Biased Managers and Management-by-Exception

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Abstract

This paper studies how the design of organisations should respond to the decision-behaviour of its members. A boundedly rational manager decides on how to use scarce resources to adapt to local shocks. I show conditions and the extent to which a firm's owner should, in response, wish to implement *management-by-exception.* The organisation may wish to fix a rigid plan of action and revisit the decision once extraordinary circumstances are encountered.

This strategy is implemented by controlling the information which the manager receives. In fact, in the absence of explicit costs of information transmission and processing, it may be optimal to not send inherently valuable signals concerning the economy's state to the manager. I show minimal conditions under which this holds true and track how further assumptions can refine the model's predictions.

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1 Introduction

Scholars have long placed the decision behaviour of the individual at the centre of the debate on how to optimally design organisations (see Simon, 1945; March and Simon, 1958; Garicano and Prat, 2011). A primary role of an organisational framework is to take into account its members' limits of cognition and mitigate the resulting challenges in meeting a pre-specified objective. While a host of previous articles has studied desirable institutional responses if the agents operating within face difficulties in processing whether a certain state of the world has been reached (*i.e.* questions of fact), this paper deals with agents that face difficulties in processing how desirable a given state of the world is towards meeting the organisation's goals (*i.e.* questions of value).

A rich literature shows that managers in top positions are biased in their decision-making by irrelevant factors in a way that negatively affect their firm's outcomes. Managers' risk attitudes are shaped by early-life and -career experiences (Malmendier et al., 2011; Dittmar and Duchin, 2016; Schoar and Zuo, 2017; Bernile et al., 2017), they are biased in hiring and wage-setting towards their place of birth (Yonker, 2017), they overvalue salient product characteristics irrespective of actual incentives (Englmaier et al., 2017) and overvalue recent experiences when forming predictions (Gennaioli et al., 2016).

In this paper, I show that biases in judgements of value can make it beneficial to introduce rigidities into the organisational framework, even if the productive setting favours adaptation to changing circumstances. In particular, it may be optimal to formulate a plan-of-action and adhere to it without regard to day-to-day occurrences. Only if something unusual or extreme happens, the plan will be forfeited and the operations re-determined with respect to the productive environment.

The main findings of this study may thus be viewed as a micro-foundation for *management-by-exception*, one of the most prevalent management styles in practice and management science. It has been subject to academic debate for more than a century, with an early treatment of the general idea dating back to Towne (1886). Mackintosh (1978) reports that by the seventies the technique already enjoyed widespread use in a large variety of fields. It has been adopted as one of seven core-principles in the *PRINCE2*-system, the world's most practised project management methodology today.

Management-by-exception has recently received further interest from the literature on air traffic control and specifically the automation of unmanned aircraft. Unmanned aircraft is already widely used in military operations (Hottman and Sortland, 2006) and is "on the verge of taking flight alongside manned aircraft in the National Airspace System" (Liu et al., 2013, p. 424) - within the United States of America. Such aircraft may perform all necessary functions automatically while skilled personnel are ready on the ground to remotely take control over the machine if unusual or dangerous circumstances arise. There appears to be a consensus in the relevant literature that a major bottleneck for a successful introduction of these systems lies in "defining the basis for switching levels of automation support to the human" (Dekker and Woods, 1999, p. 88) and that "an appropriate level of automation is critical to the safety and performance characteristics of [unmanned aircraft systems] design." (Liu et al., 2013, p. 425) It is, in fact, the optimal switching between management-by-plan and management-by-feedback which shall be the main focus of this paper.

Moreover, I claim that the implementation mechanism has some desirable properties. First, it can be installed by solely controlling the flows of information within the organisation. The solution is therefore applicable to settings with limited contractibility and verifiability of its members' actions. Second, not only the adaptive actions on the task-level may be chosen with respect to the local shocks, but also the organisational structure as represented by the communication channels. This is a relative novelty in the literature and, in fact, central to the results of the study. Third and a key insight of the paper, the organisation can meet its goals more effectively by strictly decreasing the flow of information among its members, i. e. time spent in meetings or on writing mails. It is worth noting that this result obtains without assuming explicit costs of communication, coordination across tasks or strategic interaction among members of the organisation. Instead, it is driven by the manager's propensity to "overreact" to unusual events in her environment. Fixing a plan of action on the *ex-ante* optimal strategy (before the shocks are observed) may be better than the outcome determined by the *ex-post* biased decision-making (after the shocks are observed) for a bulk of the organisation's activities. Only for some low probability-high impact events the routine operations become sufficiently unsuitable such that the adaptive qualities of the manager should be recruited.

The article should be read as complementary to the recent literature in team theory and organizational economics in general. A host of studies using a similar functional setting that favours adaptation to local shocks have pointed out the desirability of institutional rigidities. Dessein et al. (2016) find that if there are explicit costs of coordination across tasks, it may be optimal to fix the firm's operations for a large number of its activities and focus attention on a small number of core-competencies. In Powell (2015), static bureaucratic rules prevent managers to engage in costly influence-activities in an attempt to shape the organisation's outcomes towards their personal goals. However, in both these models the communication channels and governance structures, respectively, cannot respond to the realisation of the shock-vector, precluding any chance of flexibility in the organisational framework and to *manage-by-exception* in particular.

Interestingly, the main trade-off in this paper—better information versus a less-biased decision-making—is essentially identical to that of Dessein (2002) while it is arrived at and resolved from two different angles. In Dessein (2002), a principal holds decision rights and decides whether to delegate or simply gather information from an agent that strategically communicates. In my paper, delegation is fixed to a manager who is naive towards the bias in her decision-making and therefore behaves non-strategically. It is then the principal who strategically chooses the amount of information supplied to the manager in order to favourably affect the outcome.

In spirit, this paper is closest to Dessein and Santos (2016) in dealing with optimal organisational responses to managers who are biased in their valuation of the economy's state towards certain tasks. In method, however, this article can best be understood as a team-theoretical, bounded-rationality take on Brocas and Carrillo (2007) where the decision of information-transmission versus -restriction is made with respect to the size of the local shocks instead of iterative revealing of noisy signals. As an interesting sidenote, this article shows that it is possible to relax the strict assumption of information being public by assuming both the distribution of shocks as well as the information-restriction device to be symmetric.

More generally speaking, my findings corroborate articles that are driven by explicit or implicit costs of information transmission or processing such as Sah and Stiglitz (1986), de Clippel et al. (2017) or Calvó-Armengol et al. (2015).

2 The Model

I posit a team-theoretic principal-agent model in which all actors try to maximise a common utility. Decision rights over the firm's production are delegated to the agent (henceforth called the manager, *she*) who is the only one that may directly affect the firm's profits. However, she naively makes mistakes in incorporating information upon observing the state of the economy which introduces a systematic bias into her decision-making and causes her to potentially fail in maximising the firm's profits. The principal (henceforth called the owner, *he*), can influence the actions of the manager by controlling her access to information. In doing so, he faces a trade-off between a better informed manager versus a less-biased decision-making.

I follow much of the relevant literature in assuming a tracking-cost framework as a functional setting (Dessein, 2002; Rantakari, 2008; Calvó-Armengol et al., 2015; Powell, 2015; Dessein et al., 2016). Particularly, a firm's profits π are maximised in a single time period for two tasks indexed with i:

$$\pi \equiv \sum_{i=1}^{2} \left[K_i - \beta_i \cdot |\theta_i - a_i|^{\lambda}\right] \tag{1}$$

The firm incurs costs according to random, task-level shocks θ_i which are real numbers drawn independently from a single distribution with density function $g(\theta_i)$. Throughout the article I will maintain the following assumptions:

Assumption 1. *Let the density function $g(\theta_i)$ be such that for any i*

(i) $E[\theta_i]$ *exists*

(ii) $g(\theta_i)$ *is continuous*

(iii) $g(\theta_i)$ *is symmetric around* 0

(iv) $g(\theta_i)$ *has unbounded support.*

It is the manager's role to choose actions a_1 and a_2 in order to avoid such costs. Each task yields a fix profit K_i which, without loss of generality, is normalised to 0 for both i. The fixed parameters β_1 and β_2 are strictly positive real numbers which may *ex-ante* place a higher importance on one task over the other. λ globally governs the curvature of costs with respect to the intensity of the local shocks, a strictly positive real number. Figure 1 shows the model's timeline.

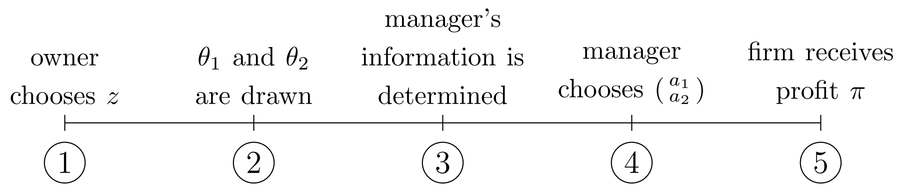

Figure 1: Timeline of the model.

2.1 The Manager

Without intervention by the manager, work for both tasks is carried out doing "business-as-usual" by setting $a_1 = a_2 = E[\theta]$. The manager can then use limited resources within the firm to adapt operations to the productive environment, for example by sending out a task-force or having employees work overtime. For simplicity, I model these adaptations to be binary so that, according to the manager's decision, either a task is perfectly adapted to its local shock or not at all:

$$\begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{cases} \begin{pmatrix} \theta_1 \\ E[\theta] \end{pmatrix} & \text{if the manager adapts task } i = 1 \\ \begin{pmatrix} E[\theta] \\ \theta_2 \end{pmatrix} & \text{if the manager adapts task } i = 2 \end{cases}$$

Hence, the manager must choose between adapting task 1 or adapting task 2. I follow the language of Dessein et al. (2016) in distinguishing two modes of decision-making for the manager: management-by-plan (, *i.e.* without regard to the current state of the economy) and management-by-feedback (, *i.e.* taking the current state of the economy into account).

Management-by-plan

The manager would prefer to adapt task 1 if and only if it yields higher profits than adapting task 2:

$$\begin{aligned} -\beta_2 \cdot |\theta_2|^\lambda &\geq -\beta_1 \cdot |\theta_1|^\lambda \\ \iff \gamma^{\frac{1}{\lambda}} |\theta_2| &\leq |\theta_1| \end{aligned} \tag{2}$$

where I define $\gamma \equiv \frac{\beta_2}{\beta_1}$.

Since under management-by-plan, by definition, the manager makes this decision without observing the local shocks θ_i, she must make her decision on the basis of the expected profits under each action[1].

$$\begin{aligned} \gamma^{\frac{1}{\lambda}} E[|\theta_2|] &\leq E[|\theta_1|] \\ \iff \gamma &\leq 1 \end{aligned} \tag{3}$$

Definition 1. *Without loss of generality, relabel β_1 and β_2 such that $\beta_1 \geq \beta_2$.*

Without observing the state-of-the economy, the manager will always choose to prioritise the task that carries the higher *ex-ante* weight. By construction, this coincides with task 1.

Management-by-feedback

This paper considers managers that incorrectly incorporate information regarding the state of the economy into their decision-making. Specifically, they are biased towards *salient* outcomes. The principle is a well-established psychological phenomenon and has received considerable attention from economics in recent

[1]Although the manager may be conscientious of the fact that her information inflow is restriction, condition 5 ensures that this leaves her expectation of the local shocks unchanged. See also the Section 2.2 for a deeper discussion on possible strategic motivations.

years. It posits that people do not consider events in isolation, but instead understand them in the context of previous averages and/or what they would have expected them to be. Everything odd, unusual or extreme will then involuntarily draw the decision-maker's attention and subsequently receive a disproportionate weight in their thinking (see Taylor and Fiske (1978) for a review).

The highly impactful Ocasio (1997) acknowledged the "saliency of issues and answers" (p. 195) as one of six main mechanisms governing managerial attention allocation. Englmaier et al. (2017) underpins this statement with empirical evidence, showing that bringing a particular product characteristic to the forefront of a manager's mind increases the valuation placed on it irrespective of monetary incentives. Barber and Odean (2008) further corroborate this in the context of stock trading. They find that, among other things, it is "stocks experiencing high abnormal trading volume (...) and stocks with extreme one-day returns" (Barber and Odean, 2008, p. 785) that manage to grab individual investors' attention and are bought disproportionately.

While Kőszegi and Szeidl (2013) formulate a model with a similar focus, I will closely follow Bordalo et al. (2013) in functionally capturing the manager's systematic bias. I identify the reference-level for evaluating the task-level shocks with their expected value $E[\theta_i] = 0$. Given a pair of realisations θ_1 and θ_2, the manager then inflates (deflates) the relative weight of the event that departed more (less) strongly from what was expected by a factor of $\frac{1}{\hat{\delta}}$ ($\hat{\delta}$). Hence, if she manages-by-feedback, she will choose to adapt task $i = 1$ if and only if

$$-\beta_2 \cdot \delta_2(\theta_1, \theta_2) \cdot |\theta_2|^\lambda \geq -\beta_1 \cdot \delta_1(\theta_1, \theta_2) \cdot |\theta_1|^\lambda \tag{4}$$

where

$$\delta_i(\theta_1, \theta_2) = \begin{cases} \hat{\delta} & \text{if } |\theta_i - E[\theta_i]| < |\theta_{-i} - E[\theta_{-i}]| \iff |\theta_i| < |\theta_{-i}| \\ 1 & \text{if } |\theta_i - E[\theta_i]| > |\theta_{-i} - E[\theta_{-i}]| \iff |\theta_i| > |\theta_{-i}| \end{cases}$$

where $0 < \hat{\delta} < 1$.

It is important to note that I assume the manager to be naive towards this bias, meaning that she is perfectly unaware of it and treats her subjective observations as truthful representations of the objective world.

2.2 The Owner

The owner cannot directly influence the profits of the firm. He can, however, affect the decision-making of the manager by purposefully controlling the amount of information available to the manager. Particularly, he anticipates that, driven by her bias towards salient outcomes, the manager will too often choose to adapt task

$i = 2$ if she manages-by-feedback. Whenever this leads to a failure in maximising the firm's profits, the owner can increase the firm's profits by restricting all information inflow to the manager and, thus, prompting her to manage-by-plan. On the other hand, categorically cutting the manager off all information would obviate her possibility to mitigate large costs for the *ex-ante* less-incentivised task when unusually extreme conditions arise. The owner must thus find an optimal switching point based on the local shocks θ_1 and θ_2 between management-by-plan and management-by-feedback.

Arguably, a natural way to do so is to *manage-by-exception*: for moderate realisations of the economy's state the manager receives no information and business is carried out by a rigid plan. Only when sufficiently extreme or unusual events occur, the plan will be forfeited and a meeting called in where the manager is briefed on the developments. Management will then be done by feedback. I will first present how this mechanism is captured functionally and then follow this up with a critical discussion on its feasibility and as well as key motivations in choices of modelling.

I express the actions of the owner by the real number $z \in [0, \infty)$ he can choose freely over the feasible support. If then the realisation of a local shock θ_i for any of the two tasks deviates by more than z from its expected value $E[\theta_i] = 0$, the manager will observe both θ_1 and θ_2. Whenever both shocks stay within a range of z around their expected levels, the manager will not receive any information. The mechanism and the corresponding choices by the manager are summarised in Figure 2. If $z = 0$, then the manager always operates under full information and no rigidities are introduced into the organisational framework. For all other cases, I shall make the following statement.

Definition 2. *Whenever the owner chooses any strictly positive value for z, the firm implements management-by-exception.*

Although the owner can restrict the manager's access to information, it is important that he cannot fabricate or misrepresent it. Otherwise, the owner could anticipate the manager's bias and present the information in exactly such a way that the decision-bias and report-distortion would cancel each other out. I follow Milgrom and Roberts (1986) by assuming that any information the manager receives is freely verifiable and/or there are sufficient penalties for lying. Although the information itself is correct, the Rao-Blackwell-theorem is not applicable in my context, since the manager does not form her conditional expectation correctly. In fact, in accordance with the theorem, any preferences on the part of the owner for information restriction will hinge on the presence of a bias (see Proposition 1).

The symmetry of the information restriction device around 0 mirrors the symmetry of the profit function. Furthermore, the level of information restriction is symmetric across both tasks i. This ensures that not receiving any information

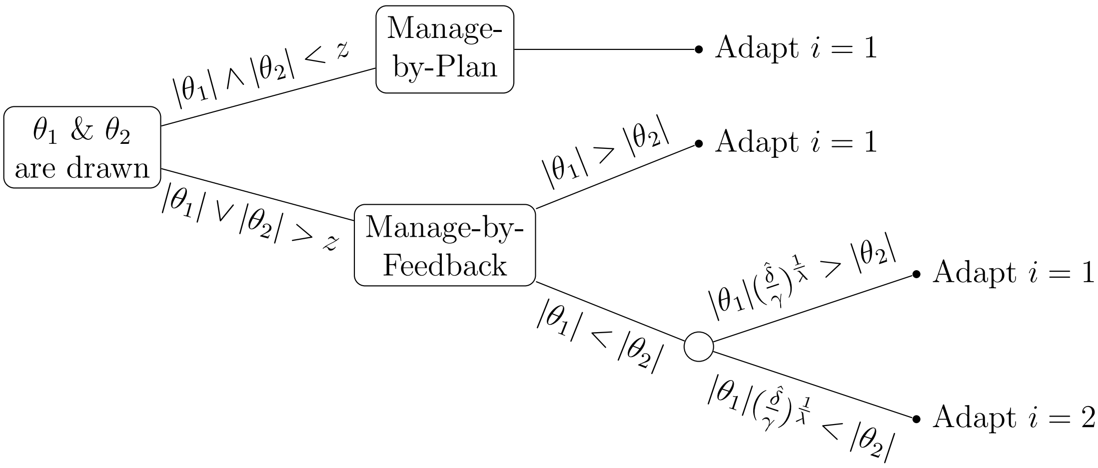

Figure 2: *Management-by-exception* implemented by flow of information. Under "normal" conditions, the manager adheres to the *ex-ante* optimal plan without regard to the state of the economy. If sufficiently unusual events occur, a briefing is called and the firm is managed by feedback.

does not favour one of the manager's alternatives over the other. In fact, the expected value of any θ_i conditional on z equals its unconditional expectation for any z:

$$E[\theta_i|z] = E[\theta_i] \quad \forall z, \theta_i \quad \forall i \tag{5}$$

Note that in this context the manager also has no incentive to behave strategically. First, she is naive towards her own decision-bias. She will thus interpret any attempts of the owner to restrict her information as a trembling-hand strategy. Second, any threats she might make in order to categorically ensure full information are incredible due to the one-shot nature of the game. If she does not receive information regarding the task-level shocks, her unconditional expectation always remains her best bet.

Given the choice correspondence depicted in Figure 2, I can express the expected profit as a tractable function of z. Due to the symmetry with respect to θ_1 and θ_2 of both the profit and the density function $g(\,\cdot\,)$ around 0, the bounds of the integrals can be mirrored arbitrarily around both θ_i-axes. We can thus restrict the focus of the investigation to positive values of θ_1 and θ_2. I arrive at the following expression:

$$\pi(z) = 4 \cdot \int_0^\infty \int_0^{max\{\left(\frac{\hat{\delta}}{\gamma}\right)^{\frac{1}{\lambda}} \cdot \theta_1, \theta_1\}} g(\theta_1) \cdot g(\theta_2) \cdot (-\beta_2 \theta_2^\lambda)\, \mathrm{d}\theta_2\, \mathrm{d}\theta_1$$
$$+4 \cdot \int_0^\infty \int_{max\{\left(\frac{\hat{\delta}}{\gamma}\right)^{\frac{1}{\lambda}} \cdot \theta_1, \theta_1\}}^\infty g(\theta_1) \cdot g(\theta_2) \cdot (-\beta_1 \theta_1^\lambda)\, \mathrm{d}\theta_2\, \mathrm{d}\theta_1$$
$$+4 \cdot \int_0^{min\{\left(\frac{\gamma}{\hat{\delta}}\right)^{\frac{1}{\lambda}} \cdot z, z\}} \int_{max\{\left(\frac{\hat{\delta}}{\gamma}\right)^{\frac{1}{\lambda}} \cdot \theta_1, \theta_1\}}^{z} g(\theta_1) \cdot g(\theta_2) \cdot (\beta_1 \theta_1^\lambda - \beta_2 \theta_2^\lambda)\, \mathrm{d}\theta_2\, \mathrm{d}\theta_1$$

As Figure 2 shows, the manager only chooses to adapt $i = 2$ if she manages-by-feedback and both $|\theta_1| < |\theta_2|$ and $|\theta_1|(\frac{\hat{\delta}}{\gamma})^{\frac{1}{\lambda}} < |\theta_2|$ hold. Of the latter two conditions, only one can be binding at any given time. For the sake of analytical simplicity, I can therefore replace the $min\{\cdot\}$- and $max\{\cdot\}$-operator by substituting the $\hat{\delta}$ in the expression above with the following parameter:

Definition 3. $\delta := max\{\gamma, \hat{\delta}\}$

Importantly, values for $\hat{\delta}$ lower than γ are not excluded from the analysis, but simply do not have any effect on it. I can then take the derivative of $\pi(z)$ with respect to z. Applying Lebniz' Rule of Integration twice yields the following expression of the profit function's slope with respect to the strength of information restriction:

$$\frac{\partial \pi(z)}{\partial z} = 4 \cdot g(z) \cdot \int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} g(\theta_1) \cdot (\beta_1 \theta_1^\lambda - \beta_2 z^\lambda)\, \mathrm{d}\theta_1 \tag{6}$$

3 Management-by-Exception as a Dominant Strategy

In this section, I will show minimal conditions under which the owner will prefer to manage the firm by exception.[2] Particularly, this is the case whenever choosing not to restrict the manager's information at all, and hence to fully manage the firm by feedback, is a strictly dominated alternative for the owner. Using the parsimonious assumptions placed on the distribution of the task-level shocks so far, I derive conditions with respect to the model's deep parameters $\widehat{\delta}, \gamma, \lambda$ under which this holds.

[2]The conception and formulation of this proof has greatly benefited from extensive discussions with Bram Driesen.

First, it is helpful to establish some properties of the following function:

$$k(z) \equiv \frac{z \cdot g((\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z)}{\int_0^{(\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1} \tag{7}$$

defined on the domain $z \in (0, \infty)$.

Lemma 1. *The function* k

(i) is continuous.

(ii) satisfies $\lim_{z\to 0} k(z) = \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \geq 1$.

Proof. (i) As all of z, $g(z)$ and $\int_0^{(\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1$ are continuous functions everywhere, by the Combination Theorem for Continuous Functions it holds that $k(z)$ is also continuous everywhere.

(ii) As $k(0) = \frac{0}{0}$ and both its numerator and denominator are differentiable everywhere, l'Hôspital's rule may be applied.

$$\lim_{z\to 0} k(z) = \lim_{z\to 0} \frac{\frac{\partial}{\partial z}\left[z \cdot g((\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z)\right]}{\frac{\partial}{\partial z}\left[\int_0^{(\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1\right]} = \lim_{z\to 0} (\frac{\delta}{\gamma})^{\frac{1}{\lambda}} + z \cdot \frac{g'\left((\frac{\gamma}{\delta})^{\frac{1}{\lambda}} \cdot z\right)}{g\left((\frac{\gamma}{\delta})^{\frac{1}{\lambda}} \cdot z\right)} = \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \tag{8}$$

Because of Definition 3 it must hold that $\left(\frac{\delta}{\gamma}\right) \geq 1$. Since $\lambda > 0$, we must have that $\lim_{z\to 0} k(z) \geq 1$. □

Before proceeding, note that as $4 \cdot g(z) > 0$ for all z, $\frac{\partial \pi}{\partial z} \geq 0$ if and only if

$$f(z) := \int_0^{(\frac{\gamma}{\delta})^{\frac{1}{\lambda}} z} g(\theta_1) \cdot (\beta_1 y_1^\lambda - \beta_2 z^\lambda)\,\mathrm{d}\theta_1 \geq 0 \tag{9}$$

Characterising $f(z)$ is thus equivalent to characterising the gradient of the profit function.

Lemma 2. *For* $z > 0$ *and* $1 > \gamma > 0$, $f'(z) \geq 0$ *if and only if* $k(z) \geq \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$.

Proof. Differentiating $f(z)$ with respect to z yields

$$f'(z) = \left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} \cdot g\left(\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} \cdot z\right) \cdot z^{\lambda}\left(\beta_1\left(\frac{\gamma}{\delta}\right) - \beta_2\right) - \beta_2 \lambda z^{\lambda-1} \cdot \int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1 \tag{10}$$

Then for $z > 0$ and $1 > \gamma > 0$, setting $f'(z) \geq 0$ and rearranging yields the desired condition. □

Before deriving the main conclusions of this section, it is helpful to make two observations. First, by an application of the Combination Theorem for Continuous Functions, the slope of the profit function is continuous at all $z \in [0, \infty)$. Hence, although the function $k(z)$ is not defined at $z = 0$ itself, the function of main interest $\frac{\partial \pi}{\partial z}$ on which inferences are made is defined and well-behaved at this point. Second, note that $\frac{\partial \pi}{\partial z}|_{z=0} = 0$ for all feasible settings. Therefore I can state that if the slope of the profit function increases when increasing z from 0, it becomes positive. In this case, expected profits also rise by increasing z from $z = 0$, rendering $z = 0$ a dominated strategy. Using the insights from Lemma 1 and Lemma 2, I now derive conditions where this holds true.

Proposition 1. *For all distributions of the task-level shocks θ_1 and θ_2 satisfying Assumption 1 it holds that*

- *not implementing management-by-exception is a strictly dominated alternative whenever $\lambda \cdot \frac{\delta}{1-\delta} < 1$. Starting from $z = 0$, the owner can increase expected profits by raising z.*
- *Management-by-exception can only be desirable when there is a bias in manager's decision-making.*
- *Ceteris paribus, a stronger bias in the manager's decision making (lower $\widehat{\delta}$), a stronger polarisation of ex-ante importances across the manager's tasks (lower γ) and a less concave profit function (lower λ) increase the chance of not managing-by-exception being dominated.*

Proof. Recall that by Lemma 1 *(ii)* $\lim_{z \to 0} k(z) = \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}}$. When $z \to 0$ it then holds that $k(z) > \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ if and only if $1 > \lambda \cdot \frac{\delta}{1-\delta}$. Due to the parsimonious assumptions placed on $g(\,\cdot\,)$ so far, not much can be said about the behaviour of $k(z)$ as z increases. Assume, however, that at $\tilde{z}$ it holds that $k(\tilde{z}) = \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$, where $\tilde{z}$ may be arbitrarily large. If then $1 > \lambda \cdot \frac{\delta}{1-\delta}$ holds with strict inequality and since by Lemma 1 *(i)* $k(z)$ is continuous, there must be a range $(0, \tilde{z})$ with some strictly positive length where it also holds that $k(z) > \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$. By Lemma 2, this also implies that $f'(z) > 0$ for the entire range. Because $\frac{\partial \pi}{\partial z}|_{z=0} = 0$, this further implies that $\frac{\partial \pi}{\partial z} > 0$ for all $z \in (0, \tilde{z})$. In this case, starting from $z = 0$ the owner can then increase expected profits by increasing z up to $\tilde{z}$, rendering $z = 0$ a strictly dominated strategy for the owner. If, on the other hand, there should exist no $\tilde{z}$ such that $k(\tilde{z}) = \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ (still assuming that $1 > \lambda \cdot \frac{\delta}{1-\delta}$), then $k(z) > \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ for all z and all $z > 0$ are better than $z = 0$. Therefore, if $1 > \lambda \cdot \frac{\delta}{1-\delta}$ then not implementing management-by-exception to any degree by choosing $z = 0$ is a strictly dominated strategy.

Since, in this paper, the manager's decision-bias is the sole driver for the owner's motivation to introduce rigidities into the institutional framework, management-by-exception can never be desirable when no such bias exists. In fact, in this case the manager correctly incorporates information and the Rao-Blackwell-theorem must apply again, precluding any motivation to optimally restrict information. It is easy to verify this. By Lemma 2, $f(z)$ and thus $\frac{\partial \pi}{\partial z}$ decreases if and only if $k(z) < \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$. If then the manager's decision bias vanishes as $\widehat{\delta} \to 1$, the right-hand side goes to ∞ and the inequality must hold for all z. Coupled again with the insight that $\frac{\partial \pi}{\partial z}|_{z=0} = 0$, this implies that in this case $\frac{\partial \pi}{\partial z} < 0$ for all z and that the owner can increase expected profits by decreasing z from all strictly positive levels.

Finally, the comparative statics results can be gained from the dominance-condition. Not implementing management-by-exception can be shown to be a strictly dominated option for the owner whenever $\lambda \cdot \frac{\delta}{1-\delta} < 1$. This is more likely to hold if λ and δ decrease. Recall, however, that by Definition 3 δ is bounded from below by the maximum of the parameters $\widehat{\delta}$ and γ. Hence, a decrease in both of these parameters makes it more likely for not implementing management-by-exception to be dominated. □

Although it is possible to derive conditions for the qualitative desirability of management-by-exception for distributions of the task-level shocks satisfying Assumption 1, much must remain unexplored at this level of generality. It is unclear whether an optimal mixture between *management-by-plan* and *management-by-feedback* exists, how much rigidity is healthy for an organisation and what exactly constitutes an "exception". In the following section I will show that such questions can, in fact, be answered if one is willing to place further restrictions on the distribution $g(\,\cdot\,)$ of the shocks θ_i.

4 Existence and Uniqueness of Optimal Management-by-Exception

In the previous section I have derived conditions under which implementing management-by-exception is a desirable strategy from the viewpoint of the owner. While the substantial attention the management-technique has received appears to agree with this sentiment, central questions need to be addressed before the theory can be put into practice. As (Dekker and Woods, 1999, p. 88) put it: *"What is an exception?"*

In this section, I will show that this question can be answered precisely if further restrictions are placed on the distribution of the task-level shocks $g(\,\cdot\,)$. Particularly, for the remainder of the article I assume that θ_1 and θ_2 are independently drawn from a standard normal distribution:

Assumption 2. *Let*

$$g(\theta_i) \equiv \frac{1}{\sqrt{2\pi}} e^{\frac{-\theta_i^2}{2}} \equiv \phi(\theta_i) \quad \forall i \tag{11}$$

As this assumption constitutes a special case of the previous ones placed on the distribution of the task-level shocks (Assumption 1), all previous results still obtain under the current setting. However, it is now possible to derive additional properties of the function $k(z)$ (see Equation (7)).

Lemma 3. *The function k*

(i) is continuous.

(ii) satisfies $\lim_{z\to 0} k(z) = \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \geq 1$.

(iii) satisfies $\lim_{z\to\infty} k(z) = 0$.

(iv) is strictly decreasing in z.

Proof. (*i*) See Lemma 1.

(*ii*) See Lemma 1.

(*iii*) To show the desired result, I determine the limits of the numerator and denominator of $k(z)$ individually. For the denominator, note that because of symmetry of $\phi(\,\cdot\,)$ coupled with the fact that $\phi(\,\cdot\,)$ is a density function, it must hold that $\int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} \phi(\theta_i)\,\mathrm{d}\theta_i = \frac{1}{2} > 0$.

For the numerator, first note that it must hold that $\lim_{z\to\infty} \int_0^z \phi(\theta_i)\theta_i\,\mathrm{d}\theta_i < \infty$, since by symmetry of $\phi(\,\cdot\,)$ (Assumption 1 *(iii)*) we would otherwise also have that $\lim_{z\to-\infty}\int_z^0 \phi(\theta_i)\theta_i \,\mathrm{d}\theta_i = -\infty$. In that case, however, $E[\theta_i]$ would not exist, contradicting Assumption 1 *(i)*.

With this in mind, I will proof the desired result by contradiction, assuming that $\lim_{z\to\infty} k(z) = C > 0$ where C is some finite, strictly positive constant. Then for all $\varepsilon > 0$, there exists a positive number M such that for all $\theta_i > M$ it holds that $|\phi(\theta_i)\cdot\theta_i - C| < \varepsilon$. Therefore, for all $\theta_i > M$ it must also hold that $C - \varepsilon < \phi(\theta_i)\cdot\theta_i < C + \varepsilon$. However, then for all $\varepsilon < C$ we would also have that

$$\infty = \int_M^\infty C - \varepsilon \,\mathrm{d}\theta_i < \int_M^\infty \phi(\theta_i)\theta_i \,\mathrm{d}\theta_i < \int_0^\infty \phi(\theta_i)\theta_i \,\mathrm{d}\theta_i$$

which contradicts the initial finding. As C cannot be negative, I conclude that it must hold that $C = 0$.

Combining the two insights, I conclude that

$$\lim_{z\to\infty} k(z) = \frac{0}{\frac{1}{2}} = 0 \tag{12}$$

(iv) Define the function

$$l(z) := \left(\int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} \phi(\theta_1)\,\mathrm{d}\theta_1\right)\cdot\left(1 - \left(\frac{\gamma}{\delta}\right)^{\frac{2}{\lambda}}\cdot z^2\right) - z\cdot\phi\left(\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z\right)\cdot\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} \tag{13}$$

Note that $l(0) = 0$ and $l'(z) = -2z\cdot\left(\frac{\gamma}{\delta}\right)^{\frac{2}{\lambda}}\cdot\left(\int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z}\phi(\theta_1)\,\mathrm{d}\theta_1\right) < 0$ for all $z > 0$. Hence, it must hold that $l(z) < 0$ for all $z > 0$.

Differentiating $k(z)$ with respect to z yields:

$$k'(z) = \frac{l(z)\phi\left(\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z\right)}{\left(\int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1\right)^2} \tag{14}$$

Because $\phi\left(\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z\right) > 0$, $\left(\int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} g(\theta_1)\,\mathrm{d}\theta_1\right)^2 > 0$ and $l(z) < 0$ for all $z > 0$, it holds that $k'(z) < 0$ for all $z > 0$. □

Given these additional insights regarding the function $k(z)$, I can state the following result. Importantly, since I am discussing a special case of the general setting from Section 3, all results from Proposition 1 continue to hold.

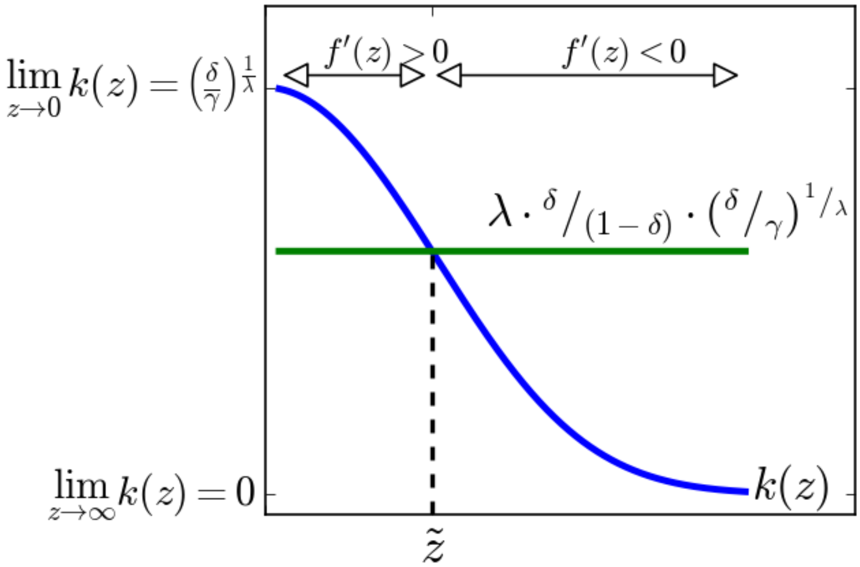

Figure 3: Illustration of findings from Lemma 2 and Lemma 3.

Proposition 2. *If the task-level shocks θ_1 and θ_2 are drawn from a standard normal distribution, there exists a uniquely optimal level of management-by-exception. For each possible productive environment, the owner determines which events constitute an "exception" determining whether any given situation will be dealt with via management-by-plan or management-by-feedback.*

Proof. The proof builds on the findings from Lemma 2 and Lemma 3, which are illustrated in Figure 3. It follows an intermediate-value-theorem-type of argument, relating $\lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ and $k(z)$ (see Equation (7)). Since the former is a constant and the latter, by Lemma 3 *(i)* and *(iv)*, is continuous and strictly decreasing in z, there can either be no crossing or exactly one crossing between the two. I will discuss both possible cases in order.

As in Proposition 1, when $z \to 0$, by Lemma 3 *(ii)*, $k(z) < \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ if and only if $\lambda \cdot \frac{\delta}{1-\delta} > 1$. However, since by Lemma 3 *(iv)* $k(z)$ is strictly decreasing in z when θ_1 and θ_2 are drawn from a standard normal distribution, then this also implies that $k(z) < \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ for all z. In turn, by Lemma 2 this implies that $f'(z) < 0$ for all z, which, coupled with the fact that $f(0) = 0$, implies that $f(z) < 0$ for all z. As characterising the sign of $f(z)$ is equivalent to characterising the slope of the profit function, we know from this that $\frac{\partial \pi}{\partial z} < 0$ for all z. Therefore, if $\lambda \cdot \frac{\delta}{1-\delta} > 1$ the owner can increase expected profits by decreasing z from all strictly positive levels. The uniquely optimal level for z is then at the its lowest possible level $z = 0$.

If, on the other hand, $\lambda \cdot \frac{\delta}{1-\delta} < 1$, then it holds that $\lim_{z \to 0} k(z) > \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta} > \lim_{z \to \infty} k(z)$ where the first inequality follows from Lemma 3 *(ii)* and the second from Lemma 3 *(iii)* (for all feasible parametric settings). Continuity of $k(z)$ (Lemma 3 *(i)*), by the intermediate value theorem, ensures that there is at least one crossing between $k(z)$ and $\lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ while the fact that $k(z)$ is strictly decreasing $k(z)$ (Lemma 3 *(iv)*) ensures that there is not more than one crossing. Denote $\tilde{z}$ where $k(\tilde{z}) = \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$. Thus, for all $z \in [0, \tilde{z})$ it holds that $k(z) > \lambda \cdot \left(\frac{\delta}{\gamma}\right)^{\frac{1}{\lambda}} \frac{\delta}{1-\delta}$ and by Lemma 2 that $f'(z) > 0$. Since furthermore $f(0) = 0$, it then holds that $f(z) > 0$ and thus that $\frac{\partial \pi}{\partial z} > 0$ for all $z \in [0, \tilde{z})$. As in Proposition 1, the owner can strictly increase the firm's expected profits by increasing z at all $z \in [0, \tilde{z})$ whenever $\lambda \cdot \frac{\delta}{1-\delta} < 1$. However, because of the single-crossing property it now also holds that the slope of the profit function decreases for all $z \in (\tilde{z}, \infty)$.

In order to ensure that a maximum is reached for some z we now simply need to ensure that $f(z)$, and therefore the slope of the profit function, does indeed turn negative at some point as z increases. This can be verified as follows.

$$\lim_{z \to \infty} f(z) = \beta_1 \lim_{z \to \infty} \int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} \phi(\theta_1) \theta_1^{\lambda} \, \mathrm{d}\theta_1 - \beta_2 \lim_{z \to \infty} z^{\lambda} \int_0^{\left(\frac{\gamma}{\delta}\right)^{\frac{1}{\lambda}} z} \phi(\theta_1) \, \mathrm{d}\theta_1 = -\infty \tag{15}$$

As noted in the proof for Lemma 3 *(iii)*, $\lim_{z \to \infty} \int_0^z \phi(\theta_1)\theta_1 \, \mathrm{d}\theta_1$ converges to a finite constant. Since $0 < \delta, \gamma, \lambda < \infty$, so must the first addend. It is then easy to see that the second addend goes to $-\infty$, showing the desired result. Therefore, there must be some $z^* > \tilde{z}$ for which it holds that $\frac{\partial \pi}{\partial z} > 0$ for all $z \in [0, z^*)$ and $\frac{\partial \pi}{\partial z} < 0$ for all $z \in (z^*, \infty)$. Therefore, there also exists a unique level of z that maximises the firm's expected profits when $\lambda \cdot \frac{\delta}{1-\delta} < 1$, proving the desired result. □

Although a closed-form solution for the optimal level of management- by-exception is not available, it is possible to run simulations in order to gain some quantitative intuition for the problem and the responsiveness in the owner's optimal strategy with respect to the underlying parameters. To further facilitate the interpretation, I express the owner's optimal solution as the expected share of the

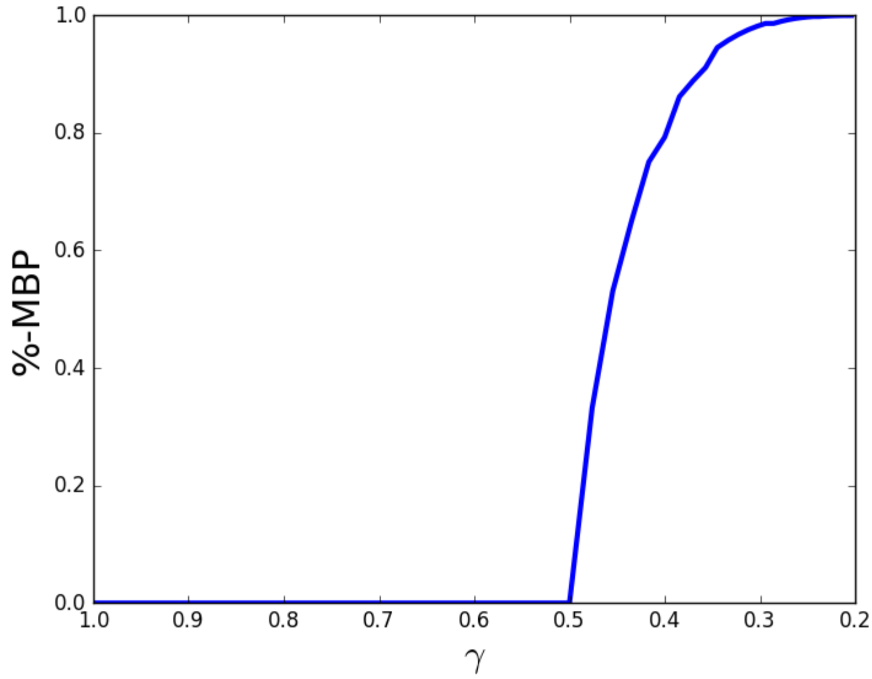

Figure 4: Optimal expected share of the firm's business managed-by-plan ($\%MBP(z^*)$) as a function of γ for $\widehat{\delta} = 0.45$ and $\lambda = 1$.

firm's activities managed-by-plan, henceforth denoted $\%MBP(z^*)$:

$$\begin{aligned}\%MBP(z^*) &\equiv \Phi^{2-sided}_{\theta_1,\theta_2}(z^*) = \Phi^{2-sided}_{\theta_1}(z^*) \cdot \Phi^{2-sided}_{\theta_2}(z^*) \\ &= \int_{-z^*}^{z^*} \phi(\theta_1)\,\mathrm{d}\theta_1 \cdot \int_{-z^*}^{z^*} \phi(\theta_2)\,\mathrm{d}\theta_2\end{aligned}$$

It is easy to see that when the owner's optimal strategy is to not implement management-by-exception at $z^* = 0$, then $\%MBP(z^*) = 0$. All business will be managed-by-feedback in these cases. When z^* rises, the manager's information will become restricted for a larger and larger set of realisations of θ_1 and θ_2 and the firm will consequently introduce rigid plans into their strategy profile.

Figure 4 shows a risk-neutral ($\lambda = 1$) owner's reaction profile as a function of γ. Consistent with Proposition 1, it must then hold that $\widehat{\delta} < 0.5$ in order to generate any incentive for the owner to introduce management-by-plan (here $\widehat{\delta} = 0.45$). Although few estimates for common levels of biases towards salient events exist, comparable strengths of biases have been reported for different phenomena of bounded rationality. For example, Tversky and Kahneman (1992) find that the median individual, *ceteris paribus*, values losses 2.25 more than gains. As by Definition 3 δ is not only capped from below by $\widehat{\delta}$ but also γ, $\%MBP(z^*)$ only begins taking positive values once $\gamma < 0.5$.

Once both these conditions are met, $\%MBP(z^*)$ rises sharply. With the manager's biased decision-making as the sole driver of optimal institutional rigidities, more than 60% of the firm's business are managed-by-plan once one of the tasks is *ex-ante* 2.5 times more important than the other. Once one task is 4 times more important than the other, management-by-plan makes up 90% of the firm's activities.

5 Conclusion

In this paper I show that *management-by-exception* may be an appropriate organisational response to boundedly-rational managers. For a sufficiently biased manager it may be optimal to adhere to a rigid production plan for a large bulk of the firm's activities, even if the productive setting favours adaptation. The manager's role is thus transformed from a central coordinator, to an emergency specialist that is called in whenever unforeseen circumstances arise.

Although *management-by-exception* is a concept with a long history in management science enjoying widespread support in practice from a large variety of fields, few work has been done specifying when and how it should be implemented. This paper lays out a framework to systematically analyse the management technique. Motivated by a single factor, I show that implementing *management-by-exception* is a desirable strategy in a large variety of cases and, if so, then strongly so.

As future avenues for further research it may be interesting how different motives, such as further decision-biases or limited organisational attention, may translate into and interact with existing preferences on the owner's side to implement *management-by-exception*.

References

Barber, Brad M. and Terrance Odean, "All That Glitters: The Effect of Attention and News on the Buying Behavior of Individual and Institutional Investors," *The Review of Financial Studies*, 2008, *21* (2), 785–818.

Bernile, Gennaro, Vineet Bhagwat, and P. Raghavendra Rau, "What Doesn't Kill You Will Only Make You More Risk-Loving: Early-Life Disasters and CEO Behavior," *The Journal of Finance*, 2017, *72* (1), 167–206.

Bordalo, Pedro, Nicola Gennaioli, and Andrei Shleifer, "Salience and Consumer Choice," *Journal of Political Economy*, 2013, *121* (5), 803–843.

Brocas, Isabelle and Juan D. Carrillo, "Influence through ignorance," *The RAND Journal of Economics*, 2007, *38* (4), 931–947.

Calvó-Armengol, Antoni, Joan de Martí, and Andrea Prat, "Communication and influence," *Theoretical Economics*, 2015, *10* (2), 649–690.

de Clippel, Geoffroy, Kfir Eliaz, and Kareen Rozen, "The Silent Treatment," 2017.

Dekker, S. W. A. and D. D. Woods, "To Intervene or not to Intervene: The Dilemma of Management by Exception," *Cognition, Technology & Work*, Sep 1999, *1* (2), 86–96.

Dessein, Wouter, "Authority and Communication in Organizations," *The Review of Economic Studies*, 2002, *69* (4), 811–838.

_ and Tano Santos, "Managerial Style and Attention," 2016.

_ , Andrea Galeotti, and Tano Santos, "Rational Inattention and Organizational Focus," *American Economic Review*, June 2016, *106* (6), 1522–36.

Dittmar, Amy and Ran Duchin, "Looking in the Rearview Mirror: The Effect of Managers' Professional Experience on Corporate Financial Policy," *The Review of Financial Studies*, 2016, *29* (3), 565–602.

Englmaier, Florian, Andreas Roider, and Uwe Sunde, "The Role of Communication of Performance Schemes: Evidence from a Field Experiment," *Management Science*, 2017, *63* (12), 4061–4080.

Garicano, Luis and Andrea Prat, "Organizational Economics with Cognitive Costs," 2011.

Gennaioli, Nicola, Yueran Ma, and Andrei Shleifer, "Expectations and Investment," *NBER Macroeconomics Annual*, 2016, *30* (1), 379–431.

Hottman, Stephen B. and Kari Sortland, "UAV Operators, Other Airspace Users, and Regulators: Critical Components of an Uninhabited System," in H. L. Pedersen, H. K. Connor, and E. Salas, eds., *Human Factors of Remotely Operated Vehicles*, New York: Elsevier Jai, 2006, pp. 71–88.

Kőszegi, Botond and Adam Szeidl, "A Model of Focusing in Economic Choice," *The Quarterly Journal of Economics*, 2013, *128* (1), 53–104.

Liu, Dahai, Christopher Reynolds, Dennis Vincenzi, and Shawn Doherty, "Effect of Pilot and Air Traffic Control Experiences and Automation Management Strategies on Unmanned Aircraft Systems Mission Task Performance," *Human Factors and Ergonomics in Manufacturing & Service Industries*, 2013, *23* (5), 424–435.

Mackintosh, Donald P., *Management by exception*, Englewood Cliffs, NJ: Prentice-Hall, 1978.

Malmendier, Ulrike, Geoffrey Tate, and Jon Yan, "Overconfidence and Early-Life Experiences: The Effect of Managerial Traits on Corporate Financial Policies," *The Journal of Finance*, 2011, *66* (5), 1687–1733.

March, James G. and Herbert Simon, *Organizations*, New York: John Wiley, 1958.

Milgrom, Paul and John Roberts, "Relying on the Information of Interested Parties," *The RAND Journal of Economics*, 1986, *17* (1), 18–32.

Ocasio, William, "Towards an attention-based view of the firm," *Strategic Management Journal*, 1997, *18* (S1), 187–206.

Powell, Michael, "An Influence-Cost Model of Organizational Practices and Firm Boundaries," *The Journal of Law, Economics, and Organization*, 2015, *31* (S1), i104–i142.

Rantakari, Heikki, "Governing Adaptation," *The Review of Economic Studies*, 2008, *75* (4), 1257–1285.

Sah, Raaj Kumar and Joseph E. Stiglitz, "The Architecture of Economic Systems: Hierarchies and Polyarchies," *The American Economic Review*, 1986, *76* (4), 716–727.

Schoar, Antoinette and Luo Zuo, "Shaped by Booms and Busts: How the Economy Impacts CEO Careers and Management Styles," *The Review of Financial Studies*, 2017, *30* (5), 1425–1456.

Simon, Herbert, *Administrative Behavior*, New York: The Free Press, 1945.

Taylor, Shelley E. and Susan T. Fiske, "Salience, Attention, and Attribution: Top of the Head Phenomena," in Leonard Berkowitz, ed., *Advances in Experimental Social Psychology*, Vol. 11, Academic Press, 1978, pp. 249 – 288.

Towne, Henry R., "The engineer as economist.," *Transactions of the American Society of Mechanical Engineers*, 1886, *7*, 428–441.

Tversky, Amos and Daniel Kahneman, "Advances in prospect theory: Cumulative representation of uncertainty," *Journal of Risk and Uncertainty*, Oct 1992, *5* (4), 297–323.

Yonker, Scott E., "Do Managers Give Hometown Labor an Edge?," *The Review of Financial Studies*, 2017, *30* (10), 3581–3604.