2)$ are independently normally distributed. As noted by Sims, Gaussian communication channels minimize the variance of $F(\theta_i|m_i)$ given the constraint (18) on the mutual information between θ_i and m_i. Hence, they maximize the correlation between m_i with θ_i.[17] Given that θ_1 and θ_2 are independently distributed, we have

$$I(\boldsymbol{\theta}; \mathbf{m}) = I(\theta_1; m_1) + I(\theta_2; m_2), \tag{19}$$

where $I(\theta_i; m_i) = H(\theta_i) - H(\theta_i|m_i)$. Moreover, since the entropy of a normal variable with variance σ^2 is given by $\frac{1}{2}\ln(2\pi e \sigma^2)$, we obtain

$$I(\theta_i, m_i) = \frac{1}{2}\left(\ln \sigma_\theta^2 - \ln \mathrm{Var}(\theta_i|m_i)\right). \tag{20}$$

It follows that the constraint (18) on the mutual information between $\boldsymbol{\theta}$ and $\mathbf{m}$

[16] The capacity of a channel is a measure of the maximum data rate that can be reliably transmitted over the channel. Shannon capacity has proven to be an appropriate concept for studying information flows in a variety of disciplines: probability theory, communication theory, computer science, mathematics, statistics, as well as in both portfolio theory and macroeconomics.

[17] This follows from a well known result in information theory that among all distributions with the same level of entropy, the normal distribution minimizes the variance.

can be rewritten as

$$\ln \sigma_\theta^2 - \ln \mathrm{Var}(\theta_1|m_1) + \ln \sigma_\theta^2 - \ln \mathrm{Var}(\theta_2|m_2) \leq 2\tau. \tag{21}$$

We can now re-interpret the *mutual information between m_i and θ_i* as the *attention devoted by the organization to task i*. Denoting $t_1 \equiv I(\theta_1, m_1)$ and $t_2 \equiv I(\theta_2, m_2)$, the constraint on mutual information (18) imposed by the Shannon capacity becomes equivalent to our attention constraint $t_1 + t_2 \leq \tau$.

Using the above formalization, we obtain a tractable expression for $\mathsf{RV}(t_i) \equiv Var(\theta_i|m_i)$. Indeed, from (20) and $t_i \equiv I(\theta_i, m_i)$, we have

$$\ln \mathsf{RV}\,(t_i) = \ln \sigma_\theta^2 - 2t_i, \quad i = 1, 2. \tag{22}$$

or still

$$\mathsf{RV}\,(t_i) = \sigma_\theta^2 e^{-2t_i}, \quad i = 1, 2, \tag{23}$$

where $t_1 + t_2 \leq \tau$. To conclude, it is easy to show that, for a given $\mathbf{t}$, the expected profits in an equilibrium with linear strategies can be written as:

$$E[\pi(\mathbf{t}|\boldsymbol{\theta})] - n\sigma_\theta^2 + \sum_{i=1}^{n} \frac{\phi\sigma_\theta^2}{\phi\sigma_\theta^2 + \beta(n-1)\mathsf{RV}(t_i)}.$$

Appendix E: Technological Trade-offs between Adaptation and Coordination

In this Appendix we show that our insights hold in a model of coordination a la Alonso, Dessein, Matouschek (2008), Rantakari (2008) and Calvó-Armengol, de Martí and Prat (2015). We consider the case for two agents, but everything can be generalized to n agents. In these class of models, instead of having the distinction between primary action and complementary action, each agent chooses one single action. We posit that agent i chooses q_i. Given a particular realization of the string of local information, $\boldsymbol{\theta} = [\theta_1, \theta_2]$, and a choice of actions, $\mathbf{q} = [q_1, q_2]$, the realized profit of the organization is:

$$\pi\,(\mathbf{q}|\boldsymbol{\theta}) = K - \phi(q_1 - \theta_1)^2 - \phi(q_2 - \theta_2)^2 - \beta(q_1 - q_2)^2, \tag{24}$$

where β is some positive constant. Without loss of generality we normalize $\phi = 1$. The communication technology follows the description in our basic model.

Standard computation allows us to derive agents' best replies, for a given network $\mathbf{t} = (t, \tau - t)$. We obtain:

$$q_1 = \frac{1+\beta}{1+2\beta+\beta^2 e^{-\lambda t_1}}\theta_1 + \frac{\beta}{1+2\beta+\beta^2 e^{-\lambda t_2}} E[\theta_2|\mathcal{I}_1] \tag{25}$$

$$q_2 = \frac{1+\beta}{1+2\beta+\beta^2 e^{-\lambda t_2}}\theta_2 + \frac{\beta}{1+2\beta+\beta^2 e^{-\lambda t_1}} E[\theta_1|\mathcal{I}_2] \tag{26}$$

where $E[\theta_2|\mathcal{I}_1]$ is θ_2 if communication is successful, otherwise it equals $\hat{\theta}_2$.

Substituting (25) and (26) into (24) and taking unconditional expectations we find that the problem

$$\max_{\mathbf{t}} E\pi(\mathbf{q}|\boldsymbol{\theta}) \ s.t.\ t_1 + t_2 = \tau$$

is equivalent to

$$\max_{t\in[0,\tau]} \frac{1}{1+2\beta+\beta^2 e^{-\lambda t}} + \frac{1}{1+2\beta+\beta^2 e^{-\lambda(\tau-t)}}$$

where $t = t_1$ and $t_2 = \tau - t$.

It is easy to verify that

$$\frac{\partial E\pi(\mathbf{q}|\boldsymbol{\theta})}{\partial t} > 0 \iff (1+2\beta)^2 - \beta^4 e^{-\lambda\tau} > 0.$$

We then obtain a result that is qualitatively the same as the one stated in Proposition 2 and Proposition 3. For every τ there exists a $\beta(\tau) > 0$, so that for all $\beta < \beta(\tau)$ the optimal organization has $t = \tau/2$, whereas for every $\beta > \beta(\tau)$ the optimal organization has $t = \{0, \tau\}$. Furthermore, $\beta(\tau)$ is increasing in τ.

Appendix F: Asymmetric Coordination Costs

In this appendix we consider tasks that are asymmetric in terms of their potential coordination costs. That is, some tasks impose larger coordination costs (delays, low product quality) should other tasks not take the appropriate coordinating actions. For example, in designing a car, important changes made to how the engine works, may have important consequences for the remainder of the design. Should attention be focused on those highly interdependent tasks? We show that this is not necessarily the case. For conciseness of the argument, we consider the two-task case and set $\phi = 1$.

Let the coordination parameters be β_1 and β_2 for task 1 and 2, respectively. We assume that coordination problems are not trivial, i.e., $\beta_1 > \beta_2 \geq 1$. Define $\beta = \sqrt{\beta_1\beta_2}$, the geometric mean of β_1 and β_2 and consider situations where

$$\beta_1 = \beta\,(1+\epsilon) \qquad \text{and} \qquad \beta_2 = \beta\,(1+\epsilon)^{-1}.$$

The parameter ϵ thus determines the "spread" between the coordination costs across tasks: An increase in $\epsilon > 0$ increases the coordination costs associated with task 1 and decreases that of task 2, leaving the geometric average, a sufficient statistic for how costly lack of coordination is to the organization, unchanged. When $\epsilon = 0$ the case collapses to the one of ex-ante symmetric tasks.

Proposition 8: *There exists* $\top(\beta) > 0$ *:*

1) *If* $\lambda\tau < \top(\beta)$*, the optimal organization is focused on task 2, i.e.,* $(t_1^*, t_2^*) = (0, \tau)$*.*

   If $\lambda\tau \geq \top(\beta)$*, let* $\widehat{\epsilon}$ *be the solution to* $(1+\widehat{\epsilon})^2 e^{-2\tau} = 1$ *:*

   a) *If* $\epsilon < \widehat{\epsilon}$ *then* $\tau > t_1^* > t_2^* > 0$*.*
   b) *If* $\epsilon \geq \widehat{\epsilon}$*, then* $(t_1^*, t_2^*) = (\tau, 0)$*.*

If attention is limited, $\lambda\tau < \top(\beta)$, then all attention is focused on the task which is *least* interdependent: Task 2. The reason is that allocating limited attention to task 1 is essentially not worth it as it would translate into limited adaptation given the large coordination costs the organization would bear. Instead, it is better to provide all attention to task 2 and let task 2 be adaptive. Task 1 is then coordinated by restricting its adaptiveness.

Instead when the attention capacity is larger and the asymmetry ϵ is not too large, both tasks receive attention but task 1 receives more than task 2. Intuitively, if both tasks are allowed to be adaptive, more attention needs to be devoted to that task that is more interdependent. If asymmetries between both tasks are sufficiently large, task 2 may even receive no attention for $\lambda\tau > \top(\beta)$. At the threshold $\lambda\hat{\tau} = \top(\beta)$, the organization then switches from being fully focussed on task 2 to being fully focussed on task 1.

Proof of Proposition 8.

We can express expected profit for a given $\mathbf{t}$ as

$$E[\pi(\mathbf{q}|\boldsymbol{\theta})] = -(1-\alpha_{11})^2\sigma_\theta^2 - (1-\alpha_{22})^2\sigma_\theta^2 - \beta_1(1-r_1)\alpha_{11}^2\sigma_\theta^2 - \beta_2(1-r_2)\alpha_{22}^2\sigma_\theta^2, \tag{27}$$

where $\alpha_{ii} = 1/(1+\beta_i(1-r(t_i)))$. Hence, the organizational problem is to choose $t_1 = t \in [0,\tau]$ to maximize expression (27). We obtain that the profits of the organization are decreasing in t, if, and only if,

$$-[1-\beta_1\beta_2 e^{-\lambda\tau}][\beta_1 e^{-\lambda t} - \beta_2 e^{-\lambda(\tau - t)}] > 0. \tag{28}$$

It is convenient to divide the analysis in two cases. Recall that we are assuming that $\beta > 1+\epsilon$ (which is equivalent of assuming $\beta_2 > \hat{\beta} = 1$).

Case 1. Assume that $\beta_1 e^{-\lambda\tau} - \beta_2 > 0$, or $\epsilon > \widehat{\epsilon}$. This assumption implies that $\beta_1 e^{-\lambda t} - \beta_2 e^{-\lambda(\tau-t)} > 0$ for all $t \in [0,\tau]$. This in turn implies that the objective function is decreasing in t if, and only if,

$$1 - \beta_1\beta_2 e^{-\lambda\tau} < 0 \Longleftrightarrow \lambda\tau < \ln\beta$$

which is always satisfied because $\beta > 1+\epsilon$. So, if $\lambda\tau < \ln\beta$ and $\epsilon > \widehat{\epsilon}$, it is optimal to set $t = 0$ and there is focus on task 2.

Case 2. Assume now that $\beta_1 e^{-\lambda\tau} - \beta_2 < 0$, or $\epsilon < \widehat{\epsilon}$. Since $\beta_1 - \beta_2 e^{-\lambda\tau} > 0$ and since $\beta_1 e^{-\lambda t} - \beta_2 e^{-\lambda(\tau - t)}$ declines in t, it follows that there exists a t^* so that $\beta_1 e^{-\lambda t^*} - \beta_2 e^{-\lambda(\tau - t^*)} = 0$. Indeed, such t^* solves $\beta_1/\beta_2 = e^{-\lambda(\tau - t^*)}/e^{-\lambda t^*}$ and since $\beta_1 > \beta_2$ and $e^{-\lambda t}$ is decreasing in t, it follows that $t^* > \lambda\tau/2$. The next two observations complete the proof:

First, if $1 - \beta_1\beta_2 e^{-\lambda\tau} > 0$, then the objective function is increasing in t for $t \leq t^*$ and it is decreasing in t for all $t > t^*$. Hence, in the optimal organization $t = t^*$. Second, if $1 - \beta_1\beta_2 e^{-\lambda\tau} < 0$, then the objective function is decreasing in t for all $t \leq t^*$ and increasing in t for all $t \geq t^*$. Hence, there are two candidates for the minimum: either $t = 0$ or $t = \tau$. Comparing the two organizations it reveals that since $1 - \beta_1\beta_2 e^{-\lambda\tau} < 0$ the optimal organization has $t = 0$, and so there is focus on task 2. Note also that $1 - \beta_1\beta_2 e^{-\lambda\tau} > 0$ and $\beta_1 e^{-\lambda\tau} - \beta_2 < 0$, are mutually compatible, if and only if, $\beta > 1 + \epsilon$, which holds by assumption. This concludes the proof of Proposition 8. ■

Appendix G: Endogenous Attention Capacity

So far we have taken τ to be a hard constraint in the amount of time agents can devote to communication with each other. In practice this is another margin that organizations can use to improve performance, by, for example, allowing more time for meetings and communication between teams. Equivalently, the organization can increase the effective communication capacity τ, by cross-training and rotating employees, by hiring employee with higher cognitive abilities, or by investing in communication technology. Assume thus that an organization can acquire a capacity τ at a cost $C(\tau)$. $C(\tau)$ represents for example the costs of having team members engaged in communications activities rather than in production. We assume that this cost has the following properties:

$$C(0) = C'(0) = 0 \qquad C'(\tau) > 0 \qquad C''(\tau) \geq 0 \quad \text{and} \quad C'''(\tau) \geq 0.$$

The problem of organizational design is now

$$\max_{\tau, \mathbf{t}} E\pi(\mathbf{q}|\boldsymbol{\theta}) - C(\tau) \qquad \text{subject to} \quad \sum_i t_i \leq \tau. \tag{29}$$

The following proposition characterizes the optimal organization in the case of two ex-ante identical agents. Without loss of generality we set $\phi = 1$.

Proposition 9: *The optimal communication capacity τ^* is increasing in σ_θ^2. Furthermore, there exists $\bar{\sigma}_\theta^2 > \underline{\sigma}_\theta^2 > 0$ such that $t_1^* \in \{0, \tau^*\}$ if $\sigma_\theta^2 \leq \underline{\sigma}_\theta^2$ and $t_1^* = \frac{\tau^*}{2}$ if $\sigma_\theta^2 > \bar{\sigma}_\theta^2$.*

Proof of Proposition 9. We first show that the optimal capacity τ^* is increasing in σ_θ^2 in the focused organization and in the balanced organization. We consider the focused organization first. Recall that the expected profits in the focused organization are

$$E\left[\pi^c\left(\mathbf{q}|\boldsymbol{\theta}\right)\right] = -\beta\sigma_\theta^2\left[\frac{1}{1+\beta}+\frac{e^{-\lambda\tau}}{1+\beta e^{-\lambda\tau}}\right]-C(\tau).$$

Taking the derivative with respect to τ we have

$$\frac{\partial E\left[\pi^c\left(\mathbf{q}|\boldsymbol{\theta}\right)\right]}{\partial\tau} = \frac{\lambda\beta\sigma_\theta^2 e^{-\lambda\tau}}{\left[1+\beta e^{-\lambda\tau}\right]^2}-C'(\tau).$$

We now observe that, since $C'(0)=0$, it follows that $\frac{\partial E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau}|_{\tau=0}>0$, and that, since $C'(\cdot)>0$, it follows that $\frac{\partial E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau}|_{\tau=\infty}<0$. Moreover

$$\frac{\partial^2 E\left[\pi^c\left(\mathbf{q}|\boldsymbol{\theta}\right)\right]}{\partial\tau\partial\tau} = -\left[\frac{\lambda^2\beta\sigma_\theta^2 e^{-\lambda\tau}}{\left[1+\beta e^{-\lambda\tau}\right]^3}\left[1-\beta e^{-\lambda\tau}\right]+C''(\tau)\right].$$

Since $C''(\cdot)\geq 0$, $C'''(\cdot)\geq 0$ and $1-\beta e^{-\lambda\tau}$ is negative for small value of τ (recall that $\beta>\hat{\beta}=1$) and, as τ increases, $1-\beta e^{-\lambda\tau}$ becomes eventually positive, it follows that $\frac{\partial^2 E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau\partial\tau}$ is either negative for all $\tau>0$, or it is positive for small value of τ and negative otherwise. Summarizing, we have shown that the function $\frac{\partial E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau}$ is (i) positive at $\tau=0$, (ii) negative at $\tau=\infty$ and (iii) it is either decreasing in τ or it is first increasing and then decreasing in τ. As a consequence of (i)-(iii) we obtain that the optimal capacity τ^c uniquely solves

$$\frac{\partial E\left[\pi^c\left(\mathbf{q}|\boldsymbol{\theta}\right)\right]}{\partial\tau} = \frac{\lambda\beta\sigma_\theta^2 e^{-\lambda\tau^c}}{\left[1+\beta e^{-\lambda\tau^c}\right]^2}-C'(\tau^c)=0.$$

Since $\frac{\partial E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau}$ is increasing in σ_θ^2 and since, from above, $\frac{\partial^2 E[\pi^c(\mathbf{q}|\boldsymbol{\theta})]}{\partial\tau\partial\tau}|_{\tau=\tau^c}<0$, an application of the implicit function theorem implies that τ^c is an increasing function of σ_θ^2. From investigation of the optimality condition of τ^c and the assumptions that $C'(0)=0$, it follows that $\tau^c\to 0$ as $\sigma_\theta^2\to 0$ and that $\tau^c\to\infty$ as $\sigma_\theta^2\to\infty$.

We now consider the case in which the organization is balanced. The expected profits in the balanced organization are

$$E\left[\pi^d\left(\mathbf{q}|\boldsymbol{\theta}\right)\right] = -\frac{2\beta\sigma_\theta^2 e^{-\frac{\lambda\tau}{2}}}{1+\beta e^{-\frac{\lambda\tau}{2}}}-C(\tau).$$

Taking the derivative with respect to τ we obtain

$$\frac{\partial E\left[\pi^d\left(\mathbf{q}|\boldsymbol{\theta}\right)\right]}{\partial\tau} = \frac{\lambda\beta\sigma_\theta^2 e^{-\frac{\lambda\tau}{2}}}{\left[1+\beta e^{-\frac{\lambda\tau}{2}}\right]^2} - C'(\tau).$$

We can now proceed in the same fashion as in the case for the balanced organization to conclude that the optimal capacity τ^d uniquely solves

$$\frac{\partial E\left[\pi^d\left(\mathbf{q}|\boldsymbol{\theta}\right)\right]}{\partial\tau} = \frac{\lambda\beta\sigma_\theta^2 e^{-\frac{\lambda\tau^d}{2}}}{\left[1+\beta e^{-\frac{\lambda\tau^d}{2}}\right]^2} - C'(\tau^d) = 0,$$

and that τ^d is an increasing function of σ_θ^2, $\tau^d \to 0$ as $\sigma_\theta^2 \to 0$ and $\tau^d \to \infty$ as $\sigma_\theta^2 \to \infty$.

Since the optimal capacity in the focused and balanced organization are both increasing in σ_θ^2 and since the optimal organization is either focused or balanced, it follows that the optimal capacity of the optimal organization is increasing in σ_θ^2.

We now prove the second part of the proposition. First note that for a given common τ

$$\frac{\partial E\left[\pi^c\left(\mathbf{q},\tau|\boldsymbol{\theta}\right)\right]}{\partial\tau} - \frac{\partial E\left[\pi^d\left(\mathbf{q},\tau|\boldsymbol{\theta}\right)\right]}{\partial\tau} > 0,$$

if, and only if,

$$\frac{e^{-\lambda\tau}}{[1+\beta e^{-\lambda\tau}]^2} - \frac{e^{-\frac{\lambda\tau}{2}}}{[1+\beta e^{-\frac{\lambda\tau}{2}}]^2} > 0,$$

and, after plain algebra, this condition is equivalent to

$$-\left[e^{-\frac{\lambda\tau}{2}} - e^{-\lambda\tau}\right]\left[1-\beta^2 e^{-\frac{3\lambda\tau}{2}}\right] > 0 \qquad \Longleftrightarrow \qquad 1-\beta^2 e^{-\frac{3\lambda\tau}{2}} < 0.$$

Since $\tau^c(\sigma_\theta^2)$ is increasing in σ_θ^2 ranging from 0 to ∞, there exists a unique $\hat{\sigma}_\theta^2$ that solves $1-\beta^2 e^{-\frac{3\lambda\tau^c(\hat{\sigma}_\theta^2)}{2}} = 0$. By construction, if $\sigma_\theta^2 = \hat{\sigma}_\theta^2$, then $\tau^c(\hat{\sigma}_\theta^2) = \tau^d(\hat{\sigma}_\theta^2)$. The next observation is used in the rest of the proof.

Observation 1. $\tau^d(\sigma_\theta^2) < \tau^c(\hat{\sigma}_\theta^2)$ if, and only if, $\sigma_\theta^2 < \hat{\sigma}_\theta^2$.

To see this note that since τ^c is increasing in σ_θ^2, it follows that $1-\beta^2 e^{-\frac{3\lambda\tau^c(\hat{\sigma}_\theta^2)}{2}} < 0$ for all $\sigma_\theta^2 < \hat{\sigma}_\theta^2$. Hence, $\frac{\partial E\left[\pi^d(\mathbf{q}|\boldsymbol{\theta})\right]}{\partial\tau}|_{\tau^c(\sigma_\theta^2)} < 0$, which implies that $\tau^d(\sigma_\theta^2) < \tau^c(\sigma_\theta^2)$. Analogously, since τ is increasing in σ_θ^2, it follows that $1-\beta^2 e^{-3\tau^c(\sigma_\theta^2)} > 0$ for all $\sigma_\theta^2 > \hat{\sigma}_\theta^2$. Hence, $\frac{\partial E\left[\pi^d(\mathbf{q}|\boldsymbol{\theta})\right]}{\partial\tau}|_{\tau^c(\sigma_\theta^2)} > 0$, which implies that $\tau^d(\sigma_\theta^2) > \tau^c(\sigma_\theta^2)$.

Define now $\underline{\sigma}_\theta^2$ as the solution to $1-\beta^2 e^{-\lambda\tau^d(\underline{\sigma}_\theta^2)} = 0$ and define $\bar{\sigma}_\theta^2$ be such that $1-\beta^2 e^{-\lambda\tau^c(\bar{\sigma}_\theta^2)} = 0$. We now show that $\underline{\sigma}_\theta^2 > \hat{\sigma}_\theta^2$. By definition of $\hat{\sigma}_\theta^2$ and $\underline{\sigma}_\theta^2$, we have that

$$1-\beta^2 e^{-\frac{3\lambda\tau^d(\hat{\sigma}^2_\theta)}{2}} = 0 = 1-\beta^2 e^{-\lambda\tau^d(\underline{\sigma}^2_\theta)},$$

which implies that $\tau^d(\underline{\sigma}^2_\theta) > \tau^d(\hat{\sigma}^2_\theta)$, and since τ^d is increasing in σ^2_θ it follows that $\underline{\sigma}^2_\theta > \hat{\sigma}^2_\theta$.

We next show that $\bar{\sigma}^2_\theta > \underline{\sigma}^2_\theta$. By definition of $\bar{\sigma}^2_\theta$ and $\underline{\sigma}^2_\theta$ we have that

$$1-\beta^2 e^{-\lambda\tau^d(\underline{\sigma}^2_\theta)} = 0 = 1-\beta^2 e^{-\lambda\tau^c(\bar{\sigma}^2_\theta)},$$

which implies that $\tau^d(\underline{\sigma}^2_\theta) = \tau^c(\bar{\sigma}^2_\theta)$. Since $\underline{\sigma}^2_\theta > \hat{\sigma}^2_\theta$ and since $\tau^d(\sigma^2_\theta) > \tau^c(\sigma^2_\theta)$ for all $\sigma^2_\theta > \hat{\sigma}^2_\theta$, we have that $\tau^d(\underline{\sigma}^2_\theta) > \tau^c(\underline{\sigma}^2_\theta)$. Hence, in order for $\tau^d(\underline{\sigma}^2_\theta) = \tau^c(\bar{\sigma}^2_\theta)$ to hold we must have that $\bar{\sigma}^2_\theta > \underline{\sigma}^2_\theta$.

We now complete the proof of the second part of Proposition 9. If $\sigma^2_\theta \leq \underline{\sigma}^2_\theta$, then $1-\beta^2 e^{-\lambda\tau^d(\sigma^2_\theta)} \leq 0$ and $1-\beta^2 e^{-\lambda\tau^c(\sigma^2_\theta)} < 0$. We know that for all τ such that $1-\beta^2 e^{-\lambda\tau} \leq 0$ the optimal organization is focused. Hence, if $\sigma^2_\theta \leq \underline{\sigma}^2_\theta$ the optimal organization is focused. Finally, if $\sigma^2_\theta \geq \bar{\sigma}^2_\theta$, then $1-\beta^2 e^{-\lambda\tau^c(\sigma^2_\theta)} \geq 0$ and $1-\beta^2 e^{-\lambda\tau^d(\sigma^2_\theta)} > 0$ and therefore it follows that the balanced organization is optimal. ■

From the first part of the Proposition, it pays to invest more in communication capacity when the environment becomes more volatile. Intuitively, the cost of not being adapted is then larger and a better communication capacity allows for better adaptation. From Part 2, a focused organization is optimal in environments for which adaptation is not very important. Intuitively, a focused organizations is optimal when the communication capacity is limited, and the organization does not invest much in communication capacity when adaptation is not very important. Similarly, balanced organizations are optimal when adaptation to the environment is very important, and the organization invests heavily in communication capacity.

Appendix H: Examples of Organizational Change

Management scholars argue that improvements in communication technology, the increased importance of adaptation to consumer needs as well as our better understanding of the principles of management have led to a profound change in the organization of production.[18] There is indeed clear and mounting evidence of organizational change[19] but the causes behind it remain murkier.[20] In our framework several sources of exogenous variation can result in different organizational

[18]Consultants have also embraced the mantra of organizational change encouraging, for instance, the adoption of flatter organizational forms as well as the blurring of traditional hierarchical relations. See, for example, Boston Consulting Group (2006).

[19]In the literature in economics two classic references have become Rajan and Wulf (2006) and Caroli and Van Reenen (2001).

[20]There are though some notable exceptions. For instance, Guadalupe and Wulf (2010) show the causal effect of competition on delayering and broader task allocation.

forms, such as an increase in the importance of adaptation, as measured by ϕ_i, or improvements in communication technology as proxied by either an increase in λ or investments in τ, perhaps driven by a drop in the costs of IT (see Appendix F in the new version of the paper.)

We next describe, briefly, three examples of organizational change and argue that our model helps illuminate the drivers of these changes. The first case discusses organizational changes at Procter & Gamble and, more broadly, global consumer packaged goods firms. The second example studies changes in the apparel-retail industries, which were caused by the interaction of an increased need for adaptation to fashion trends and improvements in IT such as Electronic Data Interchange (EDI). The final example is concerned with a particularly successful innovation in management called Quality Function Deployment (QFD), which is geared towards solving problems of coordination between different functions, such as marketing and engineering, in, for instance, product development and design.

The organization of global consumer packaged good companies

As our first example, we discuss changes in the organization of global consumer packed good (CPG) companies in the last few decades.[21] To make the link with our model concrete, one can think of global CPG companies, such as Nestle, P&G or Unilever, as having two primary and equally important functions: sales and marketing/product development. The sales organization develops the firm's short-term sales strategy and is responsible for adapting the firm's product portfolio to trends in regional markets. The sales team relies on close contacts with the distribution channel for decision-relevant information. The marketing and product development team, in contrast, is responsible for the firm's long-term marketing strategy, and relies on focus groups and market tests to develop and launch new products. In order to be effective, each functional team must be responsive to its task-specific local information and undertake steps to coordinate short-term sales and long-term marketing strategies. For the latter purpose, the head of the sales organization and the head of the marketing organization hold regular conference calls, exchange emails, in addition to face-to-face meetings. Thus, as in our model, both functions require the organization to be responsive to (different) task-specific shocks and both tasks are highly interdependent.

Our model predicts that if organizational attention is scarce, it is optimal to prioritize one of these two functions, even when both are equally important for competitive success. Thus, global consumer good companies should prioritize either global marketing and product development – and dedicate most of the inter-task communication to discuss and coordinate new initiatives in product development or, alternatively, prioritize the regional sales organizations, and spend most of the meetings and communication on how to customize products to local

[21] In this section we draw heavily on HBS case 9-707-519 "Procter & Gamble Organization 2005"

tastes. Trying to excel at both functions, local customization and new product development, is bound to produce an organization which is good at neither. Improvements in communication technology, however, may change this and allow for dual objectives.

Consistent with this prediction, global CPG companies have in the past alternated between architectures that are organized along regional lines, and prioritize local customization, and structures which are organized along product lines, and favor global product development. For example, until recently, P&G used to be organized along regional lines, with global marketing managers having limited power, and each region having its own marketing function directly reporting to regional management. By the late 1990's, however, P&G was lagging behind some of its competitors in product development and new product introductions. In response to this, P&G launched a new organizational architecture, dubbed "Organization 2005." In the new organizational chart, Market Development Organizations (MDO's) responsible for sales and tailoring global strategies to local markets, and Product Divisions, responsible for global marketing initiatives and new product development, would "sit next to each other" in the organizational chart, with no hierarchical reporting relationship between them. According to P&G's legendary CEO, A.G. Lafley, the MDO's were responsible for "the first moment of truth, where the customer sees the product in the store." The product divisions were responsible for "the second moment of truth, where the customer uses the product at home." Rather than having one function reporting to the other, as in the past, coordination in the new organization purely relied on horizontal communication. In fact, "mutual interdependence" became the new moto at P&G, and employees were given intensive training in interpersonal skills and building social networks. After some initial adjustment, the structure met with substantial success, and several of its competitors, such as Unilever, put similar structures into place. Beyond falling behind on competitors, what prompted organizational change (and its widespread imitation) is unclear. A combination of improvements in communication technology and an increase in the importance of adaptation to consumer needs (arguably because of increased global competition) seem to be the most likely drivers.

The apparel industry and lean retailing

The drivers of organizational change are more transparent in our second example: the apparel industry. Apparel is perhaps the quintessential example of a fashion good and apparel retailers compete furiously to match current trends. Forecasting fashion trends though is notoriously hard. As a result, many apparel retailers have recently adopted lean management methods[22] that allows them to avoid the "curse of forecasting" and instead adapt to current trends through the

[22] According to Abernathy et al. (1995) "[T]he term lean retailing ... refers to a cluster of inter-related practices undertaken by retail channels to achieve the objective of matching consumer demand and retail supply.

rapid replenishment of inventories. There was a time though when fashion, at least in some segments, was not as volatile and the need to adapt to fashion trends less acute. Men's fashion is a case in point.

The introduction of the sewing machine, the standardized body-size measurement system and the need to produce military uniforms for the Civil War led to a remarkable revolution in the production of men's clothes. Whereas in 1880 less than half of the men's suits were ready made, by 1920 that had become the norm.[23] Standardization of men's clothes extended to many other pieces of garments such as shirts, which, to use the Model T aphorism, men could buy in any color as long as it was white. Indeed men's white shirts accounted for about 72% of the market in 1962. But the social changes of the postwar period led to a new taste for fashion also amongst men. By 1972, a decade later, white shirts accounted for only 19% of the sales and "fancy shirts," anything that was not white, and sport shirts came to dominate the market.[24] The need to adapt to men's new fashion consciousness put considerable pressure on traditional retailers, which in the case of maladaptation were forced to offer considerable markdowns with the consequent loss in revenue.

Simultaneously, there were considerable advances during this period in communication technology. Two were the innovations that greatly increased the ability to communicate in the apparel business. First the introduction of the Uniform Product Code (UPC; the barcode) in the mid 1970s and its widespread adoption[25] in the 1980s allowed retailers to keep track of the enormous growth of different products (or SKUs, Stock Keeping Units).[26] Second the introduction of the Electronic Data Interchange (EDI) made possible for apparel manufacturers to receive information directly from the point of sales, which transmit information about what is selling or not. Whereas the adoption of UPC is an industrywide phenomenon, EDI requires specific investments by firms to connect directly points of sales to apparel manufacturers.[27]

Our model speaks to these issue as follows. Consider Figure 2. There we show the case of the organization of apparel production, which is comprised of three agents: Headquarters (HQ), where managerial and other decisions are taken, the Shop, in contact with customers, and the Supplier in charge of producing the garments. Traditional retailers are structured as in (a). In this case both the Shop and Supplier direct their attention to HQ, in charge of establishing product design and quality standards to suppliers and supplying the shop directly. Instead the lean retailing model is as in (b). There the company invests in EDI (and the

[23]See Abernathy et al. (1995, p. 180).

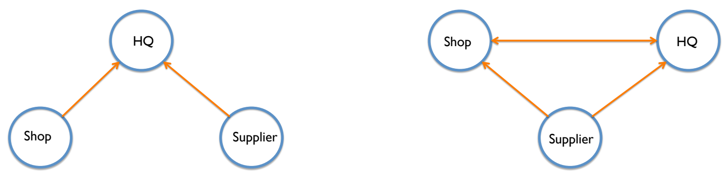
[24]See Pashigian (1988) for a wonderful study of these changes in men's fashion. He attributes these changes to "the dramatic transition toward more casual clothing where there is greater opportunity for individual expression and creativity through product selections."

[25]Barcodes were extended to the products sold by the mass retailers such as Walmart between 1983 and 1987. See Abernathy et al. (2000).

[26]For instance an average food store has gone from offering about 6000 SKUs to customers in the 1960s, to about 25,000 in the early 1990s, to almost 40,000 a decade later; see Abernathy et al. (2000).

[27]For a survey of the adoption of lean practices in the apparel business see Aberthany et al. (1995).

Figure 2. EDI and retailing



(a) Traditional retailer (b) Lean retailer

adoption of the UPC) and now HQ and the Shop both communicate with each other and the supplier directs its attention to both.[28]

There is considerable anecdotal evidence that this is what happened with some of the apparel retailers in the early 1970s. Many of the large department stores failed to meet the increased need for adaptation (an increase in ϕ) which opened the door to new, more specialized, retailers with new lean management techniques and thus more adaptive (such as Esprit, founded in 1968 or The Gap, founded in 1969).

There is also more systematic evidence. Hwang and Weil (1998) look at a sample of 103 apparel business units between 1988 and 1992. Together they comprise 20% of all apparel shipments in the US. They find that the business units that adopted the lean retailing manufacturing practices and transitioned from Figure 2 (a) to (b) invested heavily in EDI. The drop in information costs were of course industry wide. They show that what explains the adoption of these practices was precisely the need for quick replenishment of inventories, which they take as a proxy for the increased need to adapt to customer tastes.[29] In sum, the adoption of these more horizontal communication networks allows retailers to adjust the supply of products offered to consumers to match actual levels of demand for different products: "By using daily demand information arising from point-of-sale data collected at the store-level to govern supply, modern retailers change the flow of information and goods with apparel suppliers." (see Hwang and Weil, 1998, p. 7).

[28]There are also changes in the organization of production in the supplier as documented in the literature on lean retailing. Suppliers supplying lean retailers abandon traditional production methods, the Progressive Bundle System, in favor of methods of production that emphasize team work and job rotation; for these implications the model of Dessein and Santos (2006) is more appropriate.

[29]The measure is constructed by the percentage of sales provided by apparel business units to the retailers on a daily and weekly basis.

An innovation in management: Quality Function Deployment

The adoption of lean manufacturing in the apparel business has the striking characteristic that the short production cycle of garment allows for the direct connection between the customer and the manufacturer. In other sectors such a direct connection between the customer and the manufacturer is simply not feasible given the length of the production cycle. Here different solutions have to be found to the problem of adaptation without direct customer contact. One such famous solution is the Quality Function Deployment (QFD) framework, which tries to integrate customer needs at all stages of the design and production processes.[30] As explained by Hauser and Clausing (1988) "[a] set of planning and communication routines, quality function deployment focuses and coordinates skills within an organization, first to design, then to manufacture and market goods that customers want to purchase and will continue to purchase. The foundation of the house of quality[31] is the belief that products should be designed to reflect customers' desires and tastes - so marketing people, design engineers, and manufacturing staff must work closely together from the time a product is first conceived." This technique, pioneered in the early 70s in Japan,[32] stands in contrast to the traditional phase review process, where each stage in the design process is reviewed by management before it proceeds to the next one. Instead under the QFD framework, marketing, engineering and R & D are supposed to collaborate and communicate actively to integrate customer needs from the start. In terms of our model, QFD can be seen as an innovation in management which makes ex post coordination and communication more effective. As such, it can be interpreted as an increase in λ.

Most relevant with respect to our model, QFD results in clear communication patterns inside the organization that differ from the communications patterns of other organizational arrangements. Griffin and Hauser (1992) compare communication patterns in two new-product teams working on parallel component projects in the automobile industry, one working under QFD and the other subject to the phase review process described above. They find that "QFD enhances communication levels within the core team (marketing, engineering, manufacturing). QFD changes communication patterns from "up-over-down" flows through management to more horizontal routes where core team members communicate

[30] The literature on QFD is simply staggering and the number of cases studied as well. Here we discuss QFD in the context of design or product developments but there are indeed many other applications. For an overwhelming survey of the literature see Chan and Wu (2002).

[31] The house of quality is a particular technique for the implementation of QFD. See Hauser and Clausing (1988) for an example of a house of quality applied to the design of car doors.

[32] According to Chan and Wu (2002), the first application of QFD techniques was in the Kobe Dockyard of Mitsubishi Heavy Industries in 1971, followed shortly afterwards by its adoption by Toyota, first Toyota's Hino Motor in 1975, then in Toyota Autobody in 1977 with impressive results, and finally into the whole Toyota group. In the US, and always according to Chan and Wu (2002), the first recorded case study in QFD was probably in 1986 when Kelsey Hayes used QFD to develop a coolant sensor, "which fulfilled critical customer needs such as "easy-to-add coolant," "easy-to-identify unit," and "provide cap removal instructions," " Other early adopters included 3M, AT&T, Ford, ...

directly with one another." Interestingly the QFD team communicates *less* with members which are external to the core team (whereas in the phase review process everyone communicates through management in each of the stages, including those parties outside the team). Thus, consistent with the model, the adoption of QFD led to a starch dichotomy between two types of tasks: Internal ones engaged in active communication and external ones with limited input into the core activities.

Finally, a hallmark of the house of quality, the main tool to implement QFD, is the identification and prioritization of engineering and production targets in order to adapt to particular customer demands. Indeed, the house of quality features a double entry chart in which customer attributes are matched to engineering targets and are marked to reflect their relative importance, which seems to correspond well with the version of the model where adaptation to particular tasks differ in their importance.[33]

[33] The entries in the house of quality are, for instance, marked with red to denote the critical aspect of meeting targets for a particular feature of the product development or the engineering target. In the example provided by Hauser and Clausing (1988) of the use of the house quality for car door design the importance of meeting particular targets are marked strong and medium positive and strong and medium negative.

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