Information, Career Concerns, and Organizational Performance

Stephen Hansen

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Declaration

I certify that this thesis is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it).

I warrant that this authorization does not, to the best of my belief, infringe the rights of any third party.

Stephen Hansen

Abstract

This thesis explores how career concerns and information affect organizational performance.

Its first two chapters analyze a principal-agent model in which the agent has career concerns along the lines of Holmström (1999) and in which the principal observes the agent's performance but the agent and the outside labor market do not.

The first chapter shows that the presence of career concerns with asymmetric information creates a trade-off between turnover and incentives: in order for career concerns to increase, the firm must release talented workers in the future. The chapter applies its theoretical framework to examine the optimal level of labor market competition and firms' willingness to make general and firm-specific human capital investments.

In the second chapter, the agent works for the principal for two periods, after which labor market competition for talent occurs. Within this environment, it explores the firm's incentives to disclose the agent's performance to the agent in between the two periods. It finds that a profit-maximizing disclosure policy (1) always provides some information to workers; (2) never identifies the worst performers; and (3) sometimes does not identify the best performers.

In contrast to the first two, the third chapter (joint with Michael McMahon) explores information and career concerns on monetary policy committees. In particular, we ask whether a heterogeneous committee of experts can outperform a homogeneous one. We find that giving voting rights to members with different beliefs can improve social welfare due to moderation. We then examine whether differences in voting behavior between internal and external members on the Bank of England's Monetary Policy Committee are consistent with moderation, and find that they are not. In particular, some external members do not contradict internal ones. We present evidence that career concerns can explain this finding.

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Preface

Ever since Fama (1980) proposed the idea that a worker's concern for his reputation could substitute for explicit incentive schemes, economists have recognized the potential importance of career concerns in explaining behavior. Today, the career concerns framework laid out in Holmström (1999) has become a workhorse model in applied organizational economics. One reason is that the prediction from Holmström (1979) that optimal explicit incentive schemes should depend on every available signal that is (conditionally) correlated with output is manifestly not borne out in the real world. Instead, implicit incentives appear more important for explaining why workers exert effort, especially in professional service firms, which are playing an increasingly crucial role in modern economies.

While economists have a fairly solid grasp of how career concerns operate at the individual level, what is much less clear is how to design organizations in which career concerns operate. With explicit contracting, organizational design is not a first-order problem because the goal is to construct the optimal mapping from output signals to wage payments. In contrast, career concerns depend crucially on institutional details such as the quantity of information available to actors inside and outside organizations and the rewards that accrue to those perceived as more talented. The central goal of this thesis is to uncover these relationships and to show how organizations can use them to improve overall performance. For the most part, the analysis consists of applied microeconomic theory in its most literal sense. That is, the chapters use game-theoretic models to shed light on real-world phenomena, in many cases generating testable implications. The thesis is therefore a contribution to the growing field of Organizational Economics, which seeks to understand the forces that shape non-market institutions such as internal labor markets, bureaucracies, committees, and corporate hierarchies.

It is important to point out two main weaknesses in the analysis before summarizing the key results. First, the majority of the conclusions that the chapters reach depend on particular modelling assumptions, and may not hold in more general environments. General career concerns models are very difficult to solve, so the chapter uses simple functional forms for production technologies, and specifies particular distributions for random variables. Second, although the first two chapters generate testable predictions, the thesis does not provide any empirical analysis to examine them. On the other hand, many of the empirical findings in the third chapter (written jointly with Michael McMahon) are explored informally, not with an explicit model. All the chapters would benefit from stronger links between theory and data.

The first two chapters essentially analyze the same environment: one in which a principal privately observes an agent's output within a competitive labor market. This is a natural situation for career concerns to arise, because when outsiders cannot observe output, contracting on it is presumably not possible. The introduction of asymmetric information also adds more richness to the canonical Holmström model, in which all participants in the labor market have the same information at all points in time; in particular, it allows one to discuss a range of important human resource management policies about which the Holmström model is silent.

In the first chapter, an agent (the worker; he) matches with a principal (the employer; it) for an initial period, after which labor market competition takes place and the employer either retains or releases the worker for a second period. The equilibrium outcome of labor market competition is similar to that in Waldman's (1984) well-known paper: the employer retains the worker whenever his expected talent is above a threshold and releases the worker whenever his expected talent is below it. This is inefficient because the employer releases the worker with positive probability even though he always generates more output with the employer than he does with other firms. In the first period, the worker exerts effort because the wage he will be paid if the employer retains him is higher than the wage he will be paid if it releases him. A crucial result is that whenever second period output is convex in worker talent, this wage difference—and therefore the strength of career concerns—is increasing in the probability that the agent is released. So, equilibrium turnover is positively correlated with equilibrium effort.

The results suggest that policies that jointly affect turnover and effort must resolve a basic trade-off between matching and incentives, and the first chapter presents two applications. The first is to competition policy. Increased labor market competition worsens second period social surplus by increasing turnover, while improving first period social surplus by increasing effort. The same tension also arises when the employer can choose whether to invest in general or firm-specific human capital. Both kinds of human capital inversely affect the ability of the employer to retain talented workers in the second period and its ability to motivate them in the first. The fact that the presence of career concerns influences optimal competition and human capital investment means that traditional analyses of these policy choices may be missing important incentive effects.

In the second chapter, the worker exerts effort for two periods before labor market competition takes place. Its goal is two-fold: first, to identify the effects of the employer's disclosing performance information to the worker between his two effort choices; and second, given these effects, to derive the disclosure policy to which the employer would like to commit ex ante to maximize profit. This question is not simply a theoretical exercise because the problem of how to best conduct performance appraisals is one of the most vexing that firms face. There are two primary effects of information disclosure.

First, it creates uncertainty for the worker about his second period effort level, which increases his disutility from joining the employer. Second, when the worker learns his performance, the employer's belief about his second period effort choice depends on his first period output. So, the worker can use first period effort to influence the amount of effort that the employer expects him to exert in the second.

The optimal disclosure policy has three notable properties. First, it always involves some, but not full, disclosure. Second, the worker never learns that his performance is among the worst possible. Finally, in some situations, the worker does not learn that his performance is among the best possible. These results are important because real world performance appraisals tend not to identify poor performers, and to concentrate ratings in the center of the distribution. Observers often argue that these patterns reflect some dysfunctionality in appraisal systems, but in fact the rating distributions that arise from optimal disclosure policies have much in common with real-world distributions. This is not equivalent to saying that rating systems are always perfect, only that they may not be as bad as they first appear.

The third chapter (written jointly with Michael McMahon) is quite distinct from the first two. It no longer considers a principal-agent model and no longer explicitly models career concerns. The question it seeks to ask is whether monetary policy committees can benefit from having heterogeneous experts. It is pertinent because some countries (like the UK) appoint people to their monetary policy committees from outside their central banks, while some countries (like the US) do not. To address the issue, it builds a theoretical model to explore the dimensions along which mixed committees might outperform homogeneous ones. The central result is that if the committee designer knows experts' beliefs about long-term macroeconomic conditions, it should appoint the expert with the most moderate belief as the sole committee member, and allow all other experts to advise him. The only rationale for having different experts on the same committee is if the committee designer does not observe beliefs. In this case, drawing experts from two different belief distributions can produce a more moderate median voter than drawing experts from only one if every member votes according to his personal view about what is the best policy.

The remainder of the third chapter explores whether the voting record of the Bank of England's Monetary Policy Committee (MPC) is consistent with the theoretical rationale for including external members. Our first finding is that internal and external members initially vote for the same average interest rate, but that external members begin voting for lower interest rates after approximately one year on the committee. While this is not consistent with moderation (at least initially), it may simply be the case that external members are hesitant to express their views early on. A more intriguing finding is that only academic external members vote for lower rates after a year; non-academic external members continue to vote with the internals. We hypothesize that this is due to the career concerns of non-academic external members, and test this idea using a natural experiment that exogenously changed the possibility of reappointment. During a period in which reappointment was unlikely, non-academic external members also voted for lower interest rates after a year. We interpret this as evidence that the career concerns of non-academic external members keep them from expressing dissent when reappointment is possible, and conclude that career concerns may limit the efficiency gains of mixed committees. Thus, while the chapter does not begin by analyzing career concerns, it finishes by showing that they are potentially a spanner in the works of committees of experts.

Chapter 1

Turnover and Incentives in Labor Markets with Asymmetric Information

1.1 Introduction

There are two important sources of value that firms enjoy from new workers: their initial productivity and the option value from retaining talented workers in the future. Thus, a firm must achieve two distinct goals to maximize the benefit from employing workers. First, it must provide effort incentives to motivate workers. Second, it must use the information it obtains after observing worker performance to make appropriate retention decisions. Failure to adequately address either issue will impair overall performance.

Of course, there are numerous possible frictions that may prevent optimal retention and limit effective incentive provision. This chapter focuses on asymmetric information between an employer and an outside labor market as a source of both matching and contracting inefficiencies. In itself, the fact that asymmetric information distorts labor market outcomes and creates contracting difficulties is not surprising. Instead, the main contribution of this chapter is to show that the ability of firms to retain talented workers under asymmetric information is in many situations negatively related to worker motivation when effort incentives come from career concerns. In this case, firms' ability to retain talented workers is inversely related their initial productivity.

The argument is the following. A worker (he) begins working for an employer (it) in the first of two periods within a competitive labor market. The employer privately observes the worker's output, allowing it to perfectly infer his ability. Outside firms do not observe any information correlated with the worker's output. Between the first and second periods, competition takes place between the privately informed employer and the uninformed labor market. Asymmetric information implies that the employer can only pay one wage to retained ability types, and so in equilibrium it releases the worker if his ability falls below a threshold. This is inefficient because every ability type is more productive with the employer than an outside firm in period two.

As explicit contracts can only be written for publicly observable variables, they are not feasible when only the employer observes output. Effort incentives for the worker must therefore arise implicitly, and the chapter assumes they come from career concerns à la Holmström (1999). Since career concerns incentives depend on expected future earnings, this choice of contracting instrument creates a tight relationship between the worker's period one effort and the equilibrium outcome of the bidding game between the employer and outside firms. In the second period, the worker earns higher wages if he is retained by the employer than if he is released, so his second period payoff improves discreetly if the employer's belief about his ability crosses the retention threshold. He exerts effort in the first period in order to increase the employer's belief about his talent and increase his future expected payoff—the standard signal jamming logic.

A key assumption in the model is that second period output is convex in worker talent. The implication is that raising the retention threshold increases the expected market output of retained ability types by more than it increases the expected market output of released ability types. This in turn increases the difference between the equilibrium wage paid to retained and released ability types, which strengthens career concerns. However, raising the retention threshold also increases the probability of turnover. Of course, the retention threshold itself is endogenous. It is primarily determined by two deep parameters that measure worker productivity in the market and with the employer, respectively. Increasing either parameter has opposite effects on effort and turnover. When market productivity increases, the retention threshold increases, as does the amount the market is willing to pay every ability type. Both effects increase the wage difference between retained and released ability types, but the former worsens matching. By contrast, when employer productivity increases, the threshold decreases, reducing effort but improving matching. This is the fundamental logic underlying the chapter.

Since the model ties turnover and effort to productivity parameters, it can shed light on the trade-offs associated with policies that influence them. The chapter presents two such applications. The first assesses the desirability of competition. One can measure competition as the probability that the market productivity parameter takes on some non-zero value. With no competition, first-best matching obtains since the employer can retain all ability-types; however, the worker exerts no effort since wages are 0 regardless of observed performance. Increasing competition steadily worsens matching and steadily increases effort. The chapter shows that there exists a unique socially optimal level of competition that can lie anywhere from zero to one, depending on the relative magnitudes of the distortions.

The second application of the model examines the employer's firm-specific and general human capital investment incentives. Increasing general human capital raises the equilibrium retention threshold, increasing turnover along with effort. When effort costs are low enough, the firm is willing to invest in general human capital even though it limits its ability to retain talent. Firm-specific human capital presents the opposite trade-off. Increasing it decreases turnover and effort through reducing the retention threshold. Thus, investment in firm-specific skills will not occur when effort is highly sensitive to variations in wages—i.e., when effort costs are low.

The value added of the chapter lies not in analyzing labor market outcomes or career concerns per se, but in tying them together to show that two of the most basic problems facing firms regarding human resource management may not be possible to resolve simultaneously. In fact, the very popularity of adverse selection labor market models and career concerns models highlights the importance of combining both for a clearer picture of how organizations function. Doing so not only reveals an inverse relationship between incentives and turnover, but also uncovers new dimensions on which competition policy and human capital investments might have an impact.

Related Literature The Waldman (1984) model of adverse selection labor market competition is the closest to the one presented in the chapter, although there are other papers that examine the consequences of strategic bidding in labor markets with asymmetric information (see Greenwald 1986, Bar-Isaac, Jewitt, and Leaver 2008, Li 2008). The crucial assumption is that bidding occurs sequentially, beginning with the employer and followed by the outside firms. The end of the chapter will discuss how the results depend on this bidding structure.

The career concerns literature that began with Fama (1980) and Holmström (1999), has, for the most part, considered the interactions between one principal and an agent, or among multiple identical principals and an agent. This chapter, in contrast, considers the case in which an agent interacts with multiple principals that differ both in terms of their productivity and their information about the agent's output.

More generally speaking, there are few models in contract theory that study the relationship between competition and incentives. One exception is Schmidt (1997), who shows that increases in competition can both increase and decrease effort, whereas in this chapter increases in competition only increase effort. The difference is that in Schmidt, the principal can choose the incentive scheme conditional on levels of competition, whereas here the principal cannot write output contracts and can only rely on career concerns to generate effort. Moreover, Schmidt focuses on product market competition, and this chapter on factor market competition.

Acemoglu and Pischke (1998) and Acemoglu and Pischke (1999) argue that an employer will only undertake general human capital investments when it can capture some of the associated gain in worker productivity. Here, the employer does not capture any of the second period surplus from general human capital investment, and yet it still invests in general skills because by increasing the labor market's valuation of talent, it strengthens career concerns.

Finally, Mukherjee (2008) combines adverse selection labor market competition with career concerns (and explicit contracting) in order to study an employer's incentive to disclose information to an outside market. He does not study the relationship between turnover and effort under asymmetric information.

The rest of the chapter proceeds as follows. The next section lays out the model and the subsequent one presents the solution, highlighting how turnover and incentives jointly depend on productivity parameters. The fourth section applies the model to competition and human capital investments, illustrating how they create trade-offs between effort and matching. The final section discusses the assumptions that underlie the model, and the implications of changing them.

1.2 Model

In period 1, a worker (he) matches with a firm (it) F. The worker's first period output is $y_1 = \theta + e$ where $\theta \sim U[0,1]$ is worker talent and e is worker effort. The cost of effort function for the worker is $c\chi(e)$, where χ satisfies the standard properties $\chi' > 0$, $\chi'' > 0$, $\lim_{e\to 0}\chi(e) = 0$ and $\lim_{e\to\infty}\chi(e) = \infty$. The $c > 0$ parameter is a measure of the cost of effort, and will play an important role in determining how sensitive is equilibrium effort to wage variation. The worker has an outside option equal to 0.

In addition to F, there is an outside labor market that consists of a large number of firms indexed by $j \in J$. A crucial assumption is that F perfectly observes y_1 but that no firm j does; there is thus asymmetric information. This captures the fact that since F works more closely with the worker than does the outside market, it is in a better position to judge the quality of his output.

After F observes y_1, it plays a bidding game with the outside firms. First, it chooses some $w^F \in W^F = \mathbb{R}^+ \cup \{\emptyset\}$ where $w^F = \emptyset$ corresponds to not making the worker a wage offer for period 2 and $w^F \neq \emptyset$ to offering him a wage w^F for period 2. Outside firms observe w^F and each then simultaneously chooses $w^j \in \mathbb{R}^+ \cup \{\emptyset\}$. The worker joins the firm that offers him the highest wage. If the maximum wage he is offered by the outside market equals the wage that F offers him, he remains with F; if more than one outside firm offers him the highest wage, he joins each with equal probability; and if his highest wage offer is 0 he takes his outside option. All firms incur an arbitrarily small cost δ from making wage offers, which could for example reflect the legal costs of drafting a wage contract.

If the worker remains with F for period 2, his output is $y_2^F = f\theta^N$ and if he moves to an outside firm it is $y_2^j = m\theta^N$, where $f > m \geq 1$ and $N > 1$. The assumption on the magnitudes of the productivity parameters f and m implies that every ability type is more productive with F than with an outside firm in the second period. In section 1.4, the chapter gives f and m more specific interpretations, but for now they are left as abstract parameters.

The assumption that $N > 1$ implies that second period production is convex in talent.[1,2] While the particular functional form for y_2 is not itself crucial for the results of the chapter, convexity is. The exact role it plays will become clear in the next section.

In the model, there is no contracting on output since it is not publicly observable. Instead, all effort incentives will come from career concerns. Thus, the fact that second period production does not depend on effort is without loss of generality, since career concerns do not exist in the final period of the game.

1.2.1 Definition of equilibrium

The chapter uses the Perfect Bayesian Equilibrium concept to solve the model. After observing y_1, F forms a belief $\widehat{\theta}^F$ on worker talent. Denote by Θ^F the set of all possible realizations of $\widehat{\theta}^F$, and let $\widetilde{w}^F : \Theta^F \to W^F$ be F's strategy in the bidding game. Let $\widehat{w}^j$ be market firm j's belief about the strategy that F employs, and let $\widetilde{w}^j : W^F \to W^j$ be the strategy that each market firm j employs. Furthermore, let e^F and e^j denote the beliefs of firm F and j on worker effort.

The equilibrium set of strategies $\widetilde{w}^{F*} \cup \{\widetilde{w}^{j*}\}_{j=1}^J$ and beliefs $\{\widehat{w}^{j*}\}_{j=1}^J$ must satisfy the following conditions:

$$\widetilde{w}^{j*} \text{ maximizes } E\left[y_2^j\right] - w^j - \mathbb{1}\left(w^j \neq \emptyset\right)\delta \;\forall w^F \text{ given } \widehat{w}^j,\ e^j, \text{ and } \left\{\widetilde{w}^{j*}\right\}_{j=1}^J \backslash \widetilde{w}^{j*} \quad (1.1)$$

$$\widetilde{w}^{F*} \text{ maximizes } E\left[y_2^F\right] - w^F - \mathbb{1}\left(w^F \neq \emptyset\right)\delta \;\forall \widehat{\theta}^F \text{ given } e^F \text{ and } \left\{\widetilde{w}^{j*}\right\}_{j=1}^J \quad (1.2)$$

$$\widehat{w}^{j*} = \widetilde{w}^{F*} \quad (1.3)$$

[1]The discussion section provides a motivation for this assumption.

[2]One might also wonder why, given the functional forms, some talent realizations are less productive in the second period than they were in first. In fact, one can add a constant term to second period output or subtract one from first period output without altering any results.

Condition (1.1) states that the strategies employed by market firms constitute a Nash Equilibrium; (1.2) that F maximizes profit given the behavior of the labor market; and (1.3) that the belief of each market firm about the strategy employed by F is consistent with its actual strategy.

$\widetilde{w}^{F*} \cup \{\widetilde{w}^{j*}\}_{j=1}^{J}$ implicitly defines an ability-wage schedule $w\left(\widehat{\theta^F}\right)$. Let e^W be the worker's actual period 1 effort. Equilibrium effort e^* must satisfy

$$e^W = \arg\max_e -c\chi(e) + w\left(\widehat{\theta^F}\right) \tag{1.4}$$

$$\widehat{\theta^F} = y_1 - e^F \tag{1.5}$$

$$e^* = e^W = e^F = e^j \tag{1.6}$$

(1.4) requires the worker to maximize utility; (1.5) requires Bayesian learning on the part of the firm; and (1.6) requires every firm's belief about worker effort to be consistent with the worker's effort choice.

Definition 1.1 *A Perfect Bayesian Equilibrium of the model satisfies (1.1)-(1.6).*

The remainder of the chapter solves the model according to Definition 1.1

1.3 Solution

This section derives the implications of the model for turnover and effort and emphasizes their relationship to the f and m parameters. Although the model presented above is relatively simple, it delivers the important insight that increased effort implies increased turnover. The first part of the section derives properties of the equilibrium bidding strategies and their relationship to turnover, while the second part derives first period equilibrium effort as a function of the equilibrium wage schedule. The section does not impute any welfare implications to the findings, but instead leaves this for the applications presented afterwards.

1.3.1 Equilibrium Turnover

Since the labor market bidding game is sequential, the first step involved in solving it is describing the behavior of the outside firms after they observe w^F. Condition (1.3) implies that all outside firms must share the same belief about F's strategy, so that $\widehat{w}^j = \widehat{w}$. Moreover, condition (1.6) implies that every outside firm believes that $\widehat{\theta^F} \sim U[0,1]$. While there is not a unique equilibrium, there is a unique equilibrium outcome, which the following lemma describes.

Lemma 1.1 *If* $w^F \neq \emptyset$ *and* $E\left[m\theta^N \mid w^F, \widehat{w}\right] - w^F - \delta \geq 0$, *or if* $w^F = \emptyset$ *and* $E\left[m\theta^N \mid w^F, \widehat{w}\right] - \delta > 0$, *then* $\max_j w^j = E\left[m\theta^N \mid w^F, \widehat{w}\right] - \delta$. *Otherwise,* $w^j = \emptyset\ \forall j$.

If F does not pay the worker a wage at least equal to the expected surplus he could generate in the labor market, then one outside firm will pay him a wage equal to the expected surplus. The result follows from Bertrand bidding, which implies that no outside firm can capture any surplus from the worker.

The behavior of the outside firms influences the bidding behavior of F through setting the worker's outside option. The next result describes its equilibrium strategy.

Proposition 1.1 *The equilibrium strategy of* F *satisfies*

$$\widetilde{w}^{F*} = \begin{cases} \frac{m}{N+1}\frac{1-(\theta^*)^{N+1}}{1-\theta^*} \text{ if } \widehat{\theta}^F \geq \theta^* \\ \emptyset \text{ if } \widehat{\theta}^F < \theta^* \end{cases} \tag{1.7}$$

where θ^* *uniquely satisfies*

$$f \times (\theta^*)^N = \frac{m}{N+1}\frac{1-(\theta^*)^{N+1}}{1-\theta^*}. \tag{1.8}$$

In words, F retains the worker if and only if its belief on his talent exceeds θ^* and pays all retained ability-types a wage independent of $\widehat{\theta}^F$ that is equal to their expected market productivity conditional on $\widehat{\theta}^F \in [\theta^*, 1]$. This strategy combined with the labor market behavior identified in Lemma 1.1 leads to two wages in equilibrium: one to ability-types that F retains and one to ability-types that F releases. The following assumption pins down the latter.

Assumption 1.1 $0 < \delta < E\left[m\theta^{N+1} \mid \widehat{\theta}^F < \theta^*\right] = \frac{m(\theta^*)^{N+1}}{N+1}$.

Assumption 1.1 implies that an outside firm will employ the worker if he is released since the surplus he creates is positive.

The reason that F cannot pay any two retained ability-types two different wages is that wages cannot credibly signal private information. If F paid two different retained types two different wages, and the outside market believed these wage offers credibly communicated private information, F would have an immediate incentive to "lie" to the market and tell it that the higher ability-type was the lower one since it would save on wage costs. Within the set of retained workers, communication between F and the outside market is impossible.[3]

[3]The intuition is similar to that in the cheap talk literature (Crawford and Sobel 1982). Within the set of retained types, the sender of private information (the firm) has no preference concordance at all with the receiver (the outside labor market), so communication is impossible.

The reason released ability-types earn a flat wage is costly bidding. Without costly bidding, F could still only retain ability-types above θ^* at wage $\frac{m}{N+1}\frac{1-(\theta^*)^{N+1}}{1-\theta^*}$; however, it could credibly communicate its private information to the market for ability-types below θ^* since providing information would be costless and not affect second period profit. For example, one possible equilibrium strategy for F could satisfy $\widetilde{w}^{F*} = \widehat{\theta}^F - \varepsilon$ if $\widehat{\theta}^F < \theta^*$ for some arbitrarily small ε. An outside firm would then hire ability-type $\widehat{\theta}^F$ whenever $m\widehat{\theta}^F - \delta \geq 0$ at wage $m\left(\widehat{\theta}^F\right)^N - \delta$. F's employing this strategy would lead to a different ability-wage schedule than its employing the strategy specified in Proposition 1.1. This would in turn impact on the worker's first period effort incentives. Among the different equilibria of the costless bidding game, the most plausible one would maximize profit. However, solving for the optimal amount of information provision to the outside market is not the focus of this chapter. Assuming costly wage offers not only avoids this problem, but also has a realistic interpretation.

A crucial feature of this equilibrium is inefficient matching: since $f > m$, any turnover is inefficient. However, since (1.8) has a solution that lies within $(0, 1)$, F releases the worker with positive probability in equilibrium. The basic reason is wage pooling. F must earn zero profit on the lowest retained ability type while paying him a wage equal to the expected market output of all ability-types above his. Since the output of the lowest ability-types is near 0, F cannot profitably retain them.[4]

The following result summarizes the effect of the productivity parameters on equilibrium turnover.

Lemma 1.2 *θ^* is strictly decreasing in f, strictly increasing in m, and bound between* 0 *and* 1.

When f increases, F earns more on every worker type. Since an outside firm's willingness to bid for the worker is unchanged, this lowers θ^* and decreases turnover. When m increases, the outside market is willing to pay more for every ability-type, so F must raise the wage it pays to retained workers. This reduces the number of workers it can profitably retain, increasing θ^* and lowering expected second period profit. Moreover, one can also easily show that $\lim_{\frac{f}{m}\to\infty}\theta^* = 0$, in which case the probability of turnover tends to 0, and that $\lim_{\frac{f}{m}\to 1}\theta^* = 1$, in which case the probability of turnover tends to 1.

[4]The only reason F can *ever* retain the worker is because it earns a rent proportional to $f - m$ on every ability-type.

1.3.2 Equilibrium Effort

To derive first period effort, one needs to look at the entire ability-wage schedule. Combining the results from above gives

$$w\left(\widehat{\theta^F}\right)=\begin{cases}\frac{m}{N+1}\frac{1-(\theta^*)^{N+1}}{1-\theta^*} & \text{if } \widehat{\theta^F}\geq\theta^* \\ \frac{m}{N+1}\frac{(\theta^*)^{N+1}}{\theta^*} & \text{if } \widehat{\theta^F}<\theta^*.\end{cases}$$

In other words, the worker's second period earnings are higher if he is retained by F than if he is released. There is thus a reputational reward associated with remaining with F. The size of the reputational reward is given by

$$\begin{aligned} W\left(\theta^*\right) &= \frac{m}{N+1}\frac{1-\left(\theta^*\right)^{N+1}}{1-\theta^*}-\frac{m}{N+1}\frac{\left(\theta^*\right)^{N+1}}{\theta^*} \\ &= \frac{m}{N+1}\frac{1-\left(\theta^*\right)^{N}}{1-\theta^*}. \end{aligned} \tag{1.9}$$

Since contracting on output is not possible, effort incentives for the worker arise solely from the desire to signal a high ability to his employer in order to increase the probability of earning $W\left(\theta^*\right)$. The next result establishes the dependence of equilibrium effort on this quantity.

Proposition 1.2 *Equilibrium effort satisfies*

$$\chi'\left(e^*\right)=\frac{W\left(\theta^*\right)}{c}. \tag{1.10}$$

Because θ is uniformly distributed on $[0,1]$, a marginal increase in effort will increase $\Pr\left[\widehat{\theta^F}\geq\theta^*\right]$ by a constant amount 1, the probability density function for a uniform random variable.[5] Equilibrium effort equates the marginal benefit of effort—$1\times W\left(\theta^*\right)$—with the marginal cost—$c\chi'$.[6]

Clearly, the size of the reputational reward is key for determining equilibrium effort. As it changes, so too will e^* and first period profit for F.

Lemma 1.3 $W\left(\theta^*\right)$ *is decreasing in* f *and increasing in* m.

This result hinges on the assumed convexity of second period output in talent. When the retention threshold θ^* increases, the newly released types are more talented than

[5]Technically speaking, this is not true if e is large enough to guarantee that $\widehat{\theta^F}>\theta^*$. In fact, the proof of the result shows that equilibrium effort can never lie at such a corner solution.

[6]If the distribution of θ were not uniform, then changing the retention threshold θ^* would affect equilibrium effort not only through changing the size of the reputational reward, but also through altering the extent to which an increase in effort increased the probability of earning it.

the previously released types and less talented than the newly retained types. This means that the expected output of both retained and released types increases following an increase in turnover. Convexity implies that the expected output of retained types increases by more than the expected output of released types. Hence, the difference in the wage paid to retained and released types increases with turnover. Therefore, an increase in f reduces $W(\theta^*)$ since it decreases θ^*, while an increase in m has two complementary effects: it increases $W(\theta^*)$ both through increasing θ^* and directly raising the value that the outside firm place on any ability-type.

Comparing Lemma 1.3 with Lemma 1.2 leads to the immediate conclusion that changes in the productivity parameters that decrease turnover reduce first period effort and vice versa. To put it another way, the model predicts that in a cross-section of firms, after controlling for f (and N), one should observe a positive relationship between turnover and effort, and likewise after controlling for m (and N).[7] This is the central message of the chapter: under asymmetric information, the employer can either motivate the worker in the first period or retain him in the second, but not both.

The results suggest that policies designed to alter the f and m parameters will have to take into account a trade-off between turnover and effort. The next section explores this idea in more detail. First, though, it is important to discuss how sensitive is effort to changes in f and m in order to determine the relative magnitudes of the associated costs. As one can see from (1.10), e^* is more sensitive to differences in $W(\theta^*)$ the smaller is c, the cost of effort parameter. Essentially c measures the importance of career concerns. When it is large, signalling is costly, so that career concerns are weak; when it is small, signalling is cheap, so that career concerns play a larger role in the worker's effort choice.

1.4 Applications

While the results so far are useful for illustrating the inverse correlation between turnover and effort, it is silent about how to interpret the m and f parameters or why they might take on particular values. This section instead models m and f as deliberate policy choices. The first application is to a social planner choosing the optimal level of competition, and the second is to the firm choosing levels of firm-specific and general human capital. In both cases, the optimal policy must balance the trade-off between incentives and matching.

[7]One could also control for f and g and find the same relationship due to heterogeneity in N, which also affects turnover and wages through determining θ^*

1.4.1 Competition

In order to apply the model to competition, one can write m as the following random variable, realized between periods 1 and 2:

$$m = \begin{cases} f - \varepsilon \text{ with probability } p \\ 0 \text{ with probability } \ 1 - p \end{cases}$$

where $\varepsilon \in (0, f)$. If the realization of m is 0, then the worker has no value in the outside market, and F only needs to pay the worker his outside option in order to retain him. If the realization of m is $f - \varepsilon$, then F must bid for the worker and pay a positive wage to retain him. p is therefore a natural measure of competition, since it can be interpreted as the probability with which the employer faces another firm in the bidding game. Here, p measures factor market competition, not product market competition, and when $p = 0$, F is a monopsonist, not necessarily a monopolist. Finally, ε measures the output loss when the worker leaves F. Such a loss might arise for many reasons, but the most natural motivation is firm specific human capital, broadly speaking. As $\varepsilon \to 0$, then F and the outside firms become identical. Its role in determining the optimal level of competition is discussed below.

A social planner that can choose the level of competition will select

$$p^* = \arg\max_p \ e^* - c\chi(e^*) + E[y_2]. \tag{1.11}$$

In (1.11), $E[y_2]$ refers to total expected second period output, not just expected second period output in F. Denote by $\theta^*(\varepsilon)$ the retention threshold if $m = f - \varepsilon$ and $W(\theta^*)$ the wage difference between retained and released workers when $m = f - \varepsilon$.[8]

p^* must balance two forces. Whenever $m = f - \varepsilon$, the employer inefficiently releases all ability types below $\theta^*(\varepsilon)$, leading to an output loss of $\varepsilon(\theta^*(\varepsilon))^{N+1}$. Increasing p increases the probability that this loss occurs and so damages social welfare. On the other hand, one can write equilibrium effort (from Proposition 1.2) as

$$\chi'(e^*) = \frac{pW(\theta^*)}{c}, \tag{1.12}$$

meaning that increasing p increases equilibrium effort. The reason is that, conditional on $m = 0$, the worker's second period wage is 0 no matter what his employer's belief about his ability, so career concerns do not arise. On the other hand, when $m = f - \varepsilon$, there is a reputational reward for signalling an ability above θ^*, meaning that career concerns

[8] When $m = 0$, $\theta^* = 0$ and $W = 0$.

motivate effort.

Assumption 1.2 $W(\theta^*) < 1$.

Assumption 1.2 implies that even when competition is maximal (i.e., $p = 1$), the worker's effort is less than first-best. So, increasing p unambiguously increases first period social surplus.

Proposition 1.3 *A unique* $p^* \in [0,1]$ *exists. Moreover,* $\lim_{c\to\infty} p^* = 0$, $\lim_{c\to 0} p^* = 1$, *and* $\frac{\partial p^*}{\partial c} < 0$ *whenever* $p^* \in (0,1)$.

The uniqueness of p^* arises from the fact that while the marginal decrease in second period output is constant in p, the marginal increase in first period surplus is decreasing in p since it is concave in effort. The results on the c parameter arise because the welfare gain from moving effort closer to its first-best level is decreasing in the cost of effort. The novel aspect of Proposition 1.3 is that it derives optimal competition in terms of its impact on the internal and external labor market. The model shows that the effects of competition go beyond what regulators usually consider, and that competition can endogenously determine firm productivity.

Remark 1.1 $\lim_{\varepsilon\to 0} p^* = 1$

When $\varepsilon \to 0$, the employer and the outside firms become identical in the sense that the worker is equally productive in the second period no matter where he is employed. The only rationale for limiting competition in the model is to reduce the expected loss in second period output arising from turnover. So, when all firms are identical, the social planner should maximize competition in order to make first period effort as high as possible. The fact that maximum turnover results does not affect $E[y_2]$. Loosely speaking, perfect competition on the intensive margin (eliminating match-specific human capital among potential competitors) implies the social desirability of perfect competition on the extensive margin (ensuring potential competitors actually compete).

1.4.2 Human capital investments

The chapter now considers how a firm's human capital investments must take into account turnover and incentives. In order to do so, one can model the productivity parameters as $f = g + h$ and $m = g$, where g is general human capital and h is firm-specific human capital. Thus, the worker's productivity with F reflects both firm-specific and general human capital, while the worker's productivity in the market depends only on general human capital. To isolate the relevant effects of human capital accumulation, this section allows F to choose g and h prior to period 1 but after F and the worker have agreed any period 1 wage payments.[9]

To simplify the presentation, the section first considers the case in which F can invest in general human capital when firm-specific human capital is fixed at some level h^*. Without investment, general human capital is g'. However, F can pay a cost K in order to increase g to some $g'' > g'$. To examine investment incentives, one can write the employer's objective function as

$$\begin{aligned} & E\left[y_1 + y_2\right] - \mathbb{1}\left(g = g''\right) K \\ & = \frac{1}{2} + \left(\chi'\right)^{-1}\left(\frac{W(\theta^*)}{c}\right) + \frac{h^*}{N+1}\left[1 - \left(\theta^*\right)^{N+1}\right] - \mathbb{1}\left(g = g''\right) K. \end{aligned} \tag{1.13}$$

Investment in general human capital affects profit through increasing the retention threshold θ^*, which increases effort but also increases turnover. As investment in g is costly, the firm will only ever undertake it if the resulting increase in effort is large enough to both compensate for the investment outlay and the associated reduction in second period profit. Since c measures the sensitivity of effort to changes in θ^*, its value determines whether investment takes place.

Proposition 1.4 *F chooses $g = g''$ if and only if $0 < c < c^* < \infty$.*

A long-standing argument dating back to Pigou (1912) maintains that firms tend to under-invest in general human capital because the resulting productivity gains simply increase the wage payments that they must pay to retain workers. Since the rate of return on general human capital investment is thus 0, firms will not be willing undertake them. Ignoring effort for a moment, the situation in this model is even worse. F not only fails to increase the rents it earns on retained workers after investing in their general productivity, it actually reduces the number of ability-types it can retain. Thus, from the perspective of period 2, the rate of return on investment in g is actually negative.

While much of the human capital literature ignores incentive issues, the model demonstrates that the effect of general skills on effort is just as important a determinant for investment as their direct effect on future productivity. With career concerns, the value that the labor market places on workers drives their effort choices. By increasing its employee's general human capital, F increases the amount that outside firms are willing to pay for talent, increasing $W(\theta^*)$. Proposition 1.4 suggests that empirical estimates

[9]When wages and human capital investments are simultaneously chosen in traditional human capital theory (e.g. Becker 1993), the worker can finance a firm's investments by accepting lower up-front wages in exchange for higher future earnings. Since the goal here is not to provide a full account of human capital accumulation, the chapter assumes wage payments are sunk at the time the firm undertakes investments.

of the returns to general human capital investment may be underestimating their full impact if they fail to take into account incentive effects.

Firm-specific human capital investment presents F with the opposite trade-off. Suppose that g is fixed at g^*, and that F can increase h from h' to h'' by incurring a cost K. Profit as a function of h is

$$E[y_1 + y_2] - \mathbb{1}(h = h'')K$$
$$= \frac{1}{2} + (\chi')^{-1}\left(\frac{W(\theta^*)}{c}\right) + \frac{h}{N+1}\left[1 - (\theta^*)^{N+1}\right] - \mathbb{1}(h = h'')K. \tag{1.14}$$

Increasing h increases second period profit but decreases first period effort due to its lowering the retention threshold. Thus, the dependence of the optimal h on effort costs is the now the opposite of above.

Proposition 1.5 *F chooses $h = h''$ only if $c^* < c < \infty$.*

Again, the model highlights new margins on which human capital investments should theoretically depend. Traditional theory (Becker 1993) maintains that under-investment in firm-specific human capital arises when there is non-zero probability of worker turnover. However, the chapter shows that the probability of turnover is actually endogenous to the choice of firm-specific human capital. In fact, a firm-specific human capital investment motivation arises precisely to *reduce* turnover. Counteracting this force is the negative impact of firm-specific human capital on incentives. If effort is highly sensitive to wage differentials, investment in firm-specific human capital is not profitable in any circumstances. Again, the key message is that a theory of human capital investments that does not consider incentives can be seriously misleading.

1.5 Discussion

This chapter has argued that the presence of asymmetric information induces a trade-off between worker turnover and effort that should affect competition policy and human capital investments. To conclude, it examines the particular modeling assumptions that give rise to this result.

First and foremost, asymmetric information plays a critical role in the results. To see why, suppose instead that outside firms could observe y_1 along with F. Now, since F can make a profit on each ability type while paying its expected output in a market firm, there is no longer turnover in equilibrium, no matter what are the values of m and f.[10] With symmetric information, therefore, there is no longer a rationale for ever

[10] Strictly speaking, this is only true when the bidding cost δ is 0, since otherwise F would release

limiting competition even in the presence of large effort costs (so long as equilibrium effort at $p = 1$ is less than first-best). Since expected second period output is now independent of p, increasing p does not reduce second period welfare, but only boosts effort incentives. As for human capital investments, symmetric information makes both types less costly. Increasing general human capital no longer increases turnover, and increasing firm-specific human capital no longer decreases effort. Now the only margin that matters for the former is the creation of incentives and for the latter is the increase in expected second period output. In short, asymmetric information is key for creating the trade-offs that this chapter identifies.

A key question becomes in what circumstances asymmetric information is likely to arise in combination with career concerns. In some cases, there are mechanisms available that allow employers to commit to disclosing information about employees, such as sending consultants to work on-site for clients, allowing industrial scientists to publish their research, or posting authored reports on the Internet.[11] However, much of the work done by professional service firms is not done on-site, involves some element of team production, and produces a subjective output. For example, associates in law firms often have little face time with clients and work with one or more partners in developing cases. Such factors make asymmetric information, especially for junior workers, a relevant consideration.

The other crucial assumption in the model is that second period output is strictly convex in talent. If it were linear in talent, θ^* would not affect wage differentials, and if it were concave in talent, effort and turnover would be negatively, not positively, related. There are multiple plausible grounds for convexity. Suppose firms can assign workers to a set of production technologies in which a larger fixed cost implies a higher (constant) marginal productivity of talent. Then, the upper envelope of the resulting output functions is convex in talent. A more organizational grounding for convexity can be found in Rosen (1981) and Garicano and Rossi-Hansberg (2006). The idea is that an individual's output depends on his ability to leverage his knowledge, and that more talented people will occupy higher levels within organizations where they can better leverage their knowledge.

The order in which the firm and outside market bid for the worker is also important for the results. Greenwald (1986) shows that when the order is reversed and the market firms bid first, then there is no turnover without exogenous separation, and all workers

ability types for whom $m\left(\widehat{\theta}^F\right)^N < \delta$. So, turnover approaches 0 as $\delta \to 0$.

[11] In the context of the model, disclosing output clearly increases second period profit for F. However, it also increases first period profit because one can show that, with symmetric information, equilibrium effort satisfies $c\psi'(e^*) = m > \frac{m}{N+1}\frac{1-(\theta^*)^{N+1}}{1-\theta^*}$. Examining the general conditions under which reputational incentives are strengthened from disclosing information is an interesting topic for future research.

earn the same wage in equilibrium. The reason is that a winner's curse arises: when outside firms bid for a worker, they will only attract him when the employer does not match their offers, so that they are left with the low-ability "lemons" for which they will have overpaid. However, it is impossible to judge what is the more appropriate model for describing labor markets, and in some sense the order of bids is not as important as who makes the last offer.[12]

In conclusion, the chapter identifies a novel trade-off facing organizations. Its strength lies in its simplicity: deriving the results using standard models and basic assumptions uncovers clear economic intuitions for why turnover and effort should be positively related. The message for policy makers and firms is that attempting to create effort incentives and make optimal personnel decisions may be a lost cause with asymmetric information, and that intelligent human resource management must at times sacrifice one for the other.

[12]For example, Golan (2005) has shown that turnover collapses to 0 when the employer can make a counter-offer after the outside market responds to its initial wage.

1.A Proofs

1.A.1 Proof of Lemma 1.1

Proof. If $w^F \neq \emptyset$ and $E\left[m\theta^N \mid w^F, \widehat{w}\right] - w^F - \delta \leq 0$, or if $w^F = \emptyset$ and $E\left[m\theta^N \mid w^F, \widehat{w}\right] - \delta \leq 0$, then no outside firm can profitably employ the worker, so none makes a wage offer.

If instead $w^F \neq \emptyset$ and $E\left[m\theta^N \mid w^F, \widehat{w}\right] - w^F - \delta > 0$, or $w^F = \emptyset$ and $E\left[m\theta^N \mid w^F, \widehat{w}\right] - \delta > 0$, then it cannot be an equilibrium for no outside firm to make an offer, since one firm could deviate and profitably employ the worker. Suppose the highest wage offered in equilibrium is $w^{max} < E\left[m\theta^N \mid w^F, \widehat{w}\right] - \delta$. If there is one firm not offering w^{max}, then it can offer the worker $w^{max} + \varepsilon$ for small enough ε and make a positive profit. If all firms offer w^{max}, then if one offers $w^{max} + \varepsilon$ it increases the probability of employing the worker for an arbitrarily small cost, also increasing its payoff. ∎

1.A.2 Proof of Proposition 1.1

Proof. Conjecture an equilibrium pure strategy $\widetilde{w}^{F*}$ for F, and let

$$\widetilde{\Theta}^F = \left\{ \widehat{\theta}^F \mid \widetilde{w}^{F*}\left(\widehat{\theta}^F\right) \neq \emptyset \right\}.$$

Now, suppose that in equilibrium $\exists \widehat{\theta}_1^F, \widehat{\theta}_2^F \in \widetilde{\Theta}^F$ such that $\widehat{\theta}_1^F \neq \widehat{\theta}_2^F$ and, without loss of generality, $\widetilde{w}^{F*}\left(\widehat{\theta}_1^F\right) < \widetilde{w}^{F*}\left(\widehat{\theta}_2^F\right)$. It must be the case that

$$f\left(\widehat{\theta}^F\right)^N - \widetilde{w}^{F*}\left(\widehat{\theta}^F\right) - \delta \geq 0 \text{ for } \widehat{\theta}^F = \widehat{\theta}_1^F, \widehat{\theta}_2^F$$

and

$$\widetilde{w}^{F*}\left(\widehat{\theta}_2\right) \geq E\left[m\theta^N \mid \widetilde{w}^{F*}\left(\widehat{\theta}^F\right), \widehat{w} = \widetilde{w}^{F*}\right] - \delta \text{ for } \widehat{\theta}^F = \widehat{\theta}_1^F, \widehat{\theta}_2^F.$$

The first condition says that the worker yields F non-negative profits. The second condition says that the worker is paid at least his outside option, since if he were not some market firm would bid him away and F would have expended δ for no gain.

So, regardless of whether the worker is paid $\widetilde{w}^{F*}\left(\widehat{\theta}_1^F\right)$ or $\widetilde{w}^{F*}\left(\widehat{\theta}_2^F\right)$, the outside market does not bid for him. But since

$$f\left(\widehat{\theta}_2^F\right)^N - \widetilde{w}^{F*}\left(\widehat{\theta}_1^F\right) - \delta > f\left(\widehat{\theta}_2^F\right)^N - \widetilde{w}^{F*}\left(\widehat{\theta}_2^F\right) - \delta,$$

F strictly prefers to offer a worker of type $\widehat{\theta}_2^F$ a wage $\widetilde{w}^{F*}\left(\widehat{\theta}_1^F\right)$. So in any pure strategy equilibrium $\widetilde{w}^{F*}\left(\widehat{\theta}^F\right)$ is constant $\forall \widehat{\theta}^F \in \widetilde{\Theta}^F$. That is, all workers offered a wage contract by F are offered the same wage. Denote this wage by $\overline{w}$.

There are two objects needed to fully define $\widetilde{w}^{F*}$: $\overline{w}$ and the retention rule. Clearly

$$\overline{w} = E\left[m\theta^N \mid \widehat{\theta}^F \in \widetilde{\Theta}^F\right] - \delta \tag{1.15}$$

is the profit maximizing wage. It also must be the case that

$$f\left(\theta^*\right)^N - \overline{w} - \delta = 0, \text{ where } \theta^* = \inf \widetilde{\Theta}^F \tag{1.16}$$

since otherwise F could profitably retain a type $\theta^* - \varepsilon$ for small enough ε or else not make a wage offer to type θ^* and save δ. But if F makes zero profit on θ^*, it makes strictly positive profit on all types $\widehat{\theta}^F > \theta^*$, meaning the equilibrium retention rule is to retain all workers whose expect talent surpasses a threshold. The equilibrium value of this threshold can be found be plugging (1.15) into (1.16):

$$\begin{aligned} f\left(\theta^*\right)^N &= E\left[m\theta^N \mid \widehat{\theta}^F \geq \theta^*\right] \\ &= m\frac{\int_{\theta^*}^1 \theta^N d\theta}{1-\theta^*} = \frac{m}{N+1}\frac{1-\left(\theta^*\right)^{N+1}}{1-\theta^*}. \end{aligned} \tag{1.17}$$

It remains to be shown that θ^* exists and is unique. Existence is straightforward. It follows from the fact that the left-hand side of (1.17) is less than the right-hind side at $\theta^* = 0$ and greater than the right-hand side as $\theta^* \to 1$ since

$$\lim_{\theta^* \to 1} \left(\theta^*\right)^N = \lim_{\theta^* \to 1} \frac{1}{N+1}\frac{1-\left(\theta^*\right)^N}{1-\theta^*} = 1$$

and $f > m$.

Uniqueness is more involved. Instead of working with 1.17, it is easier to show that the equivalent expression

$$ax^N(1-x) = \frac{1-x^{N+1}}{N+1}, \tag{1.18}$$

where $a > 1$, has a unique solution on $x \in (0,1)$. The LHS of 1.18 is increasing on $x \in \left(0, \frac{N}{N+1}\right)$ and decreasing on $x \in \left(\frac{N}{N+1}, 1\right)$, and its first derivative is increasing on $x \in \left(0, \frac{N-1}{N+1}\right)$ and decreasing on $x \in \left(\frac{N-1}{N+1}, 1\right)$. The first and second derivatives of the RHS of 1.18 are decreasing on $x \in (0,1)$.

The first derivative of the LHS near $x = 1$—a—is bigger than the first derivative of the RHS near $x = 1$—1. Therefore, uniqueness is guaranteed if a is large enough for 1.18 to have no solution on $x \in \left(\frac{N}{N+1}, 1\right)$. Therefore, proving uniqueness is equivalent to proving that if 1.18 has a solution x^* on $x \in \left(\frac{N}{N+1}, 1\right)$, then x^* is the unique solution. A sufficient condition for this to be the case is for the second derivative of the LHS to be less than the second derivative of the RHS on $x \in \left(\frac{N}{N+1}, 1\right)$. In other words, we need

$$aN\left(N-1\right)x^{N-2} - aN\left(N+1\right) < -Nx^{N-1},$$

which holds for

$$x > \frac{a\left(N-1\right)}{a\left(N+1\right)-1}.$$

Thus, we have uniqueness if

$$\begin{aligned}
\frac{N}{N+1} &> \frac{a\left(N-1\right)}{a\left(N+1\right)-1} \Rightarrow \\
aN^2 + aN - N &> aN^2 + aN - aN - a \Rightarrow \\
N\left(a-1\right) + a &> 0,
\end{aligned}$$

which holds by the assumption $a > 1$.

Finally, for the equilibrium to exist, the wage specified in (1.15) must be greater than 0 for the worker to remain with F. Therefore, it must be the case that $0 < \delta < \frac{1}{N+1}\frac{1-(\theta^*)^N}{1-\theta^*}$.
■

1.A.3 Proof of Lemma 1.2

Proof. Let $f = f'$ and $m = m'$, and let θ' be the corresponding retention threshold. Suppose f' increases to f''. It must then be the case that

$$f''\left(\theta'\right)^N > \frac{m'}{N+1}\frac{1-\left(\theta'\right)^{N+1}}{1-\theta'}.$$

By continuity, there must then exist some $\theta'' \in (0, \theta')$ at which

$$f''\left(\theta''\right)^N = \frac{m'}{N+1}\frac{1-\left(\theta''\right)^{N+1}}{1-\theta''}.$$

Moreover, by the proof of Proposition 1.1, θ'' must be unique. Thus, the retention threshold is strictly decreasing in f. A similar argument can be made for m. ■

1.A.4 Proof of Proposition 1.2

Proof. First, suppose that out-of-equilibrium beliefs are defined in the following way.

$$\widehat{\theta^F} = \begin{cases} 0 \text{ if } y_1 - e^F \leq 0 \\ y_1 - e^F \text{ if } y_1 - e^F \in (0,1) \\ 1 \text{ if } y_1 - e^F \geq 1. \end{cases}$$

The worker's problem is

$$\begin{aligned}
&\max_e \Pr\left[\widehat{\theta}^F > \theta^*\right] W(\theta^*) - c\chi(e) \\
=&\max_e \Pr\left[\theta + e - e^F > \theta^*\right] W(\theta^*) - c\chi(e) \\
=&\max_e \Pr\left[\theta > \theta^* - e + e^F\right] W(\theta^*) - c\chi(e).
\end{aligned}$$

Clearly, the objective function is concave in e. When $e = e^F + \theta^*$, $\Pr\left[\theta > \theta^* - e + e^F\right]$ is 1, so the worker will choose some $e \in \left[0, e^F + \theta^*\right]$. When $W \geq c\chi'\left(e^F + \theta^*\right)$, then $e^W = e^F + \theta^*$ and when $W < c\chi'\left(e^F + \theta^*\right)$, e^W satisfies

$$W - c\chi'\left(e^W\right) = 0.$$

The corner solution can never be an equilibrium since $e^W \neq e^F$. On the other hand, when e^F satisfies

$$W - c\chi'\left(e^F\right) = 0,$$

then

$$W - c\chi'\left(e^F + \theta^*\right) < 0,$$

so that the $e^W = e^F \in \left(0, e^F + \theta^*\right)$. ■

1.A.5 Proof of Lemma 1.3

Proof. One needs to show that $\frac{1-(\theta^*)^N}{1-\theta^*}$ is increasing in θ^*. The derivative is

$$\frac{-N(\theta^*)^{N-1}(1-\theta^*) + 1 - (\theta^*)^N}{(1-\theta^*)^2}.$$

This expression is positive whenever

$$\frac{1}{N}\frac{1-(\theta^*)^N}{1-\theta^*} > \theta^{*N-1},$$

which is equivalent to

$$E\left[\theta^{N-1} \mid \theta \geq \theta^*\right] > \theta^{N-1},$$

which holds whenever $N > 1$. ■

1.A.6 Proof of Proposition 1.3

Proof.

Differentiating (1.11) with respect to p gives

$$(1 - pW)\frac{W}{c} - \varepsilon\left(\theta^*\right)^{N+1}. \tag{1.19}$$

Since (1.19) is decreasing on $p \in [0,1]$, (1.11) is concave in p. There are three possible cases. If

$$\frac{W}{c} < \varepsilon\left(\theta^*\right)^{N+1},$$

then $p^* = 0$. As $c \to \infty$ this condition clearly holds. Second, if

$$(1 - W)\frac{W}{c} < \varepsilon\left(\theta^*\right)^{N+1}$$

then $p^* = 1$. This condition clearly holds as $c \to 0$. Otherwise, p^* satisfies

$$(1 - p^*W)\frac{W}{c} = \varepsilon\left(\theta^*\right)^{N+1},$$

from which one obtains

$$\frac{\partial p^*}{\partial c} = \frac{1 - pW}{cW} > 0.$$

■

1.A.7 Proof of Proposition 1.4

Proof. Let θ'' and θ' be the equilibrium retention thresholds when general human capital is g'' and g', respectively. One can write the equilibrium threshold in general as

$$\left(1 + \frac{h}{g}\right)\left(\theta^*\right)^N = \frac{1}{N+1}\frac{1 - \left(\theta^*\right)^{N+1}}{1 - \theta*}.$$

By the arguments in the proof of Lemma 1.2, then, $\theta'' > \theta'$. If one denotes W'' and W' as the wage difference between retained and released workers when g'' and g', respectively, then by Lemma 1.3, $W'' > W'$.

F will therefore invest in general human capital whenever

$$(\chi')^{-1}\left(\frac{W''}{c}\right) - (\chi')^{-1}\left(\frac{W'}{c}\right) > \frac{h^*\left[\left(\theta''\right)^{N+1} - \left(\theta'\right)^{N+1}\right]}{N+1} + K,$$

which holds if and only if c is high enough. ■

1.A.8 Proof of Proposition 1.5

Proof. Let θ'' and θ' be the equilibrium retention thresholds when F chooses h'' and h', respectively, and let W'' and W' be the associated wage differentials. From previous arguments (Lemmas 1.2 and 1.3), $\theta'' < \theta'$ and $W'' < W'$. F invests in firm-specific capital whenever

$$\frac{h''\left[1-(\theta'')^{N+1}\right]-h'\left[1-(\theta')^{N+1}\right]}{N+1} > K + (\chi')^{-1}\left(\frac{W'}{c}\right) - (\chi')^{-1}\left(\frac{W''}{c}\right).$$

Clearly, this condition will not hold for small enough c. ∎

Chapter 2

The Benefits of Limited Feedback in Organizations

2.1 Introduction

Most organizations have performance appraisal systems in place that allow managers to provide feedback to workers at regular intervals. Such arrangements have existed for centuries, and their use has grown to the point that they are now a common feature of the modern workplace.[1] Not only are they ubiquitous, but performance appraisals consume vast amounts of managerial time, both for the human resource professionals that design and administer reviews as well as for the front line managers who actually conduct them.[2]

A typical firm conducts annual or semi-annual performance reviews in which supervisors give numerical ratings to the workers they oversee. Figure 2.1 displays a rating distribution from a medium-sized service firm in the United States.[3] In this firm, 1 is the rating associated with highest performance, and 5 the worst.

In this firm, almost no workers receive negative feedback: 4 and 5 make up just one percent of the sample. Moreover, there is a marked central tendency in the distribution, with fully fifty percent of workers receiving the rating 2. At the very least, one can conclude that managers in this firm do not differentiate between levels of performance as much as the rating scale allows them to. While this distribution comes from only

[1]Performance appraisal systems were in place by 300 AD in the Chinese state bureaucracy. As of the early 1980's, between seventy four and eighty nine per cent of American businesses used them (Murphy and Cleveland 1991).

[2]The Chief Human Resource Counsel for International Paper recently noted that "...few tasks occupy as much time by human resource professionals as designing, implementing, monitoring, and defending performance appraisal systems" (Murphy and Margulies 2004).

[3]This figure is taken directly from Lazear and Gibbs (2008). The data have previously been analyzed in Baker, Gibbs, and Holmström (1994a), Baker, Gibbs, and Holmström (1994b), and Gibbs (1995), among others.

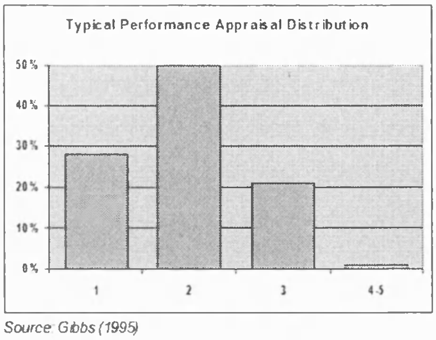

Figure 2.1: Example of Rating Distribution

one firm, other firms' rating distributions exhibit similar patterns (Medoff and Abraham 1980, Murphy 1992).

Knowing the true distribution of performance in the firm is impossible, so figure 2.1 taken by itself does not allow one to reach any definite conclusions about feedback. However, there is evidence that it reflects managers' hiding private information from workers. Several studies have shown that the ratings that supervisors report to workers are significantly higher and more skewed than the ratings they report to independent researchers (see Murphy and Cleveland 1991, p.79, and references therein). Also, the same patterns emerge when rating categories have labels such as "average" and "below average" (Gibbs 1991).[4] Finally, workers and managers themselves report that managers do not distinguish among workers.[5]

The economics and HRM literature has identified several reasons for why there might be limited feedback in organizations. First, managers are very often not rewarded for providing accurate appraisals, so they might not exert the effort required to assess and document the performance of their workers (Baron and Kreps 1999). Second, managers may exhibit favoritism and bias ratings (Prendergast and Topel 1996). Third, organizational politics may constrain truth-telling.[6] Finally, worker psychology may discourage

[4]In one particularly stark example, Milkovich, Newman, and Milkovich (2007) report a ten-year study of a thousand-member social service department in which only three of the possible ten thousand ratings were "below average".

[5]In a case study of Merck, Murphy (1992) reports such sentiments as "Tell me this, how in the world can 83 per cent of the people be exceeding job expectations while the company, as a whole, is doing just average?" and "How can I rate my people objectively when the other directors are giving all their people 4s? A 3 isn't acceptable. I wouldn't mind if everyone played by the same rules, but they don't."

[6]For example, Longenecker, Sims, and Gioia (1987) write that

> ...it is likely that political considerations influence executives when they appraise subordinates. Politics in this sense refers to deliberate attempts by individuals to enhance or protect their self-interests when conflicting courses of action are possible. Political action therefore represents a source of bias or inaccuracy in employee appraisal.

honesty.[7] In short, many argue that either a prinicpal-agent problem between those wanting to use information (an HR office) and those able to gather it (front-line managers), or else the fallibility of human psychology and relationships, limits information flow in organizations.

These views implicitly assume that limited communication is necessarily the result of organizational dysfunction. However, without a proper understanding of the effects of information disclosure and their relationship to worker motivation and wages, it is impossible to determine what is the "right" level of feedback. The goal of this chapter is both to identify the effects of feedback and to derive the optimal feedback policy to which the firm would like to commit. It finds that in a wide variety of situations, optimal feedback policies never explicitly identify poor performance, but instead pool all poorly performing workers together. Moreover, some firms never explicitly identify good performance, meaning that all workers infer their performance to be in the middle of the distribution. However, the chapter also shows that firms would always like to commit to share some of their private information with workers, meaning that providing feedback to workers is in fact a source of value for organizations through its effect on motivation.

Performance appraisal is most relevant in situations in which output is subjective. Moreover, with subjective output, work incentives arise through implicit incentives since output is non-verifiable. The chapter therefore examines information disclosure in a principal-agent model in which the agent has career concerns (the chapter will hereafter refer to the principal as the firm and the agent as the worker). The worker (he) exerts effort for two periods, after which he earns a fixed reputational reward if his expected talent surpasses a threshold; however, only the firm (it) observes output. However, before the employment relationship begins, the firm can commit to disclosing a set of its posterior beliefs on worker talent to the worker between his first and second period effort choices. There are two main effects of feedback:

1. *Effort risk.* Feedback creates uncertainty about future effort levels. Depending on the feedback that the worker receives he can either find himself working more or less hard in the second period. If he does not receive feedback, then his second period effort level is equal to the average of all possible levels under feedback. Since the worker's preferences over effort levels are given by his (convex) cost function, he would rather work some given amount for certain than the same amount in

[7]For example, Jackman and Strober (2003), writing about performance appraisal, state that workers

> ...hate being criticized, plain and simple. Psychologists have a lot of theories about why people are so sensitive to hearing about their own imperfections. One is that they associate feedback with the critical comments received in their younger years from parents and teachers.

expectation. So, feedback exposes the worker to effort risk, which increases his disutility of effort.

2. *Coasting incentive.* As in all career concerns models, signal jamming provides effort incentives in the first and second period as the worker seeks to interfere directly with the employer's learning about his ability. Feedback introduces an additional motive for first period effort.[8] Whenever the worker receives feedback, the firm's belief about the amount of effort he will exert in the second period depends on his first period performance since it anticipates he will tailor his effort choice to the probability of promotion. But this implies that the worker can use first period effort to reduce the amount of effort the firm expects him to exert in the second period, which increases the degree to which it attributes second period output to his talent. In summary, the worker wants to use first period effort to trick the firm into thinking he will not work hard—or coast—in the second.

After identifying these effects of feedback, the chapter solves for the optimal disclosure policy. This derives from the firm's profit maximization problem, and depends crucially on the expected future payoff from joining the firm. When it is large, the participation constraint never binds for any disclosure policy, and the firm extracts as much effort as possible from the worker through choosing a disclosure policy that maximizes coasting incentives. It does so by only giving feedback when its posterior on worker talent is sufficiently high. When the expected payoff is low, the worker needs to be compensated to join the firm and his participation constraint always binds. In this case, increasing feedback increases the up-front wage the firm must pay the worker, and the firm only reveals an intermediate range of talent beliefs to the worker.

The chapter then endogenizes the wage schedule and the size of the expected future payoff from joining the firm using a model of adverse selection labor market competition. The main result is that a firm offers a high payoff if the productivity of experienced workers in its industry is sufficiently sensitive to talent.

The chapter concludes by identifying the industries in which performance appraisal is most widespread using a cross-sectional survey of firms in the United Kingdom, and finds that professional service industries occupy the majority of the top places. While this evidence is consistent with the model, there are other explanations for why such a pattern would arise. The chapter therefore distinguishes its rationale for giving feedback from others, and suggests a statistical test that would allow one to identify whether feedback affects motivation when workers have career concerns.

[8] In the model, expected second period effort is independent of the disclosure policy. Hence, an important feature of the model is that the *anticipation* of feedback creates effort incentives.

The importance of the chapter is that it studies feedback in organizations in a fully micro-founded, rational choice model with standard economic preferences and technology, and yet shows that optimal feedback policies have properties that scholars often view as dysfunctional. Interestingly, it shows that if anything one should worry about certain firms giving *too much* feedback and failing to account for the social cost of their actions in the form of increased effort risk for the worker. In any case, a firm would never want to provide fully informative feedback, and one that did would face de-motivated workers and difficulty in attracting new talent.

Related Literature The chapter makes three distinct contributions to the literature. First, it analyzes general disclosure policies on a continuous output space and allows for endogenous compensation. Second, it shows that rating compression and avoidance of negative feedback are compatible with optimal feedback. Third, it examines how the worker's information affects relationships with career concerns.

Several recent papers (Aoyagi 2007, Ederer 2008, Goltsman and Mukherjee 2008) have examined effort maximizing disclosure policies in two period tournaments with two competitors. Aoyagi (2007) relates the optimal disclosure policy to the cost of effort function and finds that if the marginal cost of effort is convex, no disclosure is optimal; if the marginal cost is concave, full disclosure is optimal; and if the marginal cost is linear, all disclosure policies yield equivalent expected effort. Ederer (2008) uses a similar framework, but adds ability into the production function. In this environment, information disclosure can provide effort incentives because it allows a worker to signal his ability to his competitor. When ability and effort are complementary in production and costs are quadratic, full information disclosure is optimal under certain distributions. Goltsman and Mukherjee (2008) restrict production to only taking two values. They find that the optimal disclosure policy reveals no information to the contestants unless both produce a low output in the first period, in which case this outcome is told to both of them. A limitation of these papers is that they do not endogenize the tournament prize, nor the agents' initial compensation. Both ex ante and ex post compensation play an important role in this chapter.

Lizzeri, Meyer, and Persico (2002) study optimal disclosure in a two period moral hazard problem in which the principal can offer output contracts. With full disclosure, first period effort is always higher whenever the wage function is non-linear, but expected second period effort costs are higher, like in this chapter. When the principal can choose optimal compensation, the second effect dominates and it never reveals information to the worker. This result stands in contrast to the empirical observation that some, albeit limited, feedback appears in most organizations.

MacLeod (2003) looks at how a principal optimally uses its subjective assessment of worker output with static relational contracting. He shows that the provision of incentives entails social waste, and that the waste-minimizing contract pays the agent a fixed wage for all output signals except the one most informative about low output. Fuchs (2007) extends these results to a repeated relationship. He finds that when the principal-agent relationship is finite, the principal gives no feedback to the agent until the last period, and then only if the agent produces a low output in each period. When he is kept in the dark about his performance, the agent attaches a higher weight to being in the bad state, so he keeps working hard to avoid money burning.[9] The focus in both these papers is how to sustain work incentives while keeping social costs low. In this chapter, signal jamming incentives induce effort, and do not entail waste. Moreover, the chapter assumes the principal commits ex ante to a disclosure policy, so does not impose truth-telling constraints.

The chapter also builds on the career concerns literature initiated by Fama (1980) and Holmström (1999). Several papers have found circumstances under which more information about an agent's behavior harms the principal. For example, in Holmström (1999), increasing the precision of the principal's belief on the agent's talent reduces his effort. Dewatripont, Jewitt, and Tirole (1999) provide conditions under which an agent can exert more effort when the prinicpal knows less about his output. In a more recent paper, Kovrijnykh (2007) shows that delaying the release of information about worker performance to the labor market can reduce oversupply of effort in a dynamic career concerns model. When agents care about signalling expertise rather than effort, Prat (2005) has demonstrated how an improvement in incentives arises when the principal does not observe the action the agent takes. In contrast to all these papers, this chapter shows that limiting the amount of information that the *agent* has about his action can help the principal when the agent has career concerns. Another related paper in the literature is Martinez (2008), who shows that current effort can effect the firm's future beliefs about worker talent. However, he does not explore the relationship of this effect to information disclosure.

The rest of the chapter proceeds as follows. The next section presents and motivates the model. The third section solves for the equilibrium and identifies the effects of information disclosure. The fourth section then introduces the profit maximization problem for the firm, derives the optimal feedback policy, discusses its properties, and examines robustness. The fifth section endogenizes the rewards to talent schedule through labor market competition and connects feedback to production technology. The sixth discusses

[9]The result is related to Abreu, Milgrom, and Pearce (1991), who show that delaying the accumulation of information about actions can improve outcomes in repeated games with private monitoring.

the model in light of observed inter-industry variation in performance appraisal use and discusses possible extensions. Unless otherwise stated, all unproven results in the text are proved in the Appendix.

2.2 Model

2.2.1 Setup

There are four time periods $t = 0, 1, 2, 3$. A risk neutral firm F and a risk neutral, liquidity constrained worker meet in period 0 to determine the contract that will define their relationship over periods 1 and 2. Their relationship must last two periods, and neither party can break from the other after period 1. In periods 1 and 2, the worker produces $y_t = \theta + e_t + \varepsilon_t$, where θ is talent, e_t is effort, and $\varepsilon_t \sim N\left(0, \sigma_\varepsilon^2\right)$ is an output shock uncorrelated across time periods and with θ. Neither the worker nor the firm knows θ at period 0, but they share a common prior distribution $N\left(\overline{\theta}, \sigma_\theta^2\right)$ on it, where $\overline{\theta} > 0$. The cost to the worker of exerting effort is $g\left(e_t\right) = \frac{C}{2} e_t^2$,[10] and he has an outside option of u, which can be thought of as the utility of leisure or the wage he could receive in another industry.

As in standard principal-agent models, the worker privately observes e_t. Unlike in the standard model, though, the firm privately observes y_t. After observing $\{y_\tau\}_{\tau=1}^{t}$, the firm forms belief $\widehat{\theta}_t^F$ on worker talent. After period 2, F continues to employ the worker if $\widehat{\theta}_2^F \geq \theta^*$. The rewards to talent schedule for the worker is given by

$$w\left(\widehat{\theta}_2^F\right) = \begin{cases} \overline{W} \text{ if } \widehat{\theta}_2^F \geq \theta^* \\ \underline{W} \text{ if } \widehat{\theta}_2^F < \theta^* \end{cases}$$

where $\overline{W}$ is the utility the worker receives from continued employment with the firm, and $\underline{W}$ is the utility he receives upon release; so, $W = \overline{W} - \underline{W} > 0$ is the net return from continued employment. The results of the chapter depend quite heavily on the particular structure of this wage function, so determining its plausibility is important. In fact, the previous chapter provided a microfoundation for just such a wage function: it is the outcome of adverse selection labor market competition. Moreover, because the firm observes output and the worker does not, it is consistent to assume that outside firms can also not observe worker outcome, meaning that adverse selection labor market competition is a natural to think about the rewards to talent. The chapter later returns to discuss this issue in more detail.

[10]The robustness of the model to this cost structure is discussed in section 2.4.4

A contract in period 0 consists of two objects. The first is a payment w that F offers the worker to attract him into employment. Because the worker is liquidity constrained, this payment must be non-negative.

Assumption 2.1 $w \geq 0$.

The second is a disclosure policy that gives the worker information about $\widehat{\theta}_1^F$ before his choice of e_2. In fact, disclosing $\widehat{\theta}_1^F$ is equivalent to disclosing y_1, but since $\widehat{\theta}_1^F$ is more important for the strategic effects in the model, the chapter chooses to focus on it.

Definition 2.1 *A disclosure policy is a mapping ψ such that*

$$\psi\left(\widehat{\theta}_1^F\right) = \begin{cases} \widehat{\theta}_1^F \text{ if } \widehat{\theta}_1^F \in \Theta \\ \emptyset \text{ if } \widehat{\theta}_1^F \notin \Theta \end{cases}$$

where the firm discloses $\widehat{\theta}_1^F$ to the worker if and only if $\widehat{\theta}_1^F \in \Theta$.

The structure of a disclosure policy is that the firm communicates to the worker exactly its belief about his talent (in which case $\psi\left(\widehat{\theta}_1^F\right) = \widehat{\theta}_1^F$), or else says nothing at all (in which case $\psi\left(\widehat{\theta}_1^F\right) = \emptyset$).[11] Choosing a disclosure policy is equivalent to choosing Θ, the set of beliefs revealed to the worker. Since disclosure policies that differ at points with measure zero are equivalent, choosing Θ is equivalent to choosing a set of the form $\cup_i (\underline{x}_i, \overline{x}_i)$ such that $(\underline{x}_i, \overline{x}_i) \subseteq \mathbb{R}$ and $\overline{x}_i < \underline{x}_{i+1}$. In other words, Θ is a union of non-overlapping convex subsets of the real number line. While more general specifications of ψ are possible, this definition does allow for flexibility in the sense that the full disclosure policy $\Theta = (-\infty, \infty)$ and the no disclosure policy $\Theta = \emptyset$ are just two extremes of a continuum of admissible forms of ψ.[12]

An important assumption is that F commits to a disclosure policy in period 0 that it cannot overturn after observing y_1. This ensures the most favorable conditions possible for communication between the firm and the worker. If performance appraisals were limited in their informational content because of difficulties the firm had in credibly communicating its private information, then this would constitute a problem for the firm and limit its profit. If on the other hand the firm wants to actively *commit* to limiting information flow, then performance appraisals with limited communication are actually best for the organization.[13]

[11]Of course, the outcome $\emptyset$ still has informational content, since the worker learns that the firm's beliefs do not lie in Θ.

[12]Section 2.4.4 analyzes more general disclosure policies.

[13]The chapter later shows that F would indeed like to lie to worker after observing y_1. One possible avenue for deriving Θ as the equilibrium of a strategic communication game between the firm and the worker would be to introduce more periods into their relationship, so that the firm's lying could be found out by the worker and suitably punished.

Definition 2.2 *The informativeness of a disclosure policy* Θ *is* $\Pr\left(\widehat{\theta}_1^F \in \Theta\right)$.

Informativeness is a measure of how much feedback a disclosure policy provides. Because F discloses $\widehat{\theta}_1^F$ completely or not at all, a natural measure of the quantity of feedback a disclosure policy gives is the probability that $\widehat{\theta}_1^F$ falls in the set of disclosed beliefs.

The chapter also distinguishes between two kinds of disclosed interim beliefs.

Definition 2.3 *Positive feedback is*

$$\left\{\widehat{\theta}_1^F \mid \widehat{\theta}_1^F \in \Theta, \widehat{\theta}_1^F > \theta^*\right\}$$

and negative feedback is

$$\left\{\widehat{\theta}_1^F \mid \widehat{\theta}_1^F \in \Theta, \widehat{\theta}_1^F < \theta^*\right\}.$$

When the disclosure policy reveals to the worker that $\widehat{\theta}_1^F > \theta^*$, the worker finds out that earning the reputational reward W is relatively likely, while if he learns that $\widehat{\theta}_1^F < \theta^*$, he learns that it is not.[14] Positive feedback thus constitutes good news about the worker's future prospects of working with F, and negative feedback bad news. These two different kinds of feedback will have important implications for the optimal disclosure policy.

One important assumption is that only F and the worker observe $\psi\left(\widehat{\theta}_1^F\right)$. This essentially rules out a contract that depends explicitly on output, since there is no way for a court to enforce such a contract if it cannot observe any information about y_1. In periods 1 and 2, therefore, only implicit incentives exist for the worker, and the chapter assumes that these come from career concerns.

F chooses ψ and w to maximize expected profit, given by $E\left[y_1 + y_2\right] - w$. To summarize, the timing of the game is the following.

1. F offers the worker ψ and w.

2. The worker chooses e_1.

3. The outcome of ψ is revealed to the worker.

4. The worker chooses e_2.

5. If $\widehat{\theta}_2^F \geq \theta^*$ the worker continues to work for F and earns net reward W.

[14] In equilibrium, knowing $\widehat{\theta}_1^F > \theta^*$ leads the worker to estimate that his probability of earning W is greater than one half, while knowing $\widehat{\theta}_1^F < \theta^*$ means the estimated probability is less than one half.

2.2.2 Motivation for setup

The model provides a natural description for a professional service industry such as management consulting, law, or accounting. Maister (1993) describes the defining characteristics of these industries in detail, and the chapter uses his analysis as a benchmark with which to compare the model. Most professional service firms are partnerships with two or three layers. On top, there are the partners themselves, who engage in high-value activities, enjoy high earnings, and have relative job security, while the bottom layer(s) are composed of less experienced workers engaging in lower value tasks. These firms "make few, if any, performance differentials in their compensation of junior staff" (Maister 1993, p.196), and work incentives for juniors derive from the desire for promotion to partner. Moreover, most service firms operate an up-or-out system (either implicitly or explicitly), in which junior workers leave the firm if they have failed to reach partner within a fixed time frame. The assumption that career concerns are the main motivator for workers, and that there is a final period in which reputational rewards accrue to the most talented workers is thus highly realistic.

The chapter eventually models the period 3 reward for the worker as the outcome of labor market competition for talent, yet assumes that a particular firm extracts surplus from him in period 0. The motivation for this assumption is that junior staff in service industries "do not join professional firms for *jobs*, but for *careers*" (Maister 1993, p.6). Entry level positions in service firms give workers valuable experience and training that allow them to move on fairly quickly to prime positions in a wide variety of industries. As long as the number of entry level positions in service industries is smaller than the number of potential entrants, firms have all the bargaining power with junior workers. However, after junior workers serve their apprenticeships, their employers must compete with other firms in other industries to retain top talent.[15]

The fact that outsiders do not observe the outcome of a disclosure policy could arise from several circumstances. First, although many firms provide feedback to their employees, not all firms provide a hard copy of the outcome of performance reviews to their employees. Workers thus may not always be able to prove they did or did not get positive

[15]In a discussion of the scarcity of young, educated workers, Maister (1993) writes:

> Most professions provide attractive *initial* career opportunities relative to other industries. Law school graduates will probably continue to join law firms, accounting graduates to join accounting firms, and business school graduates will continue to fined consulting and investment banking attractive first jobs.
>
> The real impact of the people crisis will be felt in absorbing the high costs that will result from competition for educated young workers, and continuing to make the professional-firm career path attractive in an environment when mid-level employees will receive numerous "head-hunting" calls (Maister 1993, p.192-3).

feedback to potential employers. Second, outside firms may not know whether a worker was or was not given feedback in a particular job or company, and so may not even request information on feedback during interviews. Finally, even if outsiders are informed of the outcome of a particular employee's performance review, they cannot always clearly interpret the information. Using performance appraisal information to infer a worker's talent requires information on what job he did, who his supervisor was, and what targets were set for him, and these institutional details are often not known by those outside an organization.

2.2.3 Definition of equilibrium

Let e_t^F be F's belief on period t worker effort, and e_t^W be the worker's actual period t effort. Let $\widehat{\theta}_t^F = E\left[\theta \mid \{y_\tau, e_\tau^F\}_{\tau=1}^t\right]$ be F's belief on worker talent after observing a given history of output realizations, and $\widehat{\theta}_t^W = E\left[\theta \mid \{\psi(y_\tau), e_\tau^W\}_{\tau=1}^t\right]$ be the worker's belief on his talent after observing a history of disclosures. Define $\widehat{\theta}_0^i \equiv \overline{\theta}$ for $i \in \{F, W\}$. Using notation for precisions of the normally distributed variables rather than variances is more convenient in defining equilibrium effort levels, so let $h_\varepsilon \equiv (\sigma_\varepsilon^2)^{-1}$, $h_\theta \equiv (\sigma_\theta^2)^{-1}$, and $\lambda_t \equiv \frac{h_\varepsilon}{th_\varepsilon + h_\theta}$.

Definition 2.4 *Equilibrium efforts e_1^* and e_2^* satisfy the following conditions (for $t \in \{1, 2\}$):*

$$
\begin{aligned}
e_2^W &= \arg\max_{e_2} -g(e_2) + \Pr\left[\widehat{\theta}_2^F > \theta^*\right] W && (2.1)\\
e_1^W &= \arg\max_{e_1} -g(e_1) - E\left[g\left(e_2^W\right)\right] + \Pr\left[\widehat{\theta}_2^F > \theta^*\right] W && (2.2)\\
\widehat{\theta}_t^F &= \lambda_t\left(y_t - e_t^F\right) + (1-\lambda_t)\,\widehat{\theta}_{t-1}^F && (2.3)\\
\widehat{\theta}_t^W &= E\left[\lambda_t\left(y_t - e_t^W\right) + (1-\lambda_t)\,\widehat{\theta}_{t-1}^W \mid \psi\left(\widehat{\theta}_1^F\right)\right] && (2.4)\\
e_t^* &= e_t^W = e_t^F. && (2.5)
\end{aligned}
$$

These conditions together constitute a Perfect Bayesian Equilibrium. The first two require the worker to maximize utility in all periods, the next two require Bayesian learning on the parts of the worker and the firm about the worker's talent, and the final requires the firm's beliefs about worker effort to be consistent with the worker's effort choices. (2.3) also shows why disclosing $\widehat{\theta}_1^F$ is equivalent to disclosing y_1: the former is simply a linear function of the latter. On the equilibrium path, F holds the belief about worker talent consistent with his actual effort choices, and in this case $\widehat{\theta}_t^F = \widehat{\theta}_t^W = \widehat{\theta}_t$. The distributions of $\widehat{\theta}_2^F \mid \widehat{\theta}_1$ and $\widehat{\theta}_1^F$ are important for interpreting equilibrium effort levels, so they are given below.

Lemma 2.1 *Let* $\sigma_2^2 = \frac{\lambda_2}{h_\varepsilon + h_\theta}$ *and* $\sigma_1^2 = \frac{\lambda_1}{h_\theta}$.

$$\begin{aligned} \widehat{\theta}_2^F \mid \widehat{\theta}_1 &\sim N\left(\widehat{\theta}_1 + \lambda_2\left(e_2 - e_1^F\right), \sigma_2^2\right) \\ \widehat{\theta}_1^F &\sim N\left(\overline{\theta} + \lambda_1\left(e_1 - e_1^F\right), \sigma_1^2\right). \end{aligned}$$

Global concavity of the problems in (2.1) and (2.2) is necessary for equilibrium existence. The parametric restriction guaranteeing global concavity for (2.1) is used in a later proof, so it is explicitly stated as an assumption.

Assumption 2.2 $\frac{W}{C}\left(\frac{\lambda_2}{\sigma_2}\right)^2 < 1$.

With the elements of the model completely described, the chapter turns to solving it.

2.3 Effects of Feedback

This section solves for the worker's equilibrium effort levels according to Definition 2.4 via backward induction, and studies how they depend on feedback. The goal is not to study optimal disclosure, but to identify its primary effects. It first considers second period effort along with effort risk, then turns to first period effort along with coasting incentives.

2.3.1 Second period effort and effort risk

The second period is the last period of the game in which the worker exerts effort. If the game is on the equilibrium path, and the firm holds belief $\widehat{\theta}_1$ on worker talent (notation that was introduced in the previous section for equilibrium beliefs) then, by (2.3), the firm's second period belief as a function of y_2 is

$$\widehat{\theta}_2^F = \lambda_2\left(y_2 - e_2^F\right) + (1 - \lambda_2)\,\widehat{\theta}_1 \tag{2.6}$$

From (2.6) one can see the source of effort incentives in the second period. By increasing e_2 the worker can increase $\widehat{\theta}_2^F$ and improve his chance of earning W in period 3. This *signal jamming incentive* appears in all career concerns models of effort supply. In equilibrium, the firm correctly infers that the worker exerts an effort level that equates the marginal benefit of increasing $\widehat{\theta}_2^F$ with the marginal cost of effort. The next result shows how the strength of signal jamming incentives depends on the information that the disclosure policy has revealed to him. Throughout this section and the rest of the chapter, ϕ will denote the standard normal probability density function.

Proposition 2.1 *Suppose the game is on the equilibrium path in period 2. Given Assumption 2.2, e_2^* exists and is unique. If $\psi\left(\widehat{\theta}_1\right) = \widehat{\theta}_1$,*

$$e_2^*\left(\widehat{\theta}_1\right) = \frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) \tag{2.7}$$

and if $\psi\left(\widehat{\theta}_1\right) \neq \widehat{\theta}_1$,

$$e_2^* = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) \mid \widehat{\theta}_1 \notin \Theta\right]. \tag{2.8}$$

The easiest way to understand the proposition is to consider figure 2.2, which plots out second period equilibrium effort as a function of $\widehat{\theta}_1$. The top graph gives equilibrium effort under the maximally informative disclosure policy $\Theta = (-\infty, \infty)$, and the bottom graph shows equilibrium effort under some disclosure policy $\Theta = (\underline{x}, \overline{x})$ where $\underline{x}$ and $\overline{x}$ lie equidistant from θ^*.

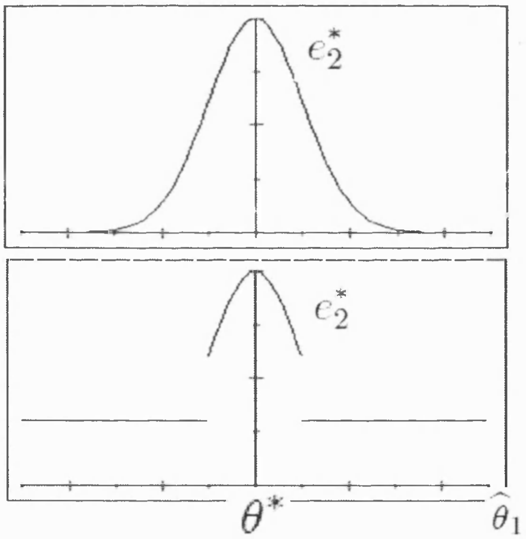

Figure 2.2: Equilibrium Effort with Full and Partial Disclosure

Under the full disclosure policy, the worker exerts the most effort when $\widehat{\theta}_1 = \theta^*$.[16] In this situation, whether or not the firm will retain the worker is still highly uncertain, so the worker's future payoff is sensitive to y_2. In contrast, if $\widehat{\theta}_1$ is either very high or very low the worker's period 3 payoff is practically a foregone conclusion: he is almost certain to earn $\overline{W}$ or $\underline{W}$ so his payoff is not sensitive to y_2. In this case, the worker exerts little effort. In terms of period 2 effort, positive and negative feedback exhibit symmetry. As

[16]This is also the reason it is important for the firm to commit to Θ. Without this commitment, it would always have an incentive to lie to the worker in order to increase his second period effort.

one can see from 2.2, a worker who learns that his expected talent is $\underline{x}$ works just as hard as worker who learns his expected talent is $\overline{x}$. What matters for effort incentives is how far the feedback is from θ^*, not on which side of θ^* the feedback falls. In this sense, negative feedback is no more demotivating than positive feedback.

The bottom graph in figure 2.2 shows another important property of a disclosure policy. When the worker does not receive feedback, second period equilibrium effort does not depend directly on first period performance. Instead, he takes the expectation over all possible undisclosed talent types in selecting effort. Although the firm's belief about the worker's talent changes when y_1 changes within Θ^C, the worker's belief about his own talent does not change, so his effort is independent of y_1. This property is important for analyzing first period effort.

Depending on the disclosure policy, the worker can exert more or less effort for any particular $\widehat{\theta}_1$. Under the disclosure policy $\Theta = (\underline{x}, \overline{x})$, a worker for whom $\widehat{\theta}_1$ is either very high or very low works harder than he would under $\Theta = (-\infty, \infty)$ since he does not learn that his talent type is far from θ^*. Conversely, a worker for whom $\widehat{\theta}_1 = \underline{x}$ or $\widehat{\theta}_1 = \overline{x}$ works less harder under $\Theta = (\underline{x}, \overline{x})$ than under $\Theta = (-\infty, \infty)$ since he infers his talent to be further away from θ^* than it actually is. An important question is therefore how a disclosure policy affects expected second period effort over all possible realizations of $\widehat{\theta}_1$. The next result shows it has no effect at all.

Lemma 2.2 *$E\left[e_2^*\right]$ is independent of Θ.*

The result is a straightforward application of the law of total probability. It arises because with quadratic effort costs the marginal cost of effort is linear, as is the expectation operator. The assumption of quadratic costs is crucial here. Using Jensen's inequality, one can show that if the marginal cost function were convex, $\Theta = \emptyset$ would maximize $E\left[e_2^*\right]$, and if it were concave, $\Theta = (-\infty, \infty)$ would. The quadratic cost function is thus the only reasonable cost specification for which there is no effect of information disclosure on $E\left[e_2^*\right]$.[17] The reason for making this assumption is to limit the effects of information disclosure to two. With non-quadratic costs there would be a third effect of feedback as well, but effort risk and coasting incentives would remain.

While information disclosure does not impact the expected value of second period effort, it does impact the worker's second period disutility of effort. This is the first major effect of information disclosure.

Lemma 2.3 *(Effort Risk). Suppose there exist two disclosure policies Θ and Θ' such that $\Theta \subset \Theta'$. Then $E\left[(e_2^*)^2 \mid \Theta'\right] > E\left[(e_2^*)^2 \mid \Theta\right]$.*

[17]This result echoes those in Aoyagi (2007) and Ederer (2008), who show that with quadratic costs and separability of talent and effort in production, all disclosure policies yield equivalent expected effort in dynamic tournaments.

Mathematically speaking, this result is an application of Jensen's inequality, which in standard form states that $E\left[(e_2^*)^2\right] > (E\left[e_2^*\right])^2$. The proof applies Jensen's inequality to $\Theta'\backslash\Theta$, the set of interim beliefs that Θ' discloses but Θ does not. Economically speaking, the result is simply risk aversion, although over effort rather than wealth levels. The worker's preferences over second period effort are given by $-\frac{C}{2}\left(e_2^*\right)^2$, a concave function. Since $E\left[e_2^*\right]$ is the same on any interval regardless of the disclosure policy, the worker prefers a fixed effort level rather than the same effort level in expectation. Information disclosure thus subjects the worker to effort risk through exposing him to uncertainty about how hard he will have to work in the future. Ceteris paribus, the worker strictly prefers the uninformative disclosure policy $\Theta = \emptyset$. Moreover, since information disclosure increases the worker's expected disutility of second period effort without raising his expected output, $\Theta = \emptyset$ maximizes second period social surplus.

2.3.2 First period effort and coasting incentives

To explore the incentives the worker has to provide first period effort, it is again useful to examine (2.3), which one can alternatively express as

$$\widehat{\theta}_2^F = \lambda_2\left(y_1 - e_1^F\right) + \lambda_2\left(y_2 - e_2^F\right) + \frac{h_\theta}{2h_\varepsilon + h_\theta}\overline{\theta}. \tag{2.9}$$

Just as with second period effort, there are signal jamming incentives in the first period since the worker can increase y_1 through exerting effort. While there is nothing that the worker can do to affect y_2, this section will show that he can affect e_2^F conditional on receiving feedback. e_2^F is relevant for the worker because what matters for his period 3 payoff is not his second period output as such, but the portion of second period output that the firm attributes to his talent. The next result makes more precise the relationship between the disclosure policy and first period effort.

Proposition 2.2 *For high enough C, first period equilibrium exists and is unique, and is given by*

$$e_1^*(\Theta) = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi(\xi)\right] + E\left[\left(\frac{W^2}{C^2}\frac{\lambda_1\lambda_2^2}{\sigma_2^3}\right)\xi\phi^2(\xi) \mid \widehat{\theta}_1 \in \Theta\right]\Pr\left[\widehat{\theta}_1 \in \Theta\right], \tag{2.10}$$

where

$$\xi = \left(\frac{\widehat{\theta}_1 - \theta^*}{\sigma_2}\right).$$

The two terms in (2.10) reflect the two sources of first period effort incentives. The first arises from signal jamming. In fact, this expression is equal to second period equilibrium effort with the disclosure policy $\Theta = \emptyset$. The reason is that in the first period, regardless of the disclosure policy, the worker does not have any information about his talent, so is in exactly the same informational environment as if he were choosing second period effort under $\Theta = \emptyset$.

The second term reflects coasting incentives, and does depend on the disclosure policy. Regardless of the worker's actual first period effort level, the firm will expect the game to be on the equilibrium path in the second. One can therefore use the results of Proposition 2.1 to derive the expression for e_2^F. As discussed in the previous section, when the worker does not receive feedback, e_2^F is independent of first period performance. So, coasting incentives arise only when the worker receives feedback from the firm. Conditional on receiving feedback, the firm expects the worker to exert effort

$$e_2^F = \frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1^F}{\sigma_2}\right). \tag{2.11}$$

The worker therefore has an incentive to increase $\widehat{\theta}_1^F$ when $\widehat{\theta}_1^F > \theta^*$ and to decrease $\widehat{\theta}_1^F$ when $\widehat{\theta}_1^F < \theta^*$. In other words, the worker always wants to push $\widehat{\theta}_1^F$ away from θ^*, where e_2^F is highest, and into the tails of the distribution.

Corollary 2.1 *(Coasting incentives). Removing negative feedback and adding positive feedback to Θ increases e_1^*.*

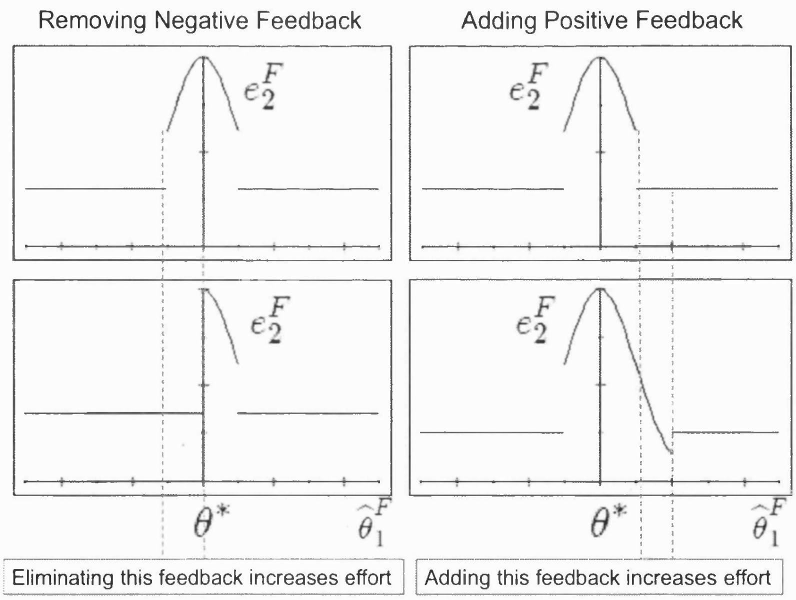

Figure 2.3: The Effects of Feedback on First Period Effort

Figure 2.3 plots out the relationship between $\widehat{\theta}_1^F$ and e_2^F under various disclosure policies. The top two graphs are both for the disclosure policy $\Theta = (\underline{x}, \overline{x})$, where $\underline{x}$ and $\overline{x}$ are equidistant from θ^*. For the feedback $(\underline{x}, 0)$ there is a positive relationship between $\widehat{\theta}_1^F$ and e_2^F. So, the worker has an incentive to work less hard in the first period in order to reduce e_2^F and make it easier to signal a hight talent in the second. In this case, coasting incentives counteract signal jamming incentives and discourage first period effort. Eliminating this negative feedback thus increases e_1^*.

Under the disclosure policy $\Theta = (\underline{x}, \overline{x})$, e_2^F is flat for $\widehat{\theta}_1^F \in (\overline{x}, \overline{x}+1)$. If instead the firm offers the disclosure policy $\Theta = (\underline{x}, \overline{x}+1)$, there is a negative relationship between two in this region. Under this disclosure policy, there are extra work incentives because when the worker receives feedback in $(\overline{x}, \overline{x}+1)$, increasing e_1 decreases e_2^F since it pushes $\widehat{\theta}_1^F$ into the upper tail of the distribution where the firm believes the worker exerts less effort. In this case, coasting incentives complement signal jamming incentives and provide an additional motive for exerting effort.

This section has now identified two primary effects of information disclosure. Feedback exposes the worker to effort risk and creates coasting incentives. The next section shows how these combine in an optimal contract.

2.4 Optimal Disclosure

The trade-off between effort incentives and risk in contract theory dates back at least to Holmström (1979). So, in some ways, the present model has analogies with previous work in principal-agent theory, although effort and risk obviously arise for different reasons in this environment. As this section shows, the way the firm optimally resolves them is also quite different. Its problem is to select a contract (w, Θ) to maximize

$$e_1^* - w \tag{2.12}$$

such that

$$w \geq 0 \tag{2.13}$$

and

$$w + \Pr\left[\widehat{\theta}_2 \geq \theta^*\right] \overline{W} + \Pr\left[\widehat{\theta}_2 < \theta^*\right] \underline{W} - g\left(e_1^*\right) - E\left[g\left(e_2^*\right)\right] \geq u. \tag{2.14}$$

(2.12) is the part of firm profit that the disclosure policy affects. It has a relatively simple form because the retention rule the firm uses is exogenous, and by Lemma 2.2, Θ does not affect $E\left[e_2^*\right]$. The firm faces two constraints in choosing a contract: (2.13) is the worker's liquidity constraint and (2.14) is his participation constraint. The left hand side of (2.14) reflects the two sources of utility that the worker derives from joining the firm.

The first is the initial compensation w and the second is the expected third period payoff net of the first and expected second period effort costs. A useful result is the following.

Lemma 2.4 $\Pr\left[\widehat{\theta}_2 \geq \theta^*\right] \overline{W} + \Pr\left[\widehat{\theta}_2 < \theta^*\right] \underline{W} - g\left(e_1^*\right) - E\left[g\left(e_2^*\right)\right]$ *is unbounded above.*

One way to demonstrate this is to note that as $\overline{W}$ becomes large, the expected third period wage is unbounded. At the same time, Assumption 2.2 places a bound on effort costs.

When the expected payoff from joining the firm is large, the worker will accept any contract terms offered him in period 0. When it is smaller, the firm will have to be more disciplined in its choice of contract since the worker will take his outside option if he is not offered enough up-front compensation. The chapter thus classifies employment relationships into two types: when the participation constraint does not bind for any contract, there are *high rewards*; when the participation constraint binds when $w = 0$ for any disclosure policy there are *low rewards*.[18] The rest of this section derives the optimal contract in both cases.

2.4.1 Optimal contract with high rewards

Let (w_H^*, Θ_H^*) denote the optimal contract with high rewards. Its structure is straightforward to derive.

Proposition 2.3 $w_H^* = 0$ *and* $\Theta_H^* = (\theta^*, \infty)$.

Proof. With high rewards, the worker will accept employment regardless of the up-front wage, so F optimally chooses the lowest possible compensation and sets $w_H^* = 0$. Since the wage is fixed, the firm chooses the disclosure policy to maximize coasting incentives, so the firm chooses $\Theta_H^* = (\theta^*, \infty)$. ■

With high rewards, the goal of the firm is simply to extract as much effort as possible from the worker, and the instrument available to it for doing so is positive feedback. The fact that positive feedback exposes the worker to effort risk is not relevant for the firm because it does not have to compensate the worker for it since the participation constraint does not bind.

One interesting feature of the result is that it gives a potential explanation of why an organization would want to create a culture of giving only positive feedback. The human resource literature has found that criticism can harm productivity and praise can

[18]These two cases are not a complete classification of the possible parameter values of the model. There are cases in which the participation constraint binds for some but not all disclosure policies when $w = 0$. However, the chapter does not study them since they add little additional insight.

boost it (Meyer, Kay, and French 1965), but has not pinned down any sharp intuitions explaining why. In this model, coasting incentives explain why a firm that only cares about maximizing worker motivation should always identify good performance and never identify poor performance.

2.4.2 Optimal contract with low rewards

With low rewards (2.14) will bind in the optimal contract since the worker must receive some compensation for working for F. Denote by (w_L^*, Θ_L^*) the optimal contract in this situation. F chooses w_L^* to make the participation constraint bind, and chooses Θ_L^* to maximize [19]

$$e_1^* - g(e_1^*) + E[e_2^* - g(e_2^*)]. \tag{2.15}$$

Expression (2.15) is simply social surplus. Θ_L^* maximizes social surplus rather than effort because now F internalizes the effort risk to which the worker becomes exposed when he receives feedback. It does so because it must increase the up-front compensation he must provide to attract the worker into employment. Unlike the case of high rewards, Θ_L^* must now trade-off effort incentives and risk. The efficient first period effort level is given by $Ce_1^{FB} = 1$. The incentive of F to provide feedback depends on $e_1^*(\emptyset)$, the level of first period effort with no feedback and just signal jamming incentives. If $Ce_1^*(\emptyset) < 1$, then giving positive feedback raises first period effort closer to its first best value, raising first period social surplus. However, it also decreases second period social surplus because of effort risk. Thus, the trade-off is between increasing first period effort closer to its first best level and exposing the worker to excess risk. The same trade-off arises if $Ce_1^*(\emptyset) > 1$, but for giving negative feedback. The next result shows how Θ_L^* resolves it.

Proposition 2.4 (w_L^*, Θ_L^*) *satisfies*

$$\begin{aligned} \text{If } Ce_1^*(\emptyset) &< 1,\ \Theta_L^* = (\theta', \theta''),\ \text{where } \theta^* < \theta' < \theta'' < \infty; \\ \text{If } Ce_1^*(\emptyset) &> 1,\ \Theta_L^* = (\theta', \theta''),\ \text{where } -\infty < \theta' < \theta'' < \theta^*; \\ \text{and if } Ce_1^*(\emptyset) &= 1,\ \Theta_L^* = \emptyset. \end{aligned}$$

and

$$w_L^* = u - \Pr\left[\widehat{\theta}_2 \geq \theta^*\right]\overline{W} - \Pr\left[\widehat{\theta}_2 < \theta^*\right]\underline{W} + g(e_1^*(\Theta_L^*)) + E[g(e_2^*)\,|\Theta = \Theta_L^*].$$

[19] One obtains this expression through taking (2.14) as an equality, plugging into (2.12), and dropping the terms that the disclosure policy does not influence.

One only needs to consider the case $Ce_1^*(\emptyset) < 1$. The argument for $Ce_1^*(\emptyset) > 1$ works in exactly the same fashion, and when $Ce_1^*(\emptyset) = 1$ feedback can only harm social welfare so $\Theta_L^* = \emptyset$ is optimal. Clearly, when $Ce_1^*(\emptyset) < 1$, including feedback anywhere in $(-\infty, \theta^*)$ is not optimal. In order to understand the particular form that Θ_L^* takes, it is useful to consider figure 2.4, whose origin is set at $(\theta^*, 0)$. The dark line traces out the marginal cost of disclosing talent beliefs $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ for an arbitrarily small Δ given a fixed Θ that does not include $(-\infty, \theta^*)$. The lighter line traces out the marginal benefit of disclosing $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ given the same Θ.

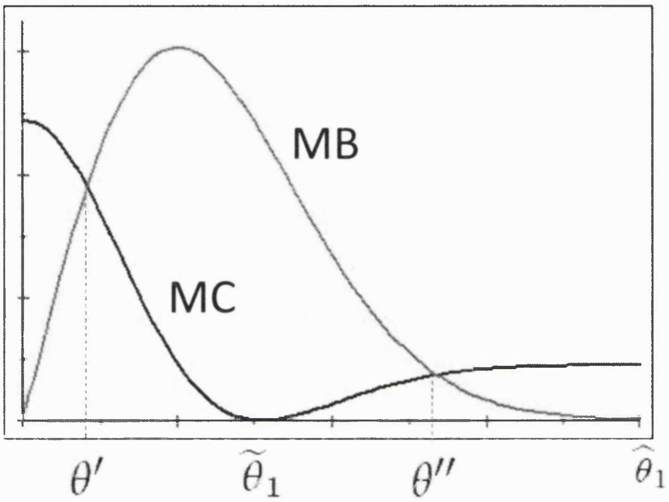

Figure 2.4: The Marginal Benefit and Cost of Information Disclosure

The most notable feature of the marginal cost curve is that it is single-troughed. To understand why, let $\widetilde{e}_2$ be the effort the worker exerts when he receives no feedback. Because the disclosure policy does not include $(-\infty, \theta^*)$, $\widetilde{e}_2$ lies strictly between 0 and θ^*. The magnitude of the effort risk from disclosing $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ is proportional to how far away is $e_2^*\left(\widehat{\theta}_1\right)$ from $\widetilde{e}_2$. For $\widehat{\theta}_1$ large and for $\widehat{\theta}_1$ close to θ^*, effort risk is high since these are circumstances in which $e_2^*\left(\widehat{\theta}_1\right)$ reaches extreme values. On the other hand, there exists a unique $\widetilde{\theta}_1$ at which $e_2^*\left(\widetilde{\theta}_1\right) = \widetilde{e}_2$. Disclosing beliefs $\left(\widetilde{\theta}_1, \widetilde{\theta}_1 + \Delta\right)$ is therefore riskless, and does not harm social welfare.

The marginal benefit curve is single-peaked. The marginal benefit of including beliefs $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ in Θ is proportional to the strength of the coasting incentives that this feedback creates. There are two clear regions where e_2^F does not vary much with e_1. For $\widehat{\theta}_1^F$ close to θ^*, the firm is convinced that the worker will exert high effort to earn the reputational reward W: e_2^F is flat in $\widehat{\theta}_1^F$ in a neighborhood around θ^*. Also, when $\widehat{\theta}_1^F$ is very high, the firm believes the worker will hardly exert effort at all since earning W is nearly guaranteed, and so an increase in e_1 has little effect on e_2^F when $\widehat{\theta}_1^F$ grows large. For these reasons, the marginal benefit curve approaches 0 as $x \longrightarrow \theta^*$ and $x \longrightarrow \infty$. It is instead for intermediate talent beliefs that coasting incentives are strongest.

One can see from figure 2.4 that for any disclosure policy Θ not including $(-\infty, \theta^*)$, there exists an interval (θ', θ'') in which the marginal benefit of disclosing beliefs around $\widehat{\theta}_1 \in (\theta', \theta'')$ exceeds the marginal cost. The marginal cost of disclosing beliefs around any $\widehat{\theta}_1$ that lies outside this interval exceeds the marginal benefit. Therefore it must be the case that the optimal disclosure policy reveals a convex set of beliefs that lie strictly within (θ^*, ∞).

2.4.3 Features of Optimal Disclosure Policies

This section discusses the properties of Θ_L^* and Θ_H^* in light of the features of real-world rating distributions featured in figure 2.1. Importantly, both feature *some* information disclosure (except when $Ce_1^*(\emptyset) = 1$ with low rewards). Thus the model provides a rationale for why firms invest in performance appraisal systems at all.

Another important feature of both disclosure policies is that neither provides full information to workers. Thus, observing that a firm does not have very informative rating distributions should in no way lead to the conclusion that its performance appraisal system is somehow dysfunctional.

The disclosure policies are uninformative in a particular way. Neither one explicitly identifies the worst performers; instead, they are always pooled with other types.[20] Moreover, Θ_L^* does not identify top performance. With low rewards, all workers infer their talent to be in the middle of performance distribution. In short, the model shows that leniency and concentration are compatible with optimal feedback.

Of course, these features arise within a specialized model with numerous simplifying assumptions. This section concludes by examining the robustness of the findings to these.

2.4.4 Robustness

One objection one might raise about Θ_L^* is that workers at the top and bottom of the performance distribution are pooled together, whereas it is perhaps more natural to think that workers know in which end of the distribution their performance lies. However, unless the firm would like to commit to sharing this information with the worker, there is no way for him to know. The next result shows that the firm cannot benefit from disclosing this additional information.

[20] Even when Θ_L^* gives negative feedback, it does not inform the worst performers of their output.

Proposition 2.5 *Let Θ_1 be the set of all beliefs $\widehat{\theta}_1^F$ and let P be a partition of Θ_1. The profit maximizing disclosure policy satisfying Definition 2.1 is also profit maximizing within the class of disclosure policies with the form $\psi\left(\widehat{\theta}_1^F\right) \to P_i$ where $\widehat{\theta}_1^F \in P_i$.*

Proof. Suppose ψ is a disclosure policy with the form $\psi\left(\widehat{\theta}_1^F\right) \to P_i$ where $\widehat{\theta}_1^F \in P_i$. From the arguments used in Proposition 2.2, coasting incentives arise over the set of exactly revealed beliefs $\widetilde{\Theta}_1 = \left\{\widehat{\theta}_1^F | \psi\left(\widehat{\theta}_1^F\right) = \widehat{\theta}_1^F\right\}$. Since e_2^F is flat in $\widehat{\theta}_1^F$ conditional on $\widehat{\theta}_1^F \in P_i \subset \Theta_1 \backslash \widetilde{\Theta}_1$, coasting incentives do not arise over $\Theta_1 \backslash \widetilde{\Theta}_1$.

Now, suppose $\exists \widehat{\theta}_{1i}, \widehat{\theta}_{1j} \in \Theta_1 \backslash \widetilde{\Theta}_1$ such that $\psi\left(\widehat{\theta}_{1i}\right) = P_i$ and $\psi\left(\widehat{\theta}_{1j}\right) = P_j$ where $P_i \neq P_j$. Modifying ψ so that $\psi\left(\widehat{\theta}_1\right) = P_i \cup P_j \; \forall \widehat{\theta}_1 \in P_i \cup P_j$ does not alter coasting incentives, but (weakly) reduces the effort risk to the worker, so cannot reduce profit. ■

Unless information contributes to improving effort incentives, the firm should suppress it because of effort risk. Coasting incentives arise whenever first period effort affects the amount of effort the firm expects in the second period. Unless the disclosure policy reveals $\widehat{\theta}_1^F$ directly to the worker, e_2^F does not depend on e_1. In order to see this more clearly, one can easily adapt Proposition 2.1 to show that e_2^F satisfies

$$e_2^F = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1^F}{\sigma_2}\right) | \widehat{\theta}_1^F \in P_i\right],$$

which does not depend on y_1 when P_i contains a positive measure of beliefs. So, coasting incentives only arise over the range of exactly revealed beliefs. While breaking the range of beliefs that are not exactly revealed to the worker into more than set does not improve first period effort, it does expose the worker to more effort risk since it increases the variance of second period effort. Hence, pooling all the beliefs that are not exactly revealed to the worker into one message cannot make the firm worse off, and the optimal disclosure policies derived in this section are optimal within a general class.

While the assumption of quadratic effort costs makes the exposition of the results clear, examining how the results depend on it is obviously important. Suppose the worker has effort costs given by $g(e_t) = \frac{C}{\beta+1}e_t^{\beta+1}$. As discussed in section 2.3.1, whenever $\beta \neq 1$ there is a third effect of feedback as well since the disclosure policy affects expected second period effort as well as effort risk and coasting incentives.

Proposition 2.6 *Let $g(e_t) = \frac{C}{\beta+1}e_t^{\beta+1}$ and suppose that $\beta > 1$. Then the effort maximizing disclosure policy takes the form $\Theta = (\theta', \theta'')$ where $\theta^* < \theta' < \theta'' < \infty$ and the social surplus maximizing disclosure policy takes the form given in Proposition 2.4.*

When $\beta > 1$ the disclosure policies with high and low rewards both feature avoidance of negative feedback and concentration. Qualitatively, then, the results do not depend on the assumption of quadratic costs. However, the results do depend on convex marginal costs, so are not robust to general cost functions.[21] Nevertheless, since the assumption of non-negative third derivatives on the effort cost function is common in the mechanism design and contract theory literatures, the conditions under which the results arise are not unduly restrictive.

The form that Θ_H^* and Θ_L^* take is also dependent on the shape of the period 3 wage profile. While effort risk and coasting incentives are presumably general effects in career concerns models, how they combine in an optimal contract is specific to their relative magnitudes. They key qualitative features of the disclosure policies derive from the fact that equilibrium effort in the second period is single-peaked in expected ability. Any wage function that generates this relationship between effort and ability will lead to similar results on optimal disclosure; the rewards to talent schedule proposed in this chapter is just one such function.

2.5 Feedback, Competition, and Technology

The goal of this section is twofold. The first is to endogenize the period 3 wage function assumed in the basic model. For this, one can simply re-use the results from Chapter 1. The second is to provide a microfoundation for high rewards via a particular third period production function.

Suppose the worker's output in period 3 with F is $y_3^F = \kappa + k\theta + \varepsilon_3$ where $k \geq 1$ and $\kappa > 0$, and his output with a market firm is $y_3^j = k\theta + \varepsilon_3$. The worker's output is therefore potentially more sensitive to his talent in period 3 than in periods 1 and 2, and F earns a rent on every worker type. The first feature captures the fact that more senior workers usually occupy positions of higher responsibility in firms, so that their skill is more important in determining the value they create. The second captures firm specific human capital accumulation. The fact that y_3 does not depend on effort is without loss of generality since final period effort is zero in career concerns models.

After observing y_1 and y_2, F chooses some $w_3^F \in W_3^F = \mathbb{R}^+ \cup \{\emptyset\}$ where $w_3^F = \emptyset$ corresponds to not making the worker a wage offer for period 3 and $w_3^F \neq \emptyset$ to offering him a wage w_3^F for period 3. Outside firms observe w_3^F and each then simultaneously chooses $w_3^j \in \mathbb{R}^+ \cup \{\emptyset\}$. The worker joins the firm that offers him the highest wage, but takes his outside option if no firm makes him a wage offer that exceeds it. All firms incur an arbitrarily small cost δ from making wage offers, which could for example reflect the legal costs of drafting a wage contract.

Denote by Θ_2 the set of all possible realizations of $\widehat{\theta}_2^F$, and let $\widetilde{w}_3^F : \Theta_2 \to W_3^F$ be F's

[21]For example, when $\beta < 1$ the effort maximizing disclosure policies does identify the worst performers.

strategy in the bidding game. Let $\widehat{w}_3^j$ be market firm j's belief about the strategy that F employs, and let $\widetilde{w}_3^j : W_3^F \to W_3^j$ be the strategy that each market firm j employs.

Definition 2.5 *An equilibrium of the labor market competition game is a set of strategies $\widetilde{w}_3^{F*} \cup \left\{\widetilde{w}_3^{j*}\right\}_{j=1}^J$ and a set of beliefs $\left\{\widehat{w}_3^j\right\}_{j=1}^J$ that satisfy the following conditions:*

$$\widetilde{w}_3^{j*} \text{ maximizes } E\left[y_3^j\right] - w_3^j - 1\left(w_3^j \neq \emptyset\right)\delta \;\forall w_3^F \text{ given } \widehat{w}_3^j \text{ and } \left\{\widetilde{w}_3^{j*}\right\}_{j=1}^J \backslash \widetilde{w}_3^{j*}; \tag{2.16}$$

$$\widetilde{w}_3^{F*} \text{ maximizes } E\left[y_3^F\right] - w_3^F - 1\left(w_3^F \neq \emptyset\right)\delta \;\forall \widehat{\theta}_2^F \text{ given } \left\{\widetilde{w}_3^{j*}\right\}_{j=1}^J; \tag{2.17}$$

$$\widehat{w}_3^j = \widetilde{w}_3^{F*}. \tag{2.18}$$

In addition, one needs outside firms' beliefs about the worker's effort choice in period t to equal e_t^F, so that they believe that $\widehat{\theta}_2^F \sim N\left(\overline{\theta}, \sigma_1^2 + \sigma_2^2\right)$. This chapter will not discuss the solution of the labor market competition game because the strategic effects are identical to those presented in the previous chapter. Instead, it goes directly to the result. Readers interested in a discussion of the result are referred to section 1.3.1.

Proposition 2.7 *The labor market competition game has a unique equilibrium outcome in which the rewards to talent schedule takes the following form:*

$$w\left(\theta_2^F\right) = \begin{cases} E\left[k\theta \mid \widehat{\theta}_2^F \geq \theta^*\right] & \text{if } \widehat{\theta}_2^F \geq \theta^* \\ \max\left\{u, E\left[k\theta \mid \widehat{\theta}_2^F \geq \theta^*\right]\right\} & \text{if } \widehat{\theta}_2^F < \theta^*, \end{cases}$$

where θ^* uniquely satisfies

$$\kappa + k\theta^* = E\left[k\theta \mid \widehat{\theta}_2^F \geq \theta^*\right]. \tag{2.19}$$

One can now turn to providing a microfoundation for high rewards. The following (unessential) parametric restriction is particularly useful for providing a clean characterization of the expected future rewards the worker enjoys from joining the firm in period 0.

Assumption 2.3 *The parameters of the model are such that $E\left[k\theta \mid \widehat{\theta}_2^F < \theta^*\right] > u$*

The main result is the following.

Lemma 2.5 *High rewards arise if k is high enough.*

Proof. Given Assumption 2.3, the expected period 3 payoff for the worker is

$$\Pr\left[\widehat{\theta}_2^F \geq \theta^*\right] E\left[k\theta \mid \widehat{\theta}_2^F \geq \theta^*\right] + \Pr\left[\widehat{\theta}_2^F < \theta^*\right] E\left[k\theta \mid \widehat{\theta}_2^F < \theta^*\right] = kE\left[\theta\right] = k\overline{\theta}.$$

Therefore, as $k \to \infty$, the expected return to employment grows without bound. ■

In period 3, the worker earns his expected output in the market conditional on being retained or released by the firm. The worker's expected period 3 wage is therefore his unconditional expected output in a market firm, or $k\overline{\theta}$. The worker's expected earnings are high whenever the productivity of senior workers in market firms is sensitive to talent. For example, one might imagine a group of consulting firms that works on highly complex and novel problems, and another one that works on more routine ones. If these groups compete within themselves for workers of high ability, beginning employment in the former group would yield higher future rewards since the output of its senior workers is presumably more sensitive to talent.

The previous section showed that in the high reward case, a firm maximizes effort, while in the low reward case it maximizes social surplus. Lemma 2.5 leads to the conclusion that firms in industries in which future output is sensitive to talent either provide too much positive feedback (if signal jamming incentives alone provide less than first best effort incentives) or not enough negative feedback (if they provide greater than first best effort incentives).

Since the typical concern with signal jamming is too little rather than too much effort provision, it is worth considering this case in more detail. In the model, information has a limited social value. When the firm chooses a disclosure policy to maximize effort, it creates effort incentives that go beyond what a welfare maximizing contract would provide. This is not to say that $e_1^*\left(\Theta_H^*\right) > e_1^{FB} > e_1^*\left(\emptyset\right)$, although in special situations it may be the case that maximizing coasting incentives drives effort above its first best level. Even if $e_1^*\left(\Theta_H^*\right) < e_1^{FB}$, Θ_H^* still motivates the worker too highly. From a social standpoint, there always exist intervals of positive feedback for which the social cost of effort risk outweighs the social gain from effort incentives. Moreover, when $e_1^*\left(\emptyset\right) < e_1^{FB}$, the effort maximizing disclosure policy is too informative since it provides feedback in situations where the social surplus maximizing policy would not.

Lemma 2.6 *As $C \to \infty$ and $\theta^* \to -\infty$, the informativeness of Θ_H^* approaches* 1, *and the informativeness of the social welfare maximizing disclosure policy approaches* 0.

This result shows that the difference between the informativeness of Θ_H^* and the social welfare maximizing disclosure policy can be maximal. When $C \to \infty$ and $\theta^* \to -\infty$, firm H always provides feedback, although a social planner never would. The reason is that when C is high, equilibrium effort in the second period is low. This in turn means that coasting incentives are weak, and from a social standpoint feedback is never justified. However, firm H always offers positive feedback in spite of the fact that it may only add a small amount of extra effort.

Finally, when $e_1^*(\emptyset)$ is greater than e_1^{FB}, an effort maximizing firm uses feedback to generate even higher levels of effort, whereas the social welfare maximizing policy would give negative feedback to dampen effort incentives. In this situation, feedback worsens a pre-existing rat race.[22]

2.6 Discussion

This chapter has argued that professional service firms with up-or-out promotion contracts can benefit from giving feedback because workers respond with higher effort. If the model is correct, then firms in which career concerns are important have a motivation for investing in performance appraisal systems that other firms do not have. The goal of this section is to identify what industries use performance appraisal the most, and to assess how closely they correspond to the kind of industry modelled in the chapter. The chapter takes data from the Workplace Employment Relations Survey (WERS) from 2004, a cross-sectional survey of 2,295 workplaces in the United Kingdom that collects information on numerous establishment characteristics.[23] The chapter considers the subset of private sector firms, since public organizations are likely to have bureaucratically controlled human resource practices. This leaves 1,557 workplaces in the dataset.

The chapter divides firms into two groups: those that formally assess the largest non-managerial occupational group and those that do not. It focuses on appraisals for this set of workers since it is the group for which career concerns are probably most important. For each five digit industry, it computes the percentage of firms that formally assess the performance of their core non-managerial employees. In order to generate sufficient inter-industry variation, it drops those industries that have fewer than five firms in the dataset. This leaves ninety five industries, twelve of which have one hundred percent performance appraisal use. These are listed in the table 2.1, along with the twelve industries with the lowest use of performance appraisal.

The majority of industries with universal use of performance appraisal provide professional services, while at the same time, professional services do not appear at all

[22]Landers, Rebitzer, and Taylor (1996) have found that junior workers in law firms exert inefficiently high levels of effort. This chapter shows that human resource practices as well as reputational rewards can contribute to the over-provision of effort.

[23]Kersley, Alpin, Forth, Bryson, Bewley, Dix, and Oxenbridge (2006) gives a detailed description of the dataset.

HIGHEST PA USE	LOWEST PA USE
Publishing of journals and periodicals	Other meat and poultry processing
Collection, purification and distribution of water	Manufacture of bread
Retail sale via mail order house	Freight transport by road not elsewhere classified
Non-life insurance	Other transport via railways
Activities auxiliary to insurance and pension funding	Other construction work involving special trades
Other letting of own property	Dispensing chemists
Software consultancy and supply	Independent public houses and bars
Legal activities	Printing not elsewhere classified
Accounting and auditing activities	Forging, pressing, stamping and roll forming of metal
Business and management consultancy activities	Storage and warehousing
Private sector hospital activities	Maintenance and repair of motor vehicles
Non-charitable social work activities	Manufacture of other builders' ware of plastic

Table 2.1: Performance Appraisal Use by Industry

among those industries in which which performance appraisal use is low. Of course, there are many reasons why professional service firms might provide feedback. Performance appraisal might allow a central HR office to more readily identify the most talented individuals and to appropriately reward them. It might also allow workers to identify training needs.[24] A more direct test of the model would be to examine data from a professional service firm that began to provide more feedback to workers, and to examine whether workers began exerting more effort at the same time. Whether such data are currently available is unclear, but the point is that the chapter presents a perspective on feedback in organizations that is empirically distinguishable from other stories.

Concluding remarks. This chapter began with the basic question: is more feedback always better? The answer is "no" for two different reasons. First, in many situations a firm would like to commit to limiting the amount of information that workers receive about their output. Full information disclosure would strictly reduce firm profits because negative feedback reduces effort and effort risk causes wages to rise. Second, firms

[24]However, in the absence of legal restrictions, it is unclear why supervisors could not give feedback on worker performance to an HR office and not the worker. Moreover, firms can provide information to workers about training needs without giving them information about the probability of future promotion (Beer 1987).

that offer more feedback than others could very well be providing too much information from a social standpoint and lowering surplus. The fact that such firms might be more productive cannot be taken as evidence of their adopting better management practices.

While the chapter has shown how one can capture characteristics of real world feedback systems in a model with standard preferences and technology, there is still much to understand. One area for future research would be how to implement the optimal disclosure policy in an organization that could not commit ex ante to disclosing certain beliefs. One avenue to explore would be having the firm share information with a continuum of workers, because through communicating with each other, the workers could detect deviations from the firm's announced disclosure policy. Even if no informative communication could ever arise in equilibrium, the results of the chapter imply that this may actually be better for the firm than forcing managers to disclose all information to workers.

A second pertinent extension would be to combine career concerns with other forms of contracting. As the literature review discussed, information disclosure in other contracting environments has quite different effects than in the case of career concerns. One issue likely to arise with multiple periods is that the contracting instrument chosen by the firm would reveal information to the worker in addition to the disclosure policy. For example, the wage paid to the worker under a piece rate contract would indirectly reveal output to the worker.

Finally, information in firms has uses beyond incentive provision. For example, information disclosure potentially allows the worker to learn how to do his job better. Exploring the trade-off between withholding information because of effort risk and disclosing it to build human capital would be another natural extension.

2.A Proofs

2.A.1 Proof of Lemma 2.1

Proof. By Bayes' Rule

$$\widehat{\theta}_2^F = \lambda_2 \left(\theta + e_2 + \varepsilon_2 - e_2^F\right) + (1 - \lambda_2)\, \widehat{\theta}_1$$

and

$$\widehat{\theta}_1^F = \lambda_1 \left(\theta + e_1 + \varepsilon_1 - e_1^F\right) + (1 - \lambda_1)\, \overline{\theta}$$

Since $\widehat{\theta}_1^F$ is a linear combination of normal random variables, it is itself normal with mean $E\left[\widehat{\theta}_1\right] = \overline{\theta} + \lambda_1 \left(e_1 - e_1^F\right)$ and variance

$$V\left[\widehat{\theta}_1\right] = \lambda_1^2 \left(\frac{h_\theta + h_\varepsilon}{h_\theta h_\varepsilon}\right) = \frac{\lambda_1}{h_\theta}.$$

A standard result in Bayesian statistics (DeGroot 1970) is that $\theta | \widehat{\theta}_1 \sim N\left(\widehat{\theta}_1, \frac{1}{h_\varepsilon + h_\theta}\right)$, so $\widehat{\theta}_2^F | \widehat{\theta}_1$ is normal with mean $\widehat{\theta}_1 + \lambda_2 \left(e_2 - e_2^F\right)$ and variance

$$V\left[\lambda_2 \left(\theta + \varepsilon_2\right)\right] = \lambda_2^2 \left[\frac{1}{h_\varepsilon + h_\theta} + \frac{1}{h_\varepsilon}\right] = \frac{\lambda_2}{h_\varepsilon + h_\theta}.$$

■

2.A.2 Proof of Proposition 2.1

The following result is used in the proof and is stated separately.

Lemma 2.7 *Suppose there exists a random variable $X \sim N\left(\mu(y), \sigma^2\right)$ where $\mu(y)$ is continuously differentiable and let ϕ be the standard normal density. Then*

$$\frac{\partial}{\partial y} \int_a^\infty f(x)\, dx = \frac{\mu'(y)}{\sigma} \phi \left(\frac{a - \mu(y)}{\sigma}\right).$$

Proof. Using the transformation $v = \frac{x - \mu(y)}{\sigma}$ one can write

$$\frac{\partial}{\partial y} \int_a^\infty f(x)\, dx = \frac{\partial}{\partial y} \int_{\frac{a - \mu(y)}{\sigma}}^\infty \phi(v)\, dv.$$

Applying the Leibnitz Rule for differentiating integrals gives

$$\frac{\mu'(y)}{\sigma} \phi \left(\frac{a - \mu(y)}{\sigma}\right).$$

■

Proposition 2.1 can now be proved.

Proof. First, suppose that $\widehat{\theta}_1 \in \Theta$. The worker's problem can be written as

$$\begin{aligned} & \arg\max_{e_2} -g(e_2) + W \Pr\left[\widehat{\theta}_2^F > \theta^*\right] \\ = & \arg\max_{e_2} -\frac{C}{2}e_2^2 + W\int_{\theta^*}^{\infty} f\left(\widehat{\theta}_2^F|\widehat{\theta}_1\right) d\widehat{\theta}_2^F. \end{aligned}$$

Applying Lemma 2.7, the first order condition for the maximization problem is

$$-Ce_2^W + W\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1 - \lambda_2\left(e_2^W - e_2^F\right)}{\sigma_2}\right) = 0.$$

For global concavity of the objective function, it must be the case that

$$-C + W\left(\frac{\lambda_2}{\sigma_2}\right)^2 \phi'\left(\frac{\theta^* - \widehat{\theta}_1 - \lambda_2\left(e_2^W - e_2^F\right)}{\sigma_2}\right) < 0$$

holds for all e_2^W and e_2^F. Since $\phi' \leq 1$ this condition is satisfied as long as

$$-C + W\left(\frac{\lambda_2}{\sigma_2}\right)^2 < 0,$$

which holds by Assumption 2.2. Plugging in the equilibrium condition $e_2^W = e_2^F$ gives the result.

Now, suppose $\widehat{\theta}_1 \notin \Theta$. The worker's maximization problem is

$$\begin{aligned} & \arg\max_{e_2} -\frac{C}{2}e_2^2 + W \Pr\left[\widehat{\theta}_2^F > \theta^*\right] \\ = & \arg\max_{e_2} -\frac{C}{2}e_2^2 + WE_{\widehat{\theta}_1}\left\{\Pr\left[\widehat{\theta}_2^F > \theta^*|\widehat{\theta}_1\right]|\widehat{\theta}_1 \notin \Theta\right\}. \end{aligned}$$

Applying the previous steps to the $\Pr\left[\widehat{\theta}_2^F > \theta^*|\widehat{\theta}_1\right]$ term completes the proof. ■

2.A.3 Proof of Lemma 2.2

Proof. Expected second period effort is

$$\begin{aligned}
&\int_{\widehat{\theta}_1\in\Theta}\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta_2^*-\widehat{\theta}_1}{\sigma_2}\right)f\left(\widehat{\theta}_1\right)d\widehat{\theta}_1\\
&+E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta_2^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\notin\Theta_1\right]\Pr\left[\widehat{\theta}_1\notin\Theta_1\right]\\
=&\int_{-\infty}^{\infty}\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta_2^*-\widehat{\theta}_1}{\sigma_2}\right)f\left(\widehat{\theta}_1\right)d\widehat{\theta}_1,
\end{aligned}$$

which is independent of Θ_1. ■

2.A.4 Proof of Lemma 2.3

Proof.

$$\begin{aligned}
E\left[(e_2^*)^2|\Theta'\right] &= \Pr\left[\widehat{\theta}_1\notin\Theta'\right]E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\notin\Theta'\right]^2\\
&\quad+\Pr\left[\widehat{\theta}_1\in\Theta'\backslash\Theta\right]E\left[\phi^2\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\in\Theta'\backslash\Theta\right]\\
&\quad+\Pr\left[\widehat{\theta}_1\in\Theta\right]E\left[\phi^2\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\in\Theta\right]\\
&> \Pr\left[\widehat{\theta}_1\notin\Theta'\right]E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\notin\Theta'\right]^2\\
&\quad+\Pr\left[\widehat{\theta}_1\in\Theta'\backslash\Theta\right]E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\in\Theta'\backslash\Theta\right]^2\\
&\quad+\Pr\left[\widehat{\theta}_1\in\Theta\right]E\left[\phi^2\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\in\Theta\right]\\
&> \Pr\left[\widehat{\theta}_1\notin\Theta\right]E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\notin\Theta\right]^2\\
&\quad+\Pr\left[\widehat{\theta}_1\in\Theta\right]E\left[\phi^2\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1\in\Theta\right]\\
&= E\left[(e_2^*)^2|\Theta\right],
\end{aligned}$$

where the first inequality comes from probability version of Jensen's inequality, and the second from the discrete version. ■

2.A.5 Proof of Proposition 2.2

In order to solve for e_1^* it is necessary to draw on the following claim, which is presented without proof.

Claim 2.1 *Suppose a uniformly bounded function $h(x,y)$ has a countable number of discontinuity points $\{(x_i, y_i)\}$ that satisfy $x_i = f(y_i)$ where f is continuous. Then*

$$\frac{\partial}{\partial y}\int_{-\infty}^{\infty} h(x,y)\,dx = \int_{-\infty}^{\infty}\frac{\partial h(x,y)}{\partial y}dx + \sum_i f'(y_i)\left(\lim_{x_i \to f(y_i)^+} h(x,y) - \lim_{x_i \to f(y_i)^-} h(x,y)\right).$$

Below is the proof of the proposition.

Proof. If $e_1^W \neq e_1^F$ then one can apply Lemma 2.7 along with equations 2.3 and 2.4 to derive

$$e_2^W = \frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1^W - \lambda_2\left(\left(e_1^W - e_1^F\right) + \left(e_2^W - e_2^F\right)\right)}{\sigma_2}\right)$$

if $\widehat{\theta}_1^F = \widehat{\theta}_1^W + \lambda_1\left(e_1^W - e_1^F\right) \in \Theta$ and

$$e_2^W = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1^W - \lambda_2\left(\left(e_1^W - e_1^F\right) + \left(e_2^W - e_2^F\right)\right)}{\sigma_2}\right)|\widehat{\theta}_1^W + \lambda_1\left(e_1^W - e_1^F\right) \notin \Theta\right]$$

if $\widehat{\theta}_1^F \notin \Theta$.

Moreover, from Proposition 2.1,

$$e_2^F = \frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1^F}{\sigma_2}\right)$$

if $\widehat{\theta}_1^F \in \Theta$ and

$$e_2^F = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \in \Theta\right]$$

if $\widehat{\theta}_1^F \notin \Theta$.

$\widehat{\theta}_2^F|\widehat{\theta}_1^W$ and $e_2^W\left(\widehat{\theta}_1^W\right)$ are discontinuous in $\widehat{\theta}_1^W$, but continuous within the regions $\widehat{\theta}_1^W + \lambda_1\left(e_1^W - e_1^F\right) \in \Theta$ and $\widehat{\theta}_1^W + \lambda_1\left(e_1^W - e_1^F\right) \notin \Theta$. One can separate the objective function into two regions along the following lines

$$
\begin{aligned}
&-\frac{C}{2}e_1^2+\int_{-\infty}^{\infty}\left[\int_{\theta^*}^{\infty} f\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)d\widehat{\theta}_2^F-\frac{C}{2}\left(e_2^W\left(\widehat{\theta}_1^W\right)\right)^2\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
=\;& -\frac{C}{2}e_1^2+\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\in\Theta}\left[\int_{\theta^*}^{\infty} f\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)d\widehat{\theta}_2^F-\frac{C}{2}\left(e_2^W\left(\widehat{\theta}_1^W\right)\right)^2\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
&+\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\notin\Theta}\left[\int_{\theta^*}^{\infty} f\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)d\widehat{\theta}_2^F-\frac{C}{2}\left(e_2^W\left(\widehat{\theta}_1^W\right)\right)^2\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W.
\end{aligned}
$$

One issue that arises when differentiating the above expression with respect to e_1 is that the boundary points separating the sets Θ and $\mathbb{R}\backslash\Theta$ depend on e_1, and these boundary points are precisely where $\left[\int_{\theta^*}^{\infty} f\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)d\widehat{\theta}_2^F-\frac{C}{2}\left(e_2^W\left(\widehat{\theta}_1^W\right)\right)^2\right]$ is discontinuous. Claim 2 resolves this difficulty.

Using Lemma 2.7, one finds that the first order condition for e_1^W is

$$
\begin{aligned}
&Ce_1^W= \\
&\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\in\Theta}\left[\begin{array}{c} W\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_2\left(\left(e_1^W-e_1^F\right)+\left(e_2^W-e_2^F\right)\right)}{\sigma_2}\right)\times \\ \left(1+\left(\frac{\partial e_2^W\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}-\left(\frac{\partial e_2^F\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}\right) \\ -Ce_2^W\left(\widehat{\theta}_1^W\right)\left(\frac{\partial e_2^W\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}\end{array}\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
&+\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\notin\Theta}\left[\begin{array}{c} W\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_2\left(\left(e_1^W-e_1^F\right)+\left(e_2^W-e_2^F\right)\right)}{\sigma_2}\right)\times \\ \left(1+\left(\frac{\partial e_2^W\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}-\left(\frac{\partial e_2^F\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}\right) \\ -Ce_2^W\left(\widehat{\theta}_1^W\right)\left(\frac{\partial e_2^W\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}\end{array}\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
&-\lambda_1\sum_i\left(\begin{array}{c}\lim_{\widehat{\theta}_1^W\to\left[a_i-\lambda_1\left(e_1^W-e_1^F\right)\right]^+}\Pr\left[\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)>\theta^*|e_1=e_1^W\right] \\ -\lim_{\widehat{\theta}_1^W\to\left[a_i-\lambda_1\left(e_1^W-e_1^F\right)\right]^-}\Pr\left[\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)>\theta^*|e_1=e_1^W\right]\end{array}\right)
\end{aligned}
$$

where $\{a_i\}$ is the set of all finite points $\underline{x}_i$ and $\overline{x}_i$. One can verify that for high enough C the problem is globally concave, but the details are omitted for the sake of space. The above expression simplifies to

$$
\begin{aligned}
&Ce_1^W = \\
&\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\in\Theta}\left[\begin{array}{c} W\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_2\left(\left(e_1^W-e_1^F\right)+\left(e_2^W-e_2^F\right)\right)}{\sigma_2}\right)\times \\ \left(1-\left(\frac{\partial e_2^F\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W}\right)\end{array}\right] f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
&+\int_{\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\notin\Theta} W\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_2\left(\left(e_1^W-e_1^F\right)+\left(e_2^W-e_2^F\right)\right)}{\sigma_2}\right) f\left(\widehat{\theta}_1^W\right)d\widehat{\theta}_1^W \\
&-\lambda_1\sum_i\left(\begin{array}{c}\lim_{\widehat{\theta}_1^W\to\left[a_i-\lambda_1\left(e_1^W-e_1^F\right)\right]^+}\Pr\left[\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)>\theta^*|e_1=e_1^W\right] \\ -\lim_{\widehat{\theta}_1^W\to\left[a_i-\lambda_1\left(e_1^W-e_1^F\right)\right]^-}\Pr\left[\left(\widehat{\theta}_2^F|\widehat{\theta}_1^W\right)>\theta^*|e_1=e_1^W\right]\end{array}\right)
\end{aligned}
$$

Conditional on $\widehat{\theta}_1^W+\lambda_1\left(e_1^W-e_1^F\right)\in\Theta$,

$$
\begin{aligned}
\left(\frac{\partial e_2^F\left(\widehat{\theta}_1^W\right)}{\partial e_1}\right)_{e_1=e_1^W} &= \left(\frac{\partial\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_1\left(e_1-e_1^F\right)}{\sigma_2}\right)\right]}{\partial e_1}\right)_{e_1=e_1^W} \\
&= \frac{W}{C}\frac{\lambda_1\lambda_2}{\sigma_2^2}\phi'\left(\frac{\theta^*-\widehat{\theta}_1^W-\lambda_1\left(e_1^W-e_1^F\right)}{\sigma_2}\right).
\end{aligned}
$$

Plugging in the equilibrium condition $e_1^W=e_1^F$ into the first order condition yields

$$
\begin{aligned}
Ce_1^W &= \int_{\widehat{\theta}_1\in\Theta}\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)\left(1-\frac{W}{C}\frac{\lambda_1\lambda_2}{\sigma_2^2}\phi'\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)\right)\right] f\left(\widehat{\theta}_1\right)d\widehat{\theta}_1 \\
&\quad+\int_{\widehat{\theta}_1\notin\Theta}\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)\right] f\left(\widehat{\theta}_1\right)d\widehat{\theta}_1.
\end{aligned}
$$

The result follows from the fact that ϕ satisfies $\phi'(x)=-x\phi(x)$. ■

2.A.6 Proof of Lemma 2.4

Proof. One can write

$$
\begin{aligned}
&\Pr\left[\widehat{\theta}_2\geq\theta^*\right]\overline{W}+\Pr\left[\widehat{\theta}_2<\theta^*\right]\underline{W}-g\left(e_1^*\right)-E\left[g\left(e_2^*\right)\right] \\
>\ &\min\left\{\Pr\left[\widehat{\theta}_2\geq\theta^*\right],\Pr\left[\widehat{\theta}_2<\theta^*\right]\right\}W-\tfrac{W^2}{2C}\tfrac{\lambda_2^2}{\sigma_2^2}k_1\left(\Theta\right)-\tfrac{W^2}{2C}\tfrac{\lambda_2^2}{\sigma_2^2}k_2\left(\Theta\right) \qquad (2.20)
\end{aligned}
$$

where $k_1(\Theta)$ and $k_2(\Theta)$ are bounded above for all Θ. Moreover, by Assumption 2.2, $\frac{W^2}{2C}\frac{\lambda_2^2}{\sigma_2^2}$ is bounded above by $\frac{1}{2}$. Therefore, as $W \to \infty$ (2.20) grows arbitrarily large. ■

2.A.7 Proof of Proposition 2.4

Proof. Expected second period effort costs under an arbitrary Θ are

$$\frac{W^2}{2C}\left(\frac{\lambda_2}{\sigma_2}\right)^2 \left\{ \begin{array}{c} \Pr\left[\widehat{\theta}_1 \notin \Theta\right] \left(E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right]\right)^2 \\ +\Pr\left[\widehat{\theta}_1 \in \Theta\right] E\left[\phi^2\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \in \Theta\right] \end{array} \right\}$$

The derivative with respect to $\underline{x}_i$ of the expression is equal to

$$\begin{aligned} & \frac{W^2}{2C}\left(\frac{\lambda_2}{\sigma_2}\right)^2 \left\{ \begin{array}{c} 2E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right]\phi\left(\frac{\theta^*-\underline{x}_i}{\sigma_2}\right) f\left(\underline{x}_i\right) \\ -\left(E\left[\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right]\right)^2 f\left(\underline{x}_i\right) - \phi^2\left(\frac{\theta^*-\underline{x}_i}{\sigma_2}\right) f\left(\underline{x}_i\right) \end{array} \right\} \\ = & -f\left(\underline{x}_i\right)\frac{W^2}{2C}\left(\frac{\lambda_2}{\sigma_2}\right)^2 \left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right) - \phi\left(\frac{\theta^*-\underline{x}_i}{\sigma_2}\right)\right]^2, \end{aligned}$$

with a corresponding expression for the derivative with respect to $\overline{x}_i$.

The derivative of first period social surplus $e_1^* - \frac{C}{2}\left(e_1^*\right)^2$ with respect to $\underline{x}_i$ is

$$-\left(\frac{W}{C}\right)^2 \frac{\lambda_1\left(\lambda_2\right)^2}{\left(\sigma_2\right)^3}\left(\frac{\underline{x}_i-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-\underline{x}_i}{\sigma_2}\right) f\left(\underline{x}_i\right)\xi$$

where

$$\xi = \left[1 - Ce_1^*\left(\Theta\right)\right]$$

with a similar expression for the derivative with respect to $\overline{x}_i$.

A necessary condition for Θ_L^* to maximize social surplus is that it satisfy the following three sets of conditions:

$$\begin{aligned} & \frac{\lambda_1}{C\sigma_2}\left(\frac{x-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-x}{\sigma_2}\right)\xi\left(\Theta_L^*\right) \\ = & \left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta_L^*\right) - \phi\left(\frac{\theta^*-x}{\sigma_2}\right)\right]^2 \end{aligned} \tag{2.21}$$

$\forall x \in \{\underline{x}_i, \overline{x}_i\}$;

$$\begin{aligned} & \frac{\lambda_1}{C\sigma_2}\left(\frac{x-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-x}{\sigma_2}\right)\xi\left(\Theta_L^*\right) \\ \geq & \left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta_L^*\right)-\phi\left(\frac{\theta^*-x}{\sigma_2}\right)\right]^2 \end{aligned} \tag{2.22}$$

$\forall\ x \in \Theta_L^*$; and

$$\begin{aligned} & \frac{\lambda_1}{C\sigma_2}\left(\frac{x-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-x}{\sigma_2}\right)\xi\left(\Theta_L^*\right) \\ \leq & \left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta_L^*\right)-\phi\left(\frac{\theta^*-x}{\sigma_2}\right)\right]^2 \end{aligned} \tag{2.23}$$

$\forall\ x \notin \Theta_L^*$.

Conditions (2.21) say that the marginal gain (loss) in second period welfare equals the marginal loss (gain) in first period welfare at all points $\underline{x}_i$ ($\overline{x}_i$). Next, conditions (2.22) say that for all disclosed beliefs, the marginal gain from disclosing information must exceed the marginal cost. If there were some x' that did not satisfy this condition, then the disclosure policy $\Theta_H^* \backslash (x', x'+\Delta)$ would strictly dominate Θ_L^* for small enough Δ. Finally, conditions (2.23) say that for all undisclosed beliefs, the marginal cost of disclosure must exceed the marginal gain.

Suppose that

$$1 > W\frac{\lambda_2}{\sigma_2}\int_{-\infty}^{\infty}\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)f\left(\widehat{\theta}_1\right)d\widehat{\theta}_1$$

so that $Ce_1(\emptyset) < 1$ (the proof works identically if the opposite is true). Clearly $(-\infty, \theta^*) \cap \Theta_L^* = \emptyset$. Now, for an arbitrary Θ not containing $(-\infty, \theta^*)$ there exists a unique point x' such that

$$E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right)-\phi\left(\frac{\theta^*-x'}{\sigma_2}\right)=0$$

since

$$\phi(0) > E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right)$$

and

$$\lim_{x\to\infty}\phi\left(\frac{\theta^*-x}{\sigma_2}\right)=0.$$

Clearly

$$\left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right)-\phi\left(\frac{\theta^*-x}{\sigma_2}\right)\right]^2$$

is decreasing in x for $x \in (\theta^*, x')$ and increasing in x for (x', ∞).

Now, for an arbitrary Θ

$$\frac{\lambda_1}{C\sigma_2}\left(\frac{x-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-x}{\sigma_2}\right)\xi(\Theta)$$

equals 0 when $x = \theta^*$, is strictly increasing in x for $x \in (\theta^*, x'')$, strictly decreasing in x for $x \in (x'', \infty)$, and tends to 0 as $x \to \infty$. From these observations one can conclude that for any Θ not containing $(-\infty, \theta^*)$, the points x that satisfy

$$\begin{aligned} &\frac{\lambda_1}{C\sigma_2}\left(\frac{x-\theta^*}{\sigma_2}\right)\phi^2\left(\frac{\theta^*-x}{\sigma_2}\right)\xi(\Theta) \\ \geq &\left[E\left(\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right)-\phi\left(\frac{\theta^*-x}{\sigma_2}\right)\right]^2 \end{aligned} \tag{2.24}$$

form the set $(x_1, x_2) \subset (\theta^*, \infty)$. For this reason, any Θ that satisfies (2.21), (2.22), and (2.23) must be convex and lie strictly in (θ^*, ∞). To prove that one can always find a Θ that satisfies (2.21), (2.22), and (2.23), consider some $\Theta = (y_1, y_2)$ and let $\widetilde{x}_2$ be the highest x_2 at which (2.24) holds with equality for all such Θ. Define

$$A \equiv \left\{(a_1, a_2)\,|\theta^* \leq a_1 \leq a_2 \leq \widetilde{x}_2, (a_1, a_2) \in \mathbb{R}^2\right\}.$$

Consider the mapping $h : A \to A$ that gives the points x_1 and x_2 at which (2.24) holds with equality as a function of the points y_1 and y_2. Because h is continuous and A is a convex, compact subset of $\mathbb{R}^2$, by Brouwer's Fixed Point Theorem there is some point $(y_1', y_2') \in A$ such that $h(y_1', y_2') = (y_1', y_2')$. Hence there exists some $\Theta = (y_1, y_2) \subset (\theta^*, \infty)$ that satisfies (2.21), (2.22), and (2.23). ■

2.A.8 Proof of Proposition 2.6

Proof. Second period equilibrium effort conditional on receiving feedback $\widehat{\theta}_2$ is

$$e_2^* = \left(\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)\right)^{\frac{1}{\beta}}$$

and conditional on not receiving feedback is

$$e_2^* = E\left[\frac{W}{C}\frac{\lambda_2}{\sigma_2}\phi\left(\frac{\theta^*-\widehat{\theta}_1}{\sigma_2}\right)|\widehat{\theta}_1 \notin \Theta\right]^{\frac{1}{\beta}}.$$

First period equilibrium effort is

$$= \left(\frac{W}{C}\frac{\lambda_2}{\sigma_2}\right)^{\frac{1}{\beta}} \left[\frac{\int_{-\infty}^{\infty} \phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) f\left(\widehat{\theta}_1\right) d\widehat{\theta}_1}{\frac{1}{\beta}\frac{W}{C}\frac{\lambda_1\lambda_2}{\sigma_2^2} \int_{\widehat{\theta}_1 \in \Theta} \left(\frac{\widehat{\theta}_1 - \theta^*}{\sigma_2}\right) \left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right)\right]^{\frac{\beta+1}{\beta}} f\left(\widehat{\theta}_1\right) d\widehat{\theta}_1} \right]^{\frac{1}{\beta}}$$

Including an interval of disclosed beliefs $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ for small Δ in a disclosure policy Θ decreases second period effort by an amount approximately proportional to

$$-\left(\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right)\right)^{\frac{1}{\beta}} + \frac{1}{\beta}\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) E\left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) | \widehat{\theta}_1 \notin \Theta\right]^{\frac{1-\beta}{\beta}}$$
$$+\left(\frac{\beta - 1}{\beta}\right) E\left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) | \widehat{\theta}_1 \notin \Theta\right]^{\frac{1}{\beta}}. \tag{2.25}$$

Whenever $\beta > 1$ this expression is positive. Since giving negative feedback reduces first period effort and expected second period effort, the effort maximizing disclosure policy will not contain any negative feedback. In the range $\widehat{\theta}_1 \in (\theta^*, \infty)$, one can verify that 2.25 is single troughed and achieves a minimum value of 0 at point $\widetilde{\theta}_1$ satisfying

$$\phi\left(\frac{\theta^* - \widetilde{\theta}_1}{\sigma_2}\right) = E\left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) | \widehat{\theta}_1 \notin \Theta\right].$$

Including an interval of disclosed beliefs $\left(\widehat{\theta}_1, \widehat{\theta}_1 + \Delta\right)$ for small Δ in a disclosure policy Θ increases first period effort by an amount approximately proportional to

$$\left(\frac{\widehat{\theta}_1 - \theta^*}{\sigma_2}\right) \left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right)\right]^{\frac{\beta+1}{\beta}} \left[\frac{\int_{-\infty}^{\infty} \phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right) f\left(\widehat{\theta}_1\right) d\widehat{\theta}_1}{\frac{1}{\beta}\frac{W}{C}\frac{\lambda_1\lambda_2}{\sigma_2^2} \int_{\widehat{\theta}_1 \in \Theta} \left(\frac{\widehat{\theta}_1 - \theta^*}{\sigma_2}\right) \left[\phi\left(\frac{\theta^* - \widehat{\theta}_1}{\sigma_2}\right)\right]^{\frac{\beta+1}{\beta}} f\left(\widehat{\theta}_1\right) d\widehat{\theta}_1} \right]^{\frac{1-\beta}{\beta}}$$

One can easily show that this expression is single peaked in $\widehat{\theta}_1$ and that it approaches 0 for $\widehat{\theta}_1 \to \theta^*$ and $\widehat{\theta}_1 \to \infty$. Thus one can apply exactly the same argument as in the proof of Proposition 2.4 to show that the effort maximizing disclosure policy when $\beta > 1$ will take the form $\Theta = (\theta', \theta'')$ where $\theta^* < \theta' < \theta'' < \infty$.

Similar arguments show why the form of the social welfare maximizing disclosure policy again takes the form of Proposition 2.4. ∎

2.A.9 Proof of Proposition 2.7

Proof. See the proof of Proposition 1.1. One need only show that $\theta*$ exists and is unique. Two helpful results are that (1) if $X \sim N(\mu, \sigma^2)$ then $E[X \mid X \geq a] = \mu + \sigma\gamma\left(\frac{a-\mu}{\sigma}\right)$ where γ is the normal hazard rate, and (2) $\gamma' \in (0,1)$ over the entire domain of γ (Greene 2003, p.759). Therefore, the derivative of the left hand side of (2.19) is bigger than the derivative of the right hand side. So, if a solution to (2.19) exists, it is unique.

Now, as $\theta^* \to -\infty$ the left hand side of (2.19) is clearly less than the right hand side. One can also show that

$$\lim_{\theta^* \to \infty} \theta^* - E\left[\theta \mid \widehat{\theta_2^F} \geq \theta^*\right] = 0$$

so that

$$\lim_{\theta^* \to \infty} \kappa + k\theta^* - E\left[\theta \mid \widehat{\theta_2^F} \geq \theta^*\right].$$

Therefore there is a $\theta*$ that solves (2.19). ■

2.A.10 Proof of Lemma 2.6

Proof. By definition, Θ_L^* is the social surplus maximizing disclosure policy. The equations that defines $\underline{x}$ and $\overline{x}$ under Θ_L^* are 2.21 evaluated at $x = \underline{x}$ and $x = \overline{x}$. The cost of effort parameter C does not play a role in defining θ^*, so one can vary it without changing the right hand side of 2.21. As $C \to \infty$ the left hand side of 2.21 approaches 0 for any Θ and x since $\frac{\lambda_1}{C\sigma_2}$ becomes arbitrarily small and $Ce_1^*(\Theta_L^*)$ is bounded above for all C. This implies that $\underline{x} - \overline{x} \to 0$ since 2.21 has a unique solution for x is the left hand side is 0. ■

Chapter 3

Assessing the Effectiveness of Mixed Committees: Evidence from the Bank of England MPC

3.1 Introduction

A dramatic change has occurred in how central banks around the globe determine monetary policy: responsibility for setting interest rates has shifted from individuals to committees. In fact, Pollard (2004) reports that ninety percent of eighty-eight surveyed central banks use committees to decide interest rates, underscoring their growing ubiquity. Although the trend is heavily in favor of collective decision making, some fundamental issues regarding the optimal structure of committees remain unclear. One of these is whether committee members should come from heterogeneous or homogeneous backgrounds. Some central banks, like the European Central Bank and US Federal Reserve, have committees composed solely of internal members (experts employed within the bank). Others, like the Bank of England and Reserve Bank of Australia, have committees that consist of internal as well as external members (experts who are not part of central bank staff).

The goal of this chapter is two-fold. The first is to provide theoretical arguments in favor of mixed committees and the second is to examine whether the voting record of the Bank of England's Monetary Policy Committee (MPC) is consistent with these arguments. We build a model that allows a committee designer to select different kinds of experts to decide monetary policy. The model identifies two primary tasks for committee members. First, they communicate private information about economic shocks to each other prior to voting. We assume that members' private information is verifiable, which allows us to apply an unraveling argument to show that communication fully aggregates information. If different members have different dimensions of expertise, then mixing them together can lead to higher utility for the designer if members are sufficiently specialized.

The second task for members is to use the collective information set to select an appropriate interest rate. We allow members to differ in their beliefs about the correct interest rate given a history of economic shocks, and for the committee designer to consider all beliefs equally likely to be correct. Thus, when two experts disagree, the designer assigns the probability one-half that each member is correct. Nevertheless, if members' beliefs are public information, then the designer's preferred committee structure takes the form of an advisory board: all members provide information to the member with the most moderate belief. Hence, with publicly observed beliefs, there is no justification for giving members with different beliefs a vote on the committee.

If the designer cannot observe beliefs, then drawing members from two different distributions can improve the designer's utility if the means of each distribution lie at opposite extremes. In this case, mixing types from the two distributions can lead to a more moderate median voter than if the designer drew from just one distribution. Therefore, the justification for giving external members a voting role in addition to an advisory role must arise through their moderating influence on internal members.

We next turn to examining the voting record of the MPC. We begin by establishing cross-sectional differences between external and internal members, namely, that externals are: (1) more likely to deviate from the committee decision and from internal members; (2) vote for, on average, lower interest rates; and (3) have higher within-group voting dispersion. In themselves, these results are not surprising, and in fact have been documented by other authors as we discuss below.

The clearest prediction of our model concerns how voting behavior changes over time. We obtain more original and interesting results when we examine voting dynamics. We find that the probability that external and internal members vote for different rates increases with time, and that the entire difference in voting behavior between external and internal members arises from members who have been on the committee longer than twelve months. It is only at this point that external members begin voting for systematically lower rates. These results are important because they are inconsistent with the rationale for giving both externals and internals voting rights since they fail to moderate each other's views initially.

We then delve deeper into the sources of external behavior and find an intriguing result: the entire drop in externals' voting levels arises from academics. We argue that this provides evidence of career concerns which influence the voting behavior of non-academics as they face more future career uncertainty than academics, all of whom joined the MPC from tenured positions. To push the results further, we examine how externals' voting behavior changed in response to an exogenous change in the probability of reappointment. External members who served during periods in which reappointment was unlikely all began voting for lower rates after twelve months. This evidence is consistent with a story in which external members with career concerns mimic internal members through their tenure on the committee in order to increase their chances of reappointment.

Another possible cause of the voting differences, and one that is often discussed in the monetary literature, is that external members may have asymmetric preferences over inflation and output. In particular, external members may be more recession-averse meaning that they cut rates by more than internal members during downturns. We examine the evidence for this and find that although tests in isolation appear to provide evidence in favor of such preferences, we conclude that it is more likely that career concerns are the driving force.

We next set out a brief description of previous research on MPC voting behavior before we explore our model more fully in Section 3.4. We then turn our attention to the data and the empirical analysis in the remaining sections. We conclude that the inclusion of external, together with internal, members on the MPC would create an unambiguous welfare gain if each group has specialized knowledge that it shares with the other, and that allowing external members to vote can also improve welfare under certain conditions. However, the evidence suggests that career concerns and the resulting failure of external members to moderate opinion, mean that these gains may be limited, or even negative. Our chapter, therefore, highlights the need for a more complete model of reputation, taking account of its effect on the optimal design of mixed committees.

3.2 Previous Research on MPC Voting

There has been a great deal of research interest in committee behavior. Blinder (2007) provides an excellent coverage of the issues relating to monetary policy committees. In the analysis below, we take for granted that there is transparency of voting behavior of MPC members and that MPC meeting minutes are published; without such a design structure, the nature of our empirical work would be impossible. As a result our chapter is not contributing to general discussion of whether having a committee influences monetary policy outcomes (interested readers are pointed toward Sibert (2006), Sibert (2003) and the references therein), or on the debate about optimal degree of transparency (see, for example, Geraats (2006) and Sibert (2002)).

Using an experimental set-up, Blinder and Morgan (2005) and Lombardelli, Proudman, and Talbot (2005) both conclude that committee decision making improves on the behavior of individuals; although neither paper explicitly examines the behavior of external members. Gerlach-Kristen (2006) constructs a model of monetary policy committee voting to formalize the idea that groups can outperform individuals, but does not explore strategic voting or communication. Li, Rosen, and Suen (2001) have studied the two-person committee voting problem in which members can report their non-verifiable private information strategically. They show that when members disagree about the correct decision, there is less than full reporting of private information. In this chapter, committees fully aggregate information due to the verifiability of private information, which allows us to apply unraveling results (Grossman 1981, Milgrom 1981).

Numerous recent papers examine empirical differences in voting behavior among MPC members. Gerlach-Kristen (2003), Spencer (2006), Harris and Spencer (2008), and Gerlach-Kristen (2009) all document the tendency of external members to dissent more often and to favor lower interest rates than internal members. Bhattacharjee and Holly (2005) and Besley, Meads, and Surico (2008) consider member heterogeneity more broadly, and find that there are systematic voting differences across members. None of these papers uncovers the growth of conflict on the MPC,[1] nor do they explore the normative implications of including internal and external members on the same committee. By and large, these papers assume member preferences derive from a weighted sum of inflation and output, with different members having different weights. However, such preferences alone are unable to explain our empirical results.

Unlike Spencer (2006) and Harris and Spencer (2008), we do find evidence of career concerns on the MPC. Our chapter is also complementary to Meade and Stasavage (2008), who have found evidence of career concerns on the Federal Open Market Committee in the US.

3.3 MPC Background

Until 1997 the Chancellor of the Exchequer (the government official in charge of the Treasury) had sole responsibility for setting interest rates in the UK. One of Gordon Brown's first actions on becoming Chancellor in the government of Tony Blair was to set up an independent committee for setting interest rates in order to make monetary policy less arbitrary and susceptible to election cycles. The MPC first convened on 6 June 1997, and has met every month since. Majority vote determines the rate of interest. Its remit, as defined in the Bank of England Act (1998) (`http://www.bankofengland.co.uk/about/legislation/1998act.pdf`) is to "maintain price stability, and subject to that, to sup-

[1]However, Gerlach-Kristen (2003) does mention a delay in a member's first dissent: on average, it occurs after nine months.

port the economic policy of Her Majesty's government, including its objectives for growth and employment." In practice, the committee seeks to achieve a target inflation rate of 2%[2], based on the Consumer Price Index. If inflation is greater than 3% or less than 1%, the Governor of the Bank of England must write an open letter to the Chancellor explaining why. The inflation target is symmetric; missing the target in either direction is treated with equal concern.

The MPC has nine members; five of these come from within the Bank of England: the Governor, two Deputy Governors, the Chief Economist, and the Executive Director for Market Operations. The Chancellor also appoints four members (subject to approval from the Treasury Select Committee) from outside the Bank. There are no restrictions on who can serve as an external member. According to the Bank of England (`http://www.bankofengland.co.uk/monetarypolicy/overview.htm`), the purpose of external appointments is to "ensure that the MPC benefits from thinking and expertise in addition to that gained inside the Bank of England." Bar the governors, all members serve three year terms; the governors serve five year terms. When members' terms end, they can either be replaced or re-appointed. Through June 2008, 25 different members have served on the MPC – 11 internal members and 14 external members. Each member is independent in the sense that they do not represent any interest group or faction. The Bank encourages members to simply determine the rate of interest that they feel is most likely to achieve the inflation target.[3]

The MPC meets on the first Wednesday and Thursday of each month. In the month between meetings, members receive numerous briefings from Bank staff and regular updates of economic indicators. On the Friday before MPC meetings, members gather for a half-day meeting in which they are given the latest analysis of economic and business trends. On the Wednesday of the meeting, members discuss their views on several issues. The discussion continues on Thursday morning; each member is given some time to summarize his or her views to the rest of the MPC, and suggest what vote they favor (although they can, if they wish, wait to hear the others views before committing to a vote (Lambert 2006)). This process begins with the Deputy Governor for monetary

[2]This target changed from the RPIX to the CPI measure of inflation in January 2004, with a reduction in the inflation target from 2.5% to 2%.

[3]According to the Bank of England website (`http://www.bankofengland.co.uk/monetarypolicy/overview.htm`)

> Each member of the MPC has expertise in the field of economics and monetary policy. Members do not represent individual groups or areas. They are independent. Each member of the Committee has a vote to set interest rates at the level they believe is consistent with meeting the inflation target. The MPC's decision is made on the basis of one-person, one vote. It is not based on a consensus of opinion. It reflects the votes of each individual member of the Committee.

policy, concludes with the Governor, and other members are selected in random order in between. To formally conclude the meeting, the Governor suggests an interest rate that he believes will command a majority. Each member then chooses whether to agree with the Governor's decision, or dissent and state an alternative interest rate. The MPC decision is announced at 12 noon. Two weeks after each meeting, members' votes are published, along with minutes of the meeting with full, but unattributed comments.

We now set out a model that captures the essential institutional details of the MPC.

3.4 Committee Voting Model

3.4.1 Assumptions and set-up

The model has an infinite number of periods $t \in \{1, 2, ...\}$. The period t forecast for inflation at the horizon[4] is given by $\pi_t \sim N(\alpha_t + \theta - \beta r_t, \sigma^2)$ where α_t is a period t state variable that captures the history of shocks to hit the economy, $\theta \sim N(\overline{\theta}, \sigma_\theta^2)$ is a parameter related to the non-inflationary level of output and independent of α_t (for example, θ could capture the effect of long-run supply),[5] and β is a simplified monetary policy transmission mechanism.

We assume that α_t is persistent and is subject to two independent shocks, $s_t \sim N(0, \sigma_s^2)$ and $d_t \sim N(0, \sigma_d^2)$; in particular, $\alpha_t = \rho\alpha_{t-1} + s_t + d_t$ where ρ is the AR(1) persistence coefficient. The key issue is that economic conditions are not unidimensional, however, for the sake of the discussion, we shall refer to d and s as temporary demand and supply shocks.[6] This means we can write economic conditions as

$$\sum_{\tau=1}^{t} \rho^{t-\tau} (s_\tau + d_\tau).$$

There is a group of experts, each with period t preferences given by

$$-E\left[(\pi_t - \pi^*)^2\right], \tag{3.1}$$

[4]To reduce notation, we define this period t forecast inflation of inflation as π_t rather than $\pi t + h$. We shall also refer to this forecast as "current inflation".

[5]In the absence of transitory shocks, and assuming a constant interest rate $\overline{r}$, inflation will equal $\theta - \beta\overline{r}$. Thus, to meet their target, the central bank must ensure $E[\theta] - \beta\overline{r} = \pi^*$ holds. This equation defines the equilibrium real interest rate.

[6]Given our specification of how shocks impact expected future inflation, a positive supply shock would result in a negative s_t, while a positive demand shock would result in a positive d_t. Moreover, as the MPC members are only concerned with those shocks to which monetary policy reacts, we can think of s_t as the second round effects of supply shocks. Therefore, a positive s_t is the second round inflationary impact of the a negative supply shock (such as an oil price spike). An alternative could be to consider s_t as consumption (saving) shocks and d_t as investment (depreciation) shocks which both affect the level of demand and inflation.

where π^* is an exogenous inflation target. Thus, experts share the same preferences. However, they disagree in the sense that each believes that $\theta \sim N\left(\overline{\theta}_i, \sigma_\theta^2\right)$. Thus, experts do not necessarily agree on the distribution of inflation conditional on an interest rate. We assume that the prior beliefs on θ are common knowledge. In contrast, we assume that experts know g up to a constant, which can be absorbed into uncertainty about θ. While this assumption may seem strong, insider accounts from the MPC suggest that most disagreements are about economic conditions rather than the transmission mechanism.[7]

In every period, each expert receives verifiable private signals about the current shocks equal to $\widehat{s}_{it} = s_t + \varepsilon_i^s$ and $\widehat{d}_{it} = d_t + \varepsilon_i^d$, where $\varepsilon_i^s \sim N\left(0, \sigma_{is}^2\right)$ and $\varepsilon_i^d \sim N\left(0, \sigma_{id}^2\right)$. The chapter will refer to the ratios $\gamma_i^s = 1/\sigma_{is}^2 \in (0, \infty)$ and $\gamma_i^d = 1/\sigma_{id}^2 \in (0, \infty)$ as the skill of member i in identifying s and d shocks, respectively. For example, as $\gamma_i^s \to 0$, member i has no useful private information about the supply shocks, and as $\gamma_i^s \to \infty$ he has near perfect knowledge of them.

The verifiability assumption on the private signals is key in the model. The motivation is that monetary policy experts arrive at their private views about the latest economic shocks through analyzing and interpreting economic data, reports and forecasts. This in turn means that when communicating their views to others, they can produce hard information to back it up. Thus, verifiability is a natural assumption given the model's application.

A committee designer (who one can think of as the government) with preferences

$$-\sum_{t=1}^{\infty} \delta^t E\left[(\pi_t - \pi^*)^2\right] \tag{3.2}$$

can appoint two experts to a committee that decides interest rates in a manner specified below. The designer receives no private information about the shocks. It also has higher-order uncertainty about the distribution of θ: it believes $\theta \sim N\left(\overline{\theta}, \sigma_\theta^2\right)$ and that $\overline{\theta} \sim U[-a, a]$. So, whereas the experts have a clear prior belief about θ, the designer does not. For consistency, we assume that for all members, $-a \leq \overline{\theta}_i \leq a$, so that the committee designer believes each member's view is correct with equal probability. The designer's incentives to appoint experts depend on what they can do once they join the committee, so to complete the model we describe this.

Once on the committee, and after receiving their private signals, experts (whom we call members hereafter) have the opportunity to communicate with each other prior to voting. For both $\widehat{d}_{it}$ and $\widehat{s}_{it}$, members simultaneously choose whether to disclose their

[7]For example, see Barker (2007). In addition, Bhattacharjee and Holly (2005) find heterogeneity in estimated individual policy reaction functions for MPC members, and argue that differences in the way individual members assimilate information supplied to them generate such differences.

Table 3.1: Distribution of Unique Votes Across Meetings

Unique Votes	Frequency	Percentage
1	47	35.3
2	81	60.9
3	5	3.8
Total	133	100

private information or not. One can characterize member i's strategy space with two sets Θ_{it}^d and Θ_{it}^s, with the interpretation that member i withholds his period t signals whenever $\widehat{d}_{it} \in \Theta_{it}^d$ and $\widehat{s}_{it} \in \Theta_{it}^s$. These sets are choice variables for each player i in each period t, and we solve below for their equilibrium structure. Because private information is verifiable, credible communication is not an issue.[8] Allowing communication is important in light of the extensive discussions that MPC members have with each other in the days leading up to the final vote. We assume that the committee designer does not observe what members communicate to each other, only the final decision that they take.

After sharing information with each other, the members simultaneously select an interest rate $r_{it} \in \{\underline{r}_t, \overline{r}_t\}$, where without loss of generality $\underline{r}_t < \overline{r}_t$. Table 3.1 provides a motivation for this assumption. In 96.2 per cent of meetings, members all vote for one or two interest rates, even though there are no restrictions (legal or otherwise) in place that prevent them from selecting other rates. We assume that if $r_{1t} = r_{2t} = \underline{r}_t$, then $r_t = \underline{r}_t$; that if $r_{1t} = r_{2t} = \overline{r}_t$, then $r_t = \overline{r}_t$; and that if $r_{1t} = \underline{r}_t$ and $r_{2t} = \overline{r}_t$, or $r_{1t} = \overline{r}_t$ and $r_{2t} = \underline{r}_t$, then member 1's preferred rate is chosen with probability p. This assumption simply says that the committee has a way of breaking ties, and that there is some non-zero probability that the tie could go either way. This is similar to the fact that the Governor of the Bank of England is charged with breaking any ties that remain after all other members have cast their votes.

After setting the interest rate r_t, all members observe the random variable $\widehat{\pi}_t = \pi_t + u_t$ where $u_t \sim N(0, \sigma_u^2)$ is again a white noise term. In other words, members receive information about the success they had in period t in achieving the inflation target before they vote in period $t+1$. This information could, for example, come from national accounts and other data releases, as well as Inflation Report projection updates which are regularly done within quarters to help interpret new data.

To summarize, the timing of the game is the following:

1. Members receive signals $\widehat{d}_{it}$ and $\widehat{s}_{it}$

2. Members simultaneously choose whether or not to disclose their signals to each

[8] One could allow members to send arbitrary messages to each other in the case where they do not provide verifiable information without altering the intuitions that underpin the solution of the model.

other

3. Members simultaneously vote for $\underline{r}_t$ or $\overline{r}_t$
4. r_t is implemented
5. Members observe π_t

3.4.2 Member behavior

This section solves the committee voting model laid out in the previous section by backward induction. It begins by deriving the Bayesian Nash Equilibrium of the voting stage given an arbitrary outcome of the communication stage, and then solves for the Bayesian Nash Equilibrium of the communication stage given equilibrium behavior in the voting stage.

Voting

There are two relevant parameters that a member needs to consider when selecting his vote in period t. The first is his estimate of current economic conditions α_t. We denote this estimate as $\widehat{\alpha}_{it} = E[\alpha \mid I_{it}]$, where I_{it} the information set of member i at time t. The second is his current belief about θ. We denote this by $\widehat{\theta}_{it} = E[\theta \mid I_{it}]$.

With strategic voting, agents have to take into account not only their private estimates of payoff-relevant parameters when selecting an optimal action, but also the strategies of the other players. A strategic effect potentially arises because when agents condition on their vote being pivotal, they might obtain information about other agents' private information. In this model, a strategic effect does not arise because each agent can independently influence the interest rate. For example, if member 1 votes for $\overline{r}_t$, then by also voting for $\overline{r}_t$, member 2 guarantees that $\overline{r}_t$ is the outcome. On the other hand, if member 2 instead votes for $\underline{r}_t$, then $\underline{r}_t$ is the outcome with probability p. Therefore, it is a dominant strategy for each member to maximize (3.1) conditional on his private information only.

Proposition 3.1 *Member i votes for $\overline{r}_t$ if and only if $\widehat{\alpha}_{it} \geq \alpha^*_{it}\left(\widehat{\theta}_{it}\right)$, where $\alpha^*_{it}\left(\widehat{\theta}_{it}\right)$ is strictly decreasing.*

To understand this result, it is first important to examine what interest rate member i would choose if he were not constrained to choose between $\underline{r}_t$ and $\overline{r}_t$. The proof of proposition 3.1 shows that the ideal interest rate r^*_{it} satisfies

$$\beta r^*_{it} + \widehat{\alpha}_{it} + \widehat{\theta}_{it} = \pi^*. \tag{3.3}$$

That is, if he could choose any interest rate, member i would choose the one that set the expected mean of the inflation distribution equal to the inflation target π^*. Moreover, one can easily show that preferences are single peaked in the sense that (3.1) is strictly declining as r_t moves away from r_{it}^*. To see the implications for voting behavior, one can examine Figure 3.1, which plots out expected utility for member i given $\widehat{\alpha}_{it}$ and $\widehat{\theta}_{it}$, as well as examples of $\underline{r}_t$ and $\overline{r}_t$. Member i will choose the interest rate that maximizes his expected utility. In terms of the figure, this entails choosing $\underline{r}_t$ over $\overline{r}_t$.

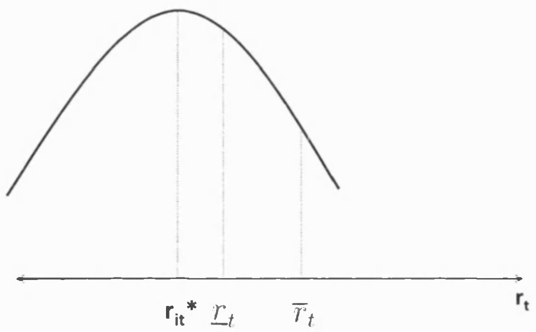

Figure 3.1: Member Preferences

We now turn to analyzing how voting depends on $\widehat{\alpha}_{it}$ and $\widehat{\theta}_{it}$. The top half of Figure 3.2 depicts the same preferences as in Figure 3.1, when the ideal interest rate for member i is r_{it}^*. We first consider what happens when $\widehat{\alpha}_{it}$ increases. In this case, member i believes more inflationary pressures have accumulated in the economy in period t, and his ideal interest rate increases. When $\widehat{\alpha}_{it}$ increases by enough, member i votes for $\overline{r}_t$ over $\underline{r}_t$, as demonstrated in the bottom half of the figure. One can therefore characterize member i's voting rule with a single parameter α_{it}^*: whenever $\widehat{\alpha}_{it} < \alpha_{it}^*$, he votes for $\underline{r}_t$, and whenever $\widehat{\alpha}_{it} \geq \alpha_{it}^*$, he votes for $\overline{r}_t$.[9]

We next consider what happens when $\widehat{\theta}_{it}$ increases. Now, for fixed beliefs about the temporary shocks, the ideal rate increases since member i believes long-term inflationary pressures are higher. The effect on preferences is the same as when $\widehat{\alpha}_{it}$ increases: the ideal rate increases. So, the preferences in the top half of Figure 3.2 shift to the right. This in turn decreases α_{it}^* since member i needs less evidence of temporary inflationary shocks to prefer the higher rate.

[9]Here, we have resolved indifference in favor of $\overline{r}_t$, an unessential assumption.

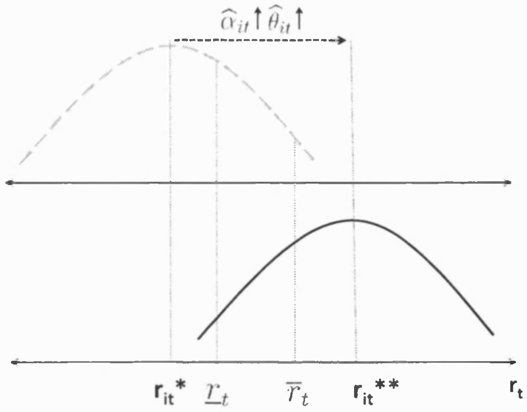

Figure 3.2: Member Preferences

Communication

Before discussing the equilibrium of the communication game, it is important to first discuss exactly how each member uses information in his decision-making. To begin, we focus on just the first period, and suppose that member 1 has a lower prior belief on θ than member 2 ($\overline{\theta}_1 < \overline{\theta}_2$). This means that member 1 requires evidence of higher temporary shocks to vote for the higher interest compared to member 2. Furthermore, instead of each member's signals being private information, we suppose that they are public information. By Proposition 3.1, member i votes for $\overline{r}_1$ if and only if $\widehat{\alpha}_{i1} \geq \alpha_{i1}^*$, where $\alpha_{11}^* > \alpha_{21}^*$.

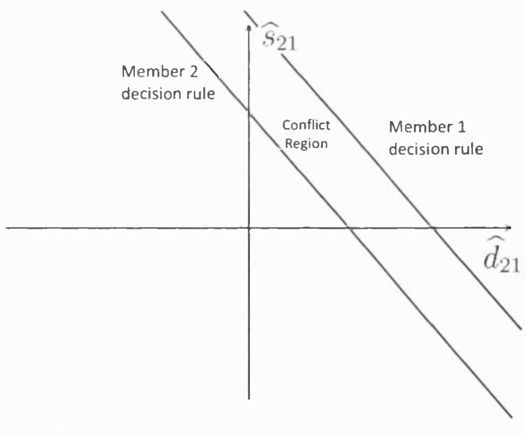

Figure 3.3: Decision Rules for Members 1 and 2 Given $\widehat{d}_{11}$ and $\widehat{s}_{11}$

Figure 3.3 graphically illustrates the decision rules of each member for fixed values of $\widehat{d}_{11}$ and $\widehat{s}_{11}$. Since both members' signals are mixtures of normal random variables, $\widehat{\alpha}_{i1}$ is linearly increasing in each signal. This means that we can represent member 1's decision rule (for a fixed $\widehat{d}_{11}$ and $\widehat{s}_{11}$) as a negatively sloped line in $\left(\widehat{d}_{21}, \widehat{s}_{21}\right)$ space that represent the combinations of member 2's signals at which $\widehat{\alpha}_{11} = \alpha^*_{11}$. All combinations of $\widehat{d}_{21}$ and $\widehat{s}_{21}$ that lie on or above this line lead member 1 to accept $\overline{r}_1$, and all combinations that fall below lead him to accept $\underline{r}_1$. Member 2's decision rule is simply member 1's shifted down by $\overline{\theta}_2 - \overline{\theta}_1$, the amount by which their beliefs on expected inflation for any realization of the signals differs.

There are three distinct regions that emerge from Figure 3.3. The first is realizations of $\left(\widehat{d}_{21}, \widehat{s}_{21}\right)$ that lie below the line $\widehat{\alpha}_{21} = \alpha^*_{21}$. In this region, both members agree that $\underline{r}_1$ is the correct interest rate. The second lies above the line $\widehat{\alpha}_{11} = \alpha^*_{11}$. Here, both members agree that $\overline{r}_1$ is the correct rate. The third region lies between $\widehat{\alpha}_{21} = \alpha^*_{21}$ and $\widehat{\alpha}_{11} = \alpha^*_{11}$. In this area, there is disagreement between the members: person 1 believes $\underline{r}_1$ is the correct rate, and person 2 believes that $\overline{r}_1$ is. This is the "conflict region" in which disagreement between the members arises. Its size is key to understanding the equilibrium.

One can now turn to analyzing the effects of communication when members privately observe their signals. For expositional purposes, we consider an equilibrium in which member 1 withholds some realizations of his demand shock, and always discloses his signal on the supply shock. When member 1 observes some $\widehat{d}_{11} \in \Theta^d_{11}$, he anticipates that person 2 will vote for $\overline{r}_1$ whenever

$$\widehat{\alpha}_{21} = E\left[\alpha_1 \mid \widehat{d}_{11} \in \Theta^d_{11}, \widehat{s}_{11}, \widehat{d}_{21}, \widehat{s}_{21}\right] \geq \alpha^*_{21}.$$

Figure 3.4 plots the line $\widehat{\alpha}_{21} = \alpha^*_{21}$ above which member 2 votes for $\overline{r}_1$. This line is the one furthest to the southwest. On the other hand, member 1 believes that the correct decision rule is to vote $\overline{r}_1$ whenever $\left(\widehat{d}_{21}, \widehat{s}_{21}\right)$ lies above $\widehat{\alpha}_{11} = \alpha^*_{11}$.

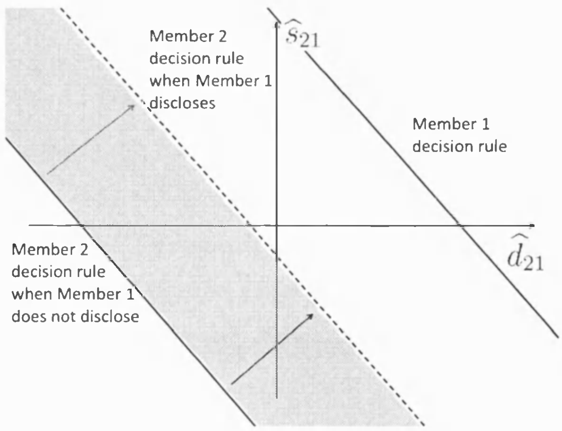

Figure 3.4: The Effect of Member 1 Disclosure on Member 2 Decision Rule

For an equilibrium to exist, it must be the case that member 1 actually wishes to withhold information whenever $\widehat{d}_{11} \in \Theta^d_1$. The inherent conflict between the two committee members is over the threshold at which the higher interest rate becomes appropriate. Member 1 would like to convince member 2 that the shocks are as small as possible in order to get him to vote for the high interest rate less often. Consider the incentives of member 1 when he observes some $\widehat{d}_{11} - \inf \Theta_1^d > \varepsilon$ for ε near 0. If member 1 shares this information with member 2 then

$$\begin{aligned}
\widehat{\alpha}_{21} &= E\left[\alpha_1 \mid \widehat{d}_{11} \in \Theta_1^d, \widehat{s}_{11} \in \Theta_1^s, \widehat{d}_{21}, \widehat{s}_{21}\right] \\
&\geq E\left[\alpha_1 \mid \widehat{d}_{11}, \widehat{s}_{11} \in \Theta_1^s, \widehat{d}_{21}, \widehat{s}_{21}\right] \\
&= \widehat{\alpha}'_{21}.
\end{aligned}$$

In other words, when member 1 discloses some $\widehat{d}_{11}$ that is one of the smallest elements in Θ_1^d, member 2 forms a lower belief on α than when member 2 withholds such a $\widehat{d}_{11}$. This happens because without disclosure, member 2 forms his belief on α_1 knowing only that $\widehat{d}_{11} \in \Theta_1^d$, so he takes the average over this set. With disclosure, member 2 infers d_1 to be lower, and so also adjusts his belief on α down. This in turn shifts member 2's decision rule to the northeast, as illustrated in Figure 3.4. For all $\left(\widehat{d}_{21}, \widehat{s}_{21}\right)$ in the shaded region, member 2 now votes for $\underline{r}_1$ instead of $\overline{r}_1$. Thus, from member 1's perspective, information disclosure reduces the probability that member 2 will take the wrong action, and strictly improves expected utility. In this way, any equilibrium without full information disclosure "unravels" since there is always some type that strictly prefers disclosing to withholding.

Proposition 3.2 *In the unique equilibrium of the communication game,* $\Theta_{it}^d = \emptyset$ *and* $\Theta_{it}^s = \emptyset\ \forall i, t$.

This result that communication on committees can indeed lead information aggregation, even when members have conflicting ideas about how to interpret each others' information.[10] It also echoes results in Grossman (1981) and Milgrom (1981), who demonstrate similar results in exchange economies with adverse selection.

Learning

We have concluded that behavior consists of full sharing of private information followed by all members' voting for their preferred interest rate in every period. One might then wonder what a dynamic structure adds to the model. The answer lies in the release of the inflation signal $\widehat{\pi}_t$. While members enter the committee with heterogeneous priors on θ, they are able to adjust their views when they obtain information on how the interest

[10]The verifiability of private information is crucial for establishing this result. Okuno-Fujiwara, Postlewaite, and Suzumura (1990) show that full information revelation need not occur if even some private information is not verifiable.

rate chosen by the committee maps into actual inflation. Since the demand and supply shocks are not correlated with θ, the communication of private signals does not allow for learning.

3.4.3 Mixed committees and welfare

So far, we have discussed two dimensions of member behavior: communication and voting. We now show how each dimension provides a margin on which mixed committees can affect welfare.

Information aggregation and welfare

The first result of our model formalizes the idea that mixed committees can add value to society due their ability to draw on members' diverse expertise.

Proposition 3.3 *For small enough a, there exist numbers $0 < \underline{d} < \overline{d}$ and $0 < \underline{s} < \overline{s}$ such that a committee composed of solely of members with $\gamma_i^d < \underline{d}$ and $\gamma_i^s > \overline{s}$ or solely of members with $\gamma_i^d > \overline{d}$ and $\gamma_i^s < \underline{s}$ will yield the committee designer a lower expected utility than a committee composed of a mixture of these types.*

To understand the intuition of this result, suppose there are only two types of experts, both of whom agree with the committee designer that $\theta \sim N(0, \sigma_\theta^2)$:[11] d-types perceive d perfectly ($\gamma_i^d \to \infty$) but have no private information about s ($\gamma_i^s = 0$); s-types perceive s perfectly ($\gamma_i^s \to \infty$) but have no private information about d ($\gamma_i^d = 0$). Once on the committee, either type will share his information with the other. When they make interest rate decisions, a committee with just d-types will therefore know d but know nothing about s, and a committee with just s-types will know s but know nothing about d. On the other hand, a mixed committee will know both d and s. Since both types agree with the committee designer about the appropriate interest rate, a mixed committee yields the designer strictly higher utility, since it has more information on which to base its decision.

This result is important because it shows that a committee composed of members with different kinds of policy-making expertise can produce a better outcome for society, even if the members do not agree perfectly about the right course of action. The key to the argument is information aggregation, since members have access to each other's expertise when they vote.

[11]The relationship between member information and designer utility is not clear when there is the possibility for members to be very far from the correct belief about θ.

Belief diversity and welfare

We have said nothing so far about voting per se. The previous result shows that information aggregation can lead to better outcomes for some level of belief diversity, but now we ask another question: whether there is a value to having a diversity of beliefs among committee members for its own sake. To isolate this issue, we assume for the moment that members' identities do not affect the amount of information to which committee members have access.

Proposition 3.4 *Suppose that members observe public information about the d and s shocks prior to voting, and have no private information. Furthermore, suppose that* $\overline{\theta}_1 = \overline{\theta}_2 = \overline{\theta}'$*. The committee designer's welfare is strictly decreasing in* $\left|\overline{\theta}'\right|$.

While the committee designer believes that all prior beliefs about θ between $-a$ and a are equally likely, the designer is not indifferent among members with these different beliefs. The more moderate the beliefs of the committee members—in the sense of distance from 0—the better off the designer is. To see the intuition for the result, an example is helpful. Suppose that $a = 1$ and the designer can appoint members for whom $\overline{\theta}_i = 0.5$ or for whom $\overline{\theta}_i = 0.75$. Then, whenever $\overline{\theta} < 0.5$, the former types take the correct decision more often. But, since $\overline{\theta} < 0.5$ is more likely than not given the distributional assumption on $\overline{\theta}$, the expected utility from the more moderate belief is higher. This has an immediate and important implication for committee design.

Corollary 3.1 *Suppose member beliefs are public information and* $\overline{\theta}_1 \neq \overline{\theta}_2$*. Then the committee designer's welfare is highest either as* $p \to 0$ *or* $p \to 1$.

p is the parameter that measures the probability that member 1's preferred rate is chosen when he conflicts with member 2. Moreover, its value does not affect the communication behavior of any member because as long as there is some probability of everyone's vote mattering, each member would like to influence the other through information disclosure. The designer can thus choose p without altering the amount of information that each member has when selecting rates. Therefore, if the designer can observe member's prior beliefs about θ, it should give full decision authority to the member with the more moderate belief. In other words, it can appoint members as advisors to the decision maker, without giving them any responsibility for decision making.

Corollary 3.1 has the important implication that a committee with heterogeneous beliefs can only benefit the designer if it does not observe members' priors. If this is the case, appointing members with different (expected) beliefs can moderate the outcome.

In order to see this, one must move beyond a two-person committee and consider the possibility of larger groups. Suppose that the designer can draw members from one of two groups. The first group has members with beliefs distributed $U\left[-a, \frac{a}{2}\right]$ and the second has members with beliefs distributed $U\left[-\frac{a}{2}, a\right]$. By appointing half the members from the first group and half the members from the second, the designer ensures moderation for a large enough committee size, since the median voter's belief converges to $\overline{\theta}_i = 0$ as the committee size becomes large. If it only appointed members from one of the two groups, the median voter's belief converges to $\left|\overline{\theta}_i\right| = \frac{a}{4}$, resulting in a utility loss relative to the mixed committee.

In terms of our application to the MPC, there would be a justification for including externals as *voting* (as opposed to advisory) members if the UK government felt that they balanced the views of internal members to yield a more moderate outcome. One might suspect that when we look at the data we will find differences in voting behavior between members—and indeed we do. The question is whether the differences we observe are consistent with moderation. Our final theoretical result provides a useful test.

Proposition 3.5 $\Pr\left[r_{1t} \neq r_{2t}\right] \xrightarrow{p} 0$.

Different beliefs about θ lead to a positive probability of members' selecting different interest rates; however, after each period, members have the opportunity to adjust their beliefs, and results from statistical theory (Blackwell and Dubins 1962, Savage 1972) show that members' beliefs about θ converge when they are exposed to a sufficient amount of information about the relationship between interest rates and inflation. Therefore, the probability of members' voting for different interest rates becomes negligible after they have sat for long enough together on the committee. In an N-person committee, one can simply apply this result to each pair of members to generate the same result.

3.5 Data

In order to test Proposition 3.5 we use the MPC voting records between July 1997 and June 2008 (data available from `http://www.bankofengland.co.uk/monetarypolicy/decisions.htm`). The data contain a record of every decision ($decision_t$) taken by the MPC, as well as each member's vote in each meeting ($vote_{it} = \Delta r_{it}$).[12] Before June 1998 there is information about whether members preferred higher or lower interest rates compared with the decision, but not about their actual preferred rate. In these cases, we treat a member's vote as either 25 basis points higher or lower than the decision, in the

[12] We express members' votes in terms of their preferred change in interest rates rather than their preferred level. This makes no difference to the results.

direction of disagreement. The Bank website also provides information on which members were external appointments and which were internal. For every member we gathered biographical information, including previous occupation, educational background, and age from press releases associated with their appointment and from information provided to the Treasury Select Committee ahead of their confirmation.

We drop the emergency meeting held after September 11th 2001 from our dataset for the programming convenience of having only one meeting per month. This does not affect our results: in the meeting after 9/11, voting was unanimously in favor of lowering interest rates, so it would not be used for econometric identification given our use of time fixed effects. Howard Davies served on the MPC for the first two meetings and is the only member who voted exclusively on unanimous committees and thus his inclusion/exclusion is unimportant for econometric identification; although we include him in our baseline regressions. Lord George, the Governor for most of our sample, always voted with the majority regardless of his starting position; as a result we think that these voting records do not represent his own views in all cases. Even under the governorship of Mervyn King, the Governor has only deviated twice since taking office in July 2003. Nonetheless, we include the observations for the Governor in the regression results presented below, though all of the results stand if we exclude the data on the Governor at each meeting.

In Table 3.2 we provide summary statistics of the individual members on the MPC. Of the 25 MPC members that we consider in our sample, 14 are external and 11 are internal as indicated by the variable[13]

$$INT_i = \begin{cases} 0 \text{ if member i is an external member} \\ 1 \text{ if member i is an internal member} \end{cases}$$

The average vote shows the mean of all votes cast by the member during their time on the MPC within our sample; this is driven largely by when a member served on the committee. The variance column reports the analogous second-moment for the voting data. Table 3.2 also shows that the educational background of both groups is heterogenous and that both groups contain members who worked as academics prior to their appointment ($acad_i = 1$).

In our model, the committee has two members each of whom can choose two interest rates, so the probability of their not agreeing on the correct rate is the only natural measure of disagreement. On the actual MPC there is not just one internal member and one external member, but many of each. Therefore, determining the correct measure of disagreement is not as straightforward. We therefore explore several possibilities for

[13]No member has so far served as both an external member and an internal member, though there is nothing that prohibits this from happening in the future

Table 3.2: Sample Statistics by Member

Member	INT_i	Average Vote	Variance of Vote	Education	$Acad_i$	Meetings
A. Sentance	0	0.07	0.026	Prof/PhD	0	21
C. Goodhart	0	0.01	0.050	Prof/PhD	1	36
C. Allsopp	0	-0.13	0.020	Masters/Accountancy	1	36
D. Blanchflower	0	-0.11	0.032	Prof/PhD	1	25
D. Walton	0	0.00	0.023	Masters/Accountancy	0	12
D. Julius	0	-0.12	0.036	Prof/PhD	0	45
K. Barker	0	-0.01	0.020	Undergraduate	0	85
M. Bell	0	-0.01	0.018	Masters/Accountancy	0	36
R. Lambert	0	0.02	0.013	Undergraduate	0	34
A. Budd	0	-0.06	0.070	Prof/PhD	0	18
S. Nickell	0	-0.05	0.028	Prof/PhD	1	72
S.Wadhwani	0	-0.11	0.041	Prof/PhD	0	36
T. Besley	0	0.07	0.025	Prof/PhD	1	22
W. Buiter	0	0.00	0.105	Prof/PhD	1	36
C. Bean	1	-0.02	0.017	Prof/PhD	1	93
D. Clementi	1	-0.04	0.034	Masters/Accountancy	0	60
I. Plenderleith	1	-0.03	0.034	Masters/Accountancy	0	60
J. Vickers	1	0.00	0.060	Prof/PhD	1	28
M. King	1	0.02	0.027	Prof/PhD	0	133
P. Tucker	1	0.03	0.014	Undergraduate	0	73
R. Lomax	1	0.02	0.010	Masters/Accountancy	0	60
A. Large	1	0.07	0.016	Masters/Accountancy	0	40
E. George	1	-0.03	0.029	Undergraduate	0	73
J. Gieve	1	0.01	0.024	Undergraduate	0	29
H.Davies	1	0.25	0.000	Masters/Accountancy	0	2

measuring conflict.

The first measure (and the one most common in the literature) is whether a member deviates from the majority of members on the committee. We therefore define the variable

$$D\left(Dev\_MPC\right)_{it} = \begin{cases} 0 \text{ if } \Delta r_{it} = decision_t \\ 1 \text{ if } \Delta r_{it} \neq decision_t \end{cases}$$

However, a measure of disagreement that is closer in spirit to our model would explicitly measure conflict between externals and internals, not compare each member against the majority. We therefore construct a second dummy variable that measures when internal (external) members deviate from the modal vote of the external (internal) group. This variable more closely captures disagreements between internals and externals on the committee. Defining the modal vote of the subset of internal (external) members in period t as $decision_t^{INT=1}$ ($decision_t^{INT=0}$), we can define:

$$D\left(Dev\_group\right)_{it} = \begin{cases} 0 \text{ if } \Delta r_{it} = decision_t^{INT=1} \& INT_i = 0 \\ 0 \text{ if } \Delta r_{it} = decision_t^{INT=0} \& INT_i = 1 \\ 1 \text{ if } \Delta r_{it} \neq decision_t^{INT=1} \& INT_i = 0 \\ 1 \text{ if } \Delta r_{it} \neq decision_t^{INT=0} \& INT_i = 1 \end{cases}$$

One issue that arises with this approach is that the modal vote among externals is not always uniquely defined; in 20 of the 133 meetings in our sample the external vote distribution is bimodal. Therefore, we need to decide between these two modes. One of the two external modes always corresponds to the mode of the internal members (which is always unique). In the construction of $D\left(Dev\_group\right)_{it}$ we set $decision_t^{INT=0} = decision_t^{INT=1}$ whenever $decision_t^{INT=0}$ is multi-valued. This reduces the number of group deviations in the sample and so may bias us toward finding support for our model. However, we also define an alternative dummy variable called $D(Dev\_group\_alt)_{it}$, which is defined similarly to $D\left(Dev\_group\right)_{it}$, except with $decision_t^{INT=0} \neq decision_t^{INT=1}$ whenever $decision_t^{INT=0}$ is multivalued.

Table 3.3 compares how frequently members deviate according to each of our measures. While the internal and external groups each contain members who deviate more and less often in all three senses, the tendency is clearly for external members to deviate from the committee decision more often than internal members. Indeed, differences along these lines have already been pointed out by Gerlach-Kristen (2003). The table also highlights that, according to the $D(Devgroup)\_it$ measure, externals deviate more frequently with internals than vice versa. This is perhaps unsurprising given the greater within-group dispersion among externals combined with the fact that $D(Devgroup)\_it$ equates the modal votes of internals and externals when the external votes is bimodal. Once we use the alternative group mode for external members, internal and external members have much more similar patterns of deviation from the other group.

Disagreement is in general quite common. For instance, in 14% of the observations of $D\left(Dev\_MPC\right)_{it} = 1$. While this number might seem quite low, we find that 65% of the 133 meetings in our sample have at least one deviation from the committee majority. Figure 3.5 shows the level of interest rate chosen by the MPC, where the markers indicate the votes of individual members; deviations from the majority are those that are off the MPC decision line. These deviations occur regularly and not just around turning points in the interest rate cycle (marked with shading on the figure).

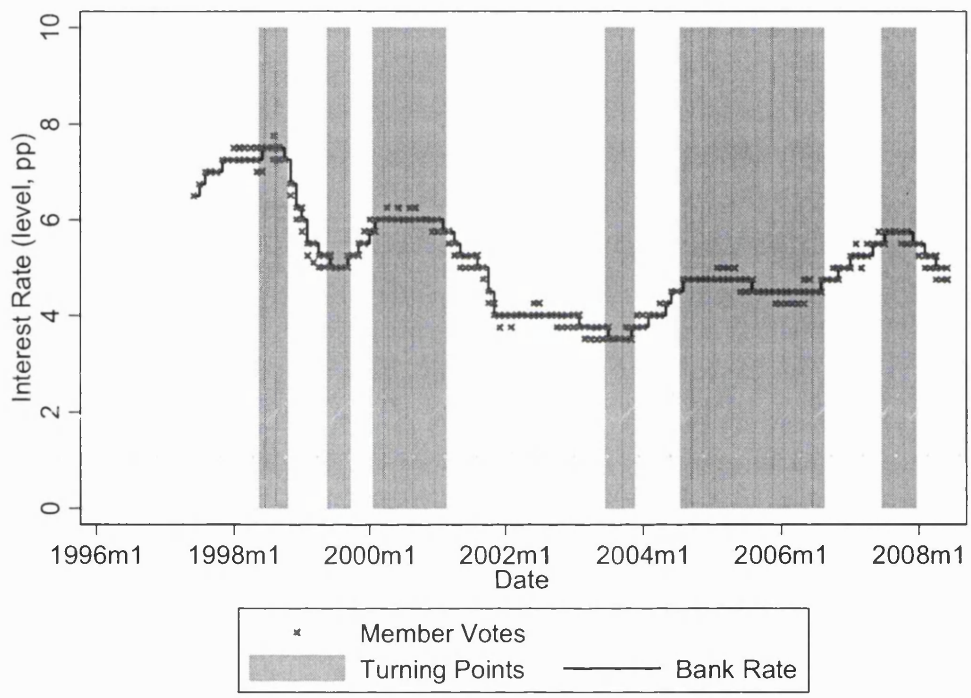

Figure 3.5: Votes and Decisions of the Monetary Policy Committee

The fact that there are numerous disagreements within the MPC is not surprising. What is unclear is what generates these differences. This chapter argues that there are two likely candidates. The first is divergent beliefs. Even though members share the same access to data as each other, and communicate their views extensively with each other, they can still have fundamentally different beliefs about the inflationary pressures facing the economy. The second is preferences. Members can have fundamental differences in what they hope to achieve when selecting interest rates. As our model shows, these two stories are empirically distinguishable. If members differ because of beliefs, then

Table 3.3: Total and Percentage Deviations using 3 Different Approaches, by Member

Member			$D(Dev\_MPC)_{it}$		$D(Dev\_group)_{it}$		$D(Dev\_group\_alt)_{it}$	
	INT_i	Meetings	Total	% Deviations	Total	% Deviations	Total	% Deviations
A. Sentance	0	21	5	23.8	6	28.6	6	28.6
C. Goodhart	0	36	3	8.3	3	8.3	3	8.3
C. Allsopp	0	36	10	27.8	13	36.1	13	36.1
D. Blanchflower	0	25	13	52.0	12	48.0	12	48.0
D. Walton	0	12	3	25.0	4	33.3	4	33.3
D. Julius	0	45	13	28.9	15	33.3	15	33.3
K. Barker	0	85	5	5.9	8	9.4	8	9.4
M. Bell	0	36	5	13.9	5	13.9	5	13.9
R. Lambert	0	34	0	0.0	1	2.9	1	2.9
A. Budd	0	18	4	22.2	4	22.2	4	22.2
S. Nickell	0	72	17	23.6	17	23.6	17	23.6
S.Wadhwani	0	36	12	33.3	15	41.7	15	41.7
T. Besley	0	22	5	22.7	6	27.3	6	27.3
W. Buiter	0	36	16	44.4	16	44.4	16	44.4
C. Bean	1	93	5	5.4	7	7.5	23	24.7
D. Clementi	1	60	4	6.7	8	13.3	15	25.0
I. Plenderleith	1	60	5	8.3	9	15.0	14	23.3
J. Vickers	1	28	5	17.9	5	17.9	8	28.6
M. King	1	133	14	10.5	19	14.3	35	26.3
P. Tucker	1	73	7	9.6	12	16.4	21	28.8
R. Lomax	1	60	5	8.3	7	11.7	14	23.3
A. Large	1	40	9	22.5	13	32.5	16	40.0
E. George	1	73	0	0.0	7	9.6	20	27.4
J. Gieve	1	29	3	10.3	4	13.8	8	27.6
H.Davies	1	2	0	0	0	0	0	0

differences between members should become less pronounced.

3.6 Econometric Modelling and Results

The primary goal of this section is to examine the time path of individual voting behavior on the MPC in order to shed light on the source of conflict within the MPC. It first analyzes how the probability of deviating evolves, and then turns to looking at the actual votes that members cast. The main result is that on a variety of measures, conflict *increases* with time, leading us to conclude that members are likely to have differences arising from their preferences; we will explore the main two potential preference differences.

3.6.1 Probability of Deviating

The measures of deviation we introduced in the previous section are all dummy variables, so ordinary least squares (OLS) will produce inconsistent estimates. Instead, we adopt the regression model:

$$\begin{aligned} \operatorname{logit}(D\_dev_{it}) &= \alpha + \lambda \cdot z_i + \psi_1 \cdot INT_i + \psi_2 \cdot exp_{it} + \psi_3 \cdot (INT_i exp_{it}) \\ &\quad + \sum_t \tau_t \cdot Time_t + \sum_T \delta_T \cdot Q_T + \sum_j \kappa_j \cdot COM_j + \varepsilon_{it} \end{aligned} \tag{3.4}$$

where:

- D_dev_{it} is the deviation outcome variable of interest;
- INT_i is the internal dummy variable defined earlier;
- exp_{it} is a dummy variable indicating that a member has experience on the committee (defined below in more detail);
- z_i are time-invariant individual characteristics;
- $Time_t$ are monthly dummy variables (month fixed effects);
- Q_T are quarterly dummies (quarter fixed effects);
- COM_j is a committee fixed effect

The two sets of time fixed effects control for the variation in voting behavior that is common to each period of time, such as variations in the business cycle. We include, in addition to month fixed effects, quarter fixed effects to capture the fact that some key information is quarter specific (national accounts data, as well as the Bank's own forecast). An alternative was to include data on inflation and GDP, as well as the information that comes from Bank of England quarterly forecast meetings as controls; this approach does not alter the conclusions of our work.

As a further control, we also include committee fixed effects. In the regressions we run, there is a separate dummy variable for each unique combination of committee members in our sample. This is potentially important if a member's vote (and the extent to which it conflicts with other members') is affected by the identity of the other committee members. These committee fixed effects require inclusion of a separate dummy variable for *every* different committee composition that has met. Therefore, if a member leaves the committee and is replaced by a new member, this represents a new committee composition and so a new dummy variable. Also, if a member is absent and so only 8 members meet in a particular month, then this committee composition is also different and so controlled for separately.

In order to ensure that INT_i is not capturing the effects of other variables that are correlated with being an internal member, we include a set of controls for individual characteristics. The regressions control for age as well as dummy variables for whether a member worked in the private sector immediately before joining the committee, whether a member was an academic immediately before joining the committee, and whether a member holds a Master's or PhD degree.[14]

We allow the errors to be clustered by MPC member since it is unlikely that members' errors are independent across time periods, especially if there is some systemic heterogeneity in member voting. Clustering corrects the standard errors of the estimates for this correlation, making it less likely that we wrongly fail to reject a null hypothesis of coefficient significance. However, our results are unchanged without clustering the errors by member.

The key variable of interest in our regressions is exp_{it}, the variable that distinguishes new MPC members from those with experience. This variable is:

$$exp_{it} = \begin{cases} 0 \text{ if member } i \text{ in time } t \text{ has been on the committee 12 months or less} \\ 1 \text{ if member } i \text{ in time } t \text{ has been on the committee more than 12 months} \end{cases}$$

The 12 month cutoff represents one-third of the term for non-Governor MPC members, and half the average number of meetings attended by an external member in our sample. Since this threshold may seem arbitrary, we shall carry out robustness tests to ensure

[14]The effect of the two kinds of degrees was similar in the regressions, so we combine them. Also, most of the professors in our sample without a PhD hold a Master's degree.

that results are qualitatively unchanged if we consider alternative cutoff values to define experience. In particular, we consider 9-month and 18-month cutoffs.

The regression output in the tables below reports the estimated odds-ratios associated with each variable. Interpreting the output therefore requires some care. If we define the odds of deviating as

$$odds(deviate) = \frac{\Pr(deviate)}{\Pr(not\ deviate)}$$

then the odds-ratio for the INT_i variable is given by:

$$\begin{aligned} odds - ratio(internals) &= \frac{(odds\,(deviate) \mid INT_i = 1)}{(odds\,(deviate) \mid INT_i = 0)} \\ &= \frac{\left(\frac{\Pr(deviate)|INT_i=1}{\Pr(not\ deviate)|INT_i=1}\right)}{\left(\frac{\Pr(deviate)|INT_i=0}{\Pr(not\ deviate)|INT_i=0}\right)}. \end{aligned}$$

Therefore the odds-ratio, as reported in the tables below, will always be greater than zero. If it is greater (less) than 1, this means that, holding all other variables constant, the odds of deviating for internals is higher (lower) than for external members. Finally, the interpretation of the coefficient ψ_3 — the coefficient on the interaction term $INT_i \cdot exp_{it}$ — is that of the ratio of the odds-ratios. It will tell us if the odds-ratio for experience is different between internals and externals.

Table 3.4 reports the results from estimating equation (3.4) without the exp_{it} variables. The results confirm what was expected from the earlier examination of Table 3.3. Namely, for the first two measures of deviation ($D(Dev\_MPC)_{it}$ and $D(Dev\_group)_{it}$), internals are less likely to deviate than externals. For the third approach to measuring deviations ($D(Dev\_group\_alt)_{it}$), there is no statistically significant difference between internals and externals. These results are robust to the inclusion of the other covariates, and all regressions include the month, quarter and committee fixed effects discussed above.

Table 3.5 introduces the exp_{it} variables; for each deviation variable, we estimate (3.4) both excluding and including the interaction term. These regression results provide a clear test of our model. If conflict on the committee arises because people have different beliefs about the correct monetary policy, then over time there should be fewer deviations since members' beliefs should converge after observing enough data. In fact, the opposite is true. In all cases, the exp_{it} odds-ratio is larger than 1 and statistically significant at the 5% level. This means that, holding all other variables constant, the likelihood of deviating *increases* when an MPC member has been on the committee for more than 12 months. In terms of magnitude, 12 months on the committee makes a member over twice as likely to deviate in nearly all cases. In columns (2) and (4), the interaction term

Table 3.4: Logit Model - Basic Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
	$D(Dev\_MPC)_{it}$		$D(Dev\_group)_{it}$		$D(Dev\_group\_alt)_{it}$	
INT_i	0.287***	0.193***	0.340***	0.271***	1.338	1.150
	(0.103)	(0.078)	(0.137)	(0.114)	(0.587)	(0.499)
D(high education)		5.089***		3.987***		2.845**
		(2.323)		(2.046)		(1.211)
D(private sector)		0.396**		0.536		0.532
		(0.164)		(0.249)		(0.245)
Age when start		0.9359**		0.9511		0.9637
		(0.0301)		(0.0340)		(0.0249)
Month FE?	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE?	Yes	Yes	Yes	Yes	Yes	Yes
Committee FE?	Yes	Yes	Yes	Yes	Yes	Yes
Clustered Residuals?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.215	3.046	16.216*	6.731	6.861	434.538***
	(0.231)	(6.111)	(26.416)	(14.950)	(9.966)	(939.464)
Observations	763	763	754	754	754	754

Odds-ratios reported rather than coefficient estimates

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

is insignificantly different from 1, indicating that there is no difference in the odds-ratio for experienced internals and experienced externals. In column (6), where we use the alternative measure, internals that become experienced have a smaller increase in their probability of deviating than externals who become experienced.

The results in Table 3.6 replicate the results in columns (2), (4), and (6) in Table 3.5 using the alternative cut-off values for experience discussed above. The variable exp_{it}^{9} measures experience as beginning after 9 months on the MPC, while the exp_{it}^{18} uses a value of 18 months. The results are qualitatively unchanged, and in fact the estimated magnitudes on the experience variable are almost always higher. Thus, there is robust evidence that members do not vote more in line with each other as they gain experience.

3.6.2 Voting Levels and Dispersion

So far, we have looked at members' deviation probabilities in order to stay true to our model. We now turn to members' actual votes. There are several reasons for doing so. First, the change in the average vote level between internals and externals provides another test of convergence. Second, the voting data allows us to examine the direction of conflict, not merely its existence. Third, we can use voting data to construct measures of within-group voting dispersion for internals and externals to see how it behaves through time.

There are three possible measures for voting dispersion:

1. the squared deviation from the average vote in each time period $\left(\Delta r_{i,t} - \overline{\Delta r_t}\right)^2$;
2. the squared deviation from the committee's decision $\left(\Delta r_{i,t} - \Delta r_t^{dec}\right)^2$;
3. the squared deviation from the average external or internal vote $\left(\Delta r_{i,t} - \overline{\Delta r_t}^{grp}\right)^2$.

Each of these variables measures the dispersion of member i from the group, thereby capturing the underlying variance of their voting behavior. In practice, these three measures are highly correlated (with correlation coefficients above 0.9), so we shall report only a selection of the regressions focusing on the first measure.

Following equation (3.4), we now estimate the following regression model using ordinary least squares:[15]

$$\begin{aligned} y_{it} &= \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \beta_1.\left(INT_i.exp_{it}\right) \\ &\sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \varepsilon_{it} \end{aligned} \tag{3.5}$$

[15]Although our data is categorical (in 25bp devisions) we proceed using OLS. Use of multinomial logit estimation is not feasible with seven distinct groupings in our sample (and theoretically more groupings).

Table 3.5: Logit Model - Experience Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
	$D(Dev\_MPC)_{it}$		$D(Dev\_group)_{it}$		$D(Dev\_group\_alt)_{it}$	
INT_i	0.171***	0.126***	0.230***	0.309	1.009	2.476
	(0.073)	(0.076)	(0.108)	(0.236)	(0.475)	(1.587)
D(high education)	5.606***	5.460***	4.413***	4.512***	3.048**	3.318***
	(2.907)	(2.798)	(2.504)	(2.583)	(1.355)	(1.535)
D(private sector)	0.405**	0.405**	0.541	0.540	0.509	0.500
	(0.163)	(0.164)	(0.246)	(0.246)	(0.235)	(0.232)
Age when start	0.9324**	0.9323*	0.9469	0.9471	0.9598	0.9607
	(0.0329)	(0.0334)	(0.0370)	(0.0367)	(0.0273)	(0.0271)
exp_{it}	2.141**	1.927*	2.574**	2.889**	2.410**	4.122**
	(0.673)	(0.677)	(1.102)	(1.451)	(1.003)	(2.346)
INT_i*exp_{it}		1.460		0.690		0.301*
		(1.072)		(0.491)		(0.189)
Month FE?	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE?	Yes	Yes	Yes	Yes	Yes	Yes
Committee FE?	Yes	Yes	Yes	Yes	Yes	Yes
Clustered Residuals?	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.807	2.024	0.702	0.616	0.247	0.141
	(5.837)	(6.501)	(2.334)	(2.037)	(0.681)	(0.385)
Observations	763	763	754	754	754	754

Odds-ratios reported rather than coefficient estimates
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.6: Logit Model - Robustness to Different Experience Variables

	(1)	(2)	(3)	(4)	(5)	(6)
	$D(Dev\_MPC)_{it}$		$D(Dev\_group)_{it}$			$D(Dev\_group\_alt)_{it}$
INT_i	0.179***	0.219**	0.641	0.402	5.402***	1.824
	(0.101)	(0.145)	(0.507)	(0.289)	(3.489)	(1.082)
D(high education)	5.455***	6.197***	4.512***	4.920***	3.199**	3.278**
	(2.661)	(3.372)	(2.484)	(2.971)	(1.463)	(1.566)
D(private sector)	0.418**	0.397**	0.563	0.529	0.538	0.492
	(0.169)	(0.162)	(0.254)	(0.245)	(0.246)	(0.227)
Age when start	0.9349**	0.9318*	0.9486	0.9482	0.9629	0.9616
	(0.0320)	(0.0339)	(0.0352)	(0.0368)	(0.0258)	(0.0271)
exp^9_{it}	2.134*		3.396**		4.147**	
	(0.873)		(2.092)		(2.515)	
$INT_i{*}exp^9_{it}$	0.998		0.324		0.144***	
	(0.716)		(0.260)		(0.103)	
exp^{18}_{it}		3.173**		3.509**		3.696**
		(1.458)		(1.721)		(1.907)
$INT_i{*}exp^{18}_{it}$		0.581		0.395		0.354*
		(0.371)		(0.231)		(0.197)
All regressions contain the usual month, quarter and committee FE, and residuals are clustered by member.						
Constant	1.807	2.024	0.702	0.616	0.247	0.141
	(5.837)	(6.501)	(2.334)	(2.037)	(0.681)	(0.385)
Observations	763	763	754	754	754	754

Odds-ratios reported rather than coefficient estimates
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

where y_{it} is the outcome variable of interest, and the other variables are as in (3.4). Here, the interpretation of the coefficients is more straightforward. The three coefficients of interest are ψ_1, the marginal effect of being an internal member; ψ_2, the marginal effect of having at least one year of MPC experience; and β_1, the marginal effect of being an experienced, internal member. Another advantage of the OLS model is that estimation with member fixed effects (i.e., modelling the error terms as $\varepsilon_{it} = \nu_i + \eta_{it}$, where ν_i is a member-specific intercept that captures any unobserved heterogeneity at the member level) becomes computationally feasible. We will estimate (3.5) both with and without member fixed effects, since their inclusion forces us to drop all time-invariant individual characteristics.

The results of estimating (3.5) are reported in Table 3.7. Columns (1) - (3) report the coefficient estimates when $y_{it} = \Delta r_{i,t}$. In Column (1), only time and committee fixed effects, the usual covariates, and the INT_i variable are included. It is clear that internal members vote, on average, for higher interest rates. The three basis point difference between internals and externals is economically significant. Consider the conterfactual switching an external member to an internal member. Since members conventionally vote in 25 basis point increments, this would mean that such a member would vote for higher interest rates in 12% more meetings ($\frac{3}{25} \approx 0.12$). What is rather suprising is that this effect arises even while controlling for individual characteristics. Internals and externals appear to vote for different interest rates not because of different educational or occupational backgrounds, but simply because one group has managerial responsibilities within the Bank and the other does not.

In Column (2) we include the exp_{it} variable as well as the interaction term. This essentially allows us to use a differences-in-differences approach for estimating convergence of opinions. The results are striking. The effect of being an internal is no longer significant, but the effect of being experienced is highly significant and large in magnitude (-5.3 bps lower on average). Moreover, the coefficient on the interaction term is also highly significant and large ($+5.5$ bps higher on average). Thus, the effect of experience is different for internals and externals. Experience by itself leads people to vote for lower rates, but this is driven entirely by the external members; it is not possible to reject the hypothesis that internal members do not change their vote once they become experienced. Therefore, neither inexperienced nor experienced internals vote for different rates on average. This implies that although inexperienced externals do not behave any differently from inexperienced internals, experienced externals vote for systematically lower interest rates on average. This finding is qualitatively robust to the inclusion of member fixed effects (Column (3)). These regressions provide yet more evidence of growing disagreement between externals and internals on the MPC.

Table 3.7: Level and Vote Variablilty Regression Results

	(1) $vote_{it}$	(2) $vote_{it}$	(3) $vote_{it}$	(4) $(\Delta r_{i,t} - \overline{\Delta r_t})^2$	(5) $(\Delta r_{i,t} - \overline{\Delta r_t})^2$	(6) $(\Delta r_{i,t} - \overline{\Delta r_t}^{grp})^2$
INT_i	0.030**	-0.007	-	-0.006**	-	-0.006**
	(0.014)	(0.019)		(0.002)		(0.002)
D(high education)	-0.010	-0.013	-	0.004**	-	0.002***
	(0.013)	(0.013)		(0.002)		(0.001)
D(private sector)	-0.010	-0.010	-	-0.002	-	-0.002
	(0.016)	(0.015)		(0.002)		(0.002)
Age when start	0.000	0.000	-	-0.000	-	-0.000
	(0.001)	(0.001)		(0.000)		(0.000)
exp_{it}		-0.053***	-0.034***	0.002	0.002	-0.001
		(0.016)	(0.009)	(0.002)	(0.002)	(0.002)
INT_i*exp_{it}		0.0547***	0.0454***	-0.0006	0.0004	0.0012
		(0.0158)	(0.0117)	(0.0025)	(0.0020)	(0.0030)
Month FE?	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE?	Yes	Yes	Yes	Yes	Yes	Yes
Committee FE?	Yes	Yes	Yes	Yes	Yes	Yes
Clustered Residuals?	Yes	Yes		Yes		Yes
Member FE?			Yes		Yes	
Constant	0.235***	0.257***	0.247***	0.007	-0.000	0.006*
	(0.042)	(0.042)	(0.035)	(0.005)	(0.006)	(0.003)
Observations	1163	1163	1163	1163	1163	1163
R^2	0.79	0.80	0.82	0.22	0.20	0.24

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Columns (4) and (5) repeat the regressions in columns (2) and (3) using $y_{it} = \left(\Delta r_{i,t} - \overline{\Delta r_t}\right)^2$. The main finding is that externals as a group display more volatility in their voting behavior, and that volatility does not decline with time for either internals or externals. Thus, not only do internals and externals not reach consensus with each other through time, but they also do not seem to reach a consensus with each other. Moreover, the greater volatility of external members clearly reduces the expected utility of a committee designer with preferences given by (3.2), so the only rationale for including them at all must come from some other margin. Column (6) shows the robustness of the findings to an alternative definition of group dispersion $\left(\left(\Delta r_{i,t} - \overline{\Delta r_t}^{grp}\right)^2\right)$.

To summarize, the main empirical findings are that:

- There are systematic differences in the voting behavior of internals and externals;
- On numerous measures, internal and externals members display increasing conflict through time;
- Through their greater volatility, external members reduce the welfare of a committee designer with a quadratic loss function.

Our second finding is the most important. We believe that it rules out a model in which all members share the same preferences over interest rates. We have shown that such a model generates declining disagreement, but in fact the opposite is true in the data. Therefore, the source of conflict between members must arise for reasons other than conflicting beliefs, and the most likely candidate is conflicting preferences. However, if internals and externals have different preferences, then at least one group maximizes an objective function other than the committee designer's. Thus, we also believe that we have identified an agency problem on the MPC. In other words, the MPC appears to not work as effectively as its designers might have hoped. In the next section, we explore what preferences underlie internals' and externals' behavior.

3.7 Alternative Models

Exposure to increasing amounts of information should not drive Bayesian agents apart, and yet our econometric results show that this is the case on the MPC. The data also show that external members separate from internal members and vote for systematically lower interest rates. Therefore, although our regressions offer no support for the model of ideal mixed-committee voting presented above, we are not given an insight into why the model fails.

We believe that any reasonable model with Bayesian learning and ideal behavior assumptions could not explain the patterns in the data. This finding is important because it indicates the presence of an agency problem resulting from the presence of internal and external members on the MPC. If we are going to reject the model of ideal voting behavior, however, a natural question to ask is what model we need to use in its place. Also, the policy and committee design implications depend on the underlying reasons for the failure of our ideal behavior model.

To begin with, we shall take as given the initial period of agreement and examine what causes the votes to change, and in particular why the votes of externals appear to become systematically lower. In this section we explore a number of the leading candidate explanations; we examine the presence of career concerns, and the possibility of asymmetric preferences.

3.7.1 Career Concerns

One possibility is that members not only want to maximize equation (3.1), but also want to signal their competence or preferences through their voting record. In other words, committee members may have career concerns. There are many reasonable career concern stories. For example, internals may want to signal to the government and to the central banking community that they are tough inflation fighters. Externals, who face more uncertainty about their future prospects after their terms end, may want to signal that they are competent economists. These concerns may lead MPC members to vote for interest rates that differ from those predicted by our ideal voting model.

We shall examine a particular form of career concern that is consistent with the idea that MPC members reputation shall be assessed, largely, by the central banking community and by the government. Gordon Brown was not only the Chancellor who set-up the MPC structure, but he was the key person in approving the members who got appointed to the MPC over the majority of our sample. In setting up the MPC with a narrowly-defined inflation target, he made clear his belief that the correct focus of monetary policy is fighting inflation. He was clearly aware that attempts to try to exploit short-run output gains from monetary policy would quickly lead to inflation. While it is often assumed that internal members would worry about their inflation-fighting credibility, it also seems clear that in order to either build a reputation, or in terms of getting reappointed, external members would need to be considered inflation-averse.

Our experience effect may, therefore, already be capturing a career concern; upon joining, new members may wish to build a reputation for fighting inflation and so start by voting with the other members. Our results are consistent with this being the case particularly in the first year, and applying, on average, to both internal and external members.

However, after the initial reputation building period, career concerns may play a differential role with different members. If career concerns explain the behavior of MPC members after one year, then we would expect to see the change in behavior only for those groups for whom career concerns do not play a major role. To test this hypothesis, we divide internals and externals into groups for which reputational considerations should play varying roles and examine whether these different groups display the same divergence as they gain experience[16]. If they do, then signalling is not a convincing factor in explaining our experience results, while if they don't, it cannot be ruled out.

We split the members according to whether, or not, they are an academic when they join the committee. There are substantial numbers of academics and non-academics in both the internal and external group. Because of the tenure system, one could argue that academics should have less of a need to signal since they have a stronger outside option should they fail to build a good reputation. In order to test whether non-academics and academics differ in voting behavior, we run the following regression with member fixed effects[17]:

$$\begin{aligned} y_{it} &= \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \psi_3.Acad_i \\ &\quad +\beta_1.\left(INT_i.exp_{it}\right) + \beta_2.\left(INT_i.Acad_i\right) + \beta_3.\left(exp_{it}.Acad_i\right) \\ &\quad +\mu_1.\left(INT_i.exp_{it}.Acad_i\right) \\ &\quad +\sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \nu_i + \eta_{it} \end{aligned} \tag{3.6}$$

where $Acad_i$ is the dummy variable indicating that a member is an academic, and all other variables are as defined above.

With two different distinguishing dummy variables ($Acad_i$,and INT_i), there are four different "types" of MPC member. For each type, the last dummy variable (exp_{it}) allows us to calculate the effect of experience on each group. Rather than discuss the values of the coefficients themselves, it is easier to discuss the sums of coefficients that represent this experience effect for each particular set of characteristics. For example, the experience effect of being an internal, non-academic is $\psi_2 + \beta_1$[18] and the experience effect of being an external academic is $\psi_2 + \beta_3$. The results are listed in Table 3.8; the experience effect is listed along with the P-value associated with the null hypothesis that

[16]We have also carried out the same analysis for the variance of voting behavior; these results are not included as the variance results are less puzzling than the level results, but are available on request.

[17]Estimating without member-fixed effects leads to qualitatively unchanged results.

[18]The effect of being an experienced, internal, non-academic is $\psi_1 + \psi_2 + \beta_1$ while the effect of being a new, internal, non-academic is ψ_1. The experience effect for this group is the difference of these two.

Table 3.8: Estimates of "Experience-Effect" by Member Type: Career Concerns

	Members		Experience Effect	P-Value	95% Confidence Interval	
(1)	External	Non-academic	-0.01	0.57	-0.03	0.02
(2)	External	Academic	-0.07	0.00	-0.10	-0.05
(3)	Internal	Non-academic	0.01	0.57	-0.02	0.03
(4)	Internal	Academic	0.01	0.50	-0.03	0.05

the effect is zero, and the 95% confidence intervals.

The results clearly lend support to the career concerns hypothesis. Controlling for whether members are academic or not can seemingly explain the entire experience result. Experience drives the voting of academic externals down by 7bps. Hypothesis tests confirm that the experience effect for academic externals is different from zero, and from the experience effect of other types of member (all of whom have no experience effect). This is surprising as the regression controls for not only the time and committee fixed effects, but also for member fixed effects.

Thus, our results seem consistent with the idea that career concerns, the building of an anti-inflation reputation, remain important for some external members beyond the initial period on the committee.

3.7.2 Asymmetric Preferences

Although the UK Treasury officially sets the inflation target and instructs MPC members that the target is symmetric, it may be that individual members, consciously or subconsciously, view phases of the business/inflation cycle differently. We have assumed symmetric preferences in our model of voting behavior, but the results in Table 3.8 may be consistent with asymmetric preferences; this is our second potential explanation.

The idea of asymmetric preferences is not new in monetary economics (see Surico (2007)). Gerlach-Kristen (2009) simulates an asymmetric preferences voting model and concludes that it would lead to similar patterns of voting to that of the MPC. External members, in her model, are assumed to be recession-averse in that they dislike negative output gaps more than positive output gaps. To be consistent with our findings, this hypothesis states that, after initially behaving as the government expected them to, some members reveal themselves to be less willing to fight inflation at the expense of a recession.

We split the interest rate cycle into a tightening phase (when interest rates are, or have been most recently, increasing) and a loosening phase (when interest rates have most recently been declining) so that we can examine the evidence for recession aversion. We use the variable $Loosen_i$ - a dummy variable indicating that period t is in a loosening phase - to distinguish the two phases. These are displayed in Figure 3.6; grey shading denotes the tightening cycle, and other periods are therefore considered the loosening cycle.

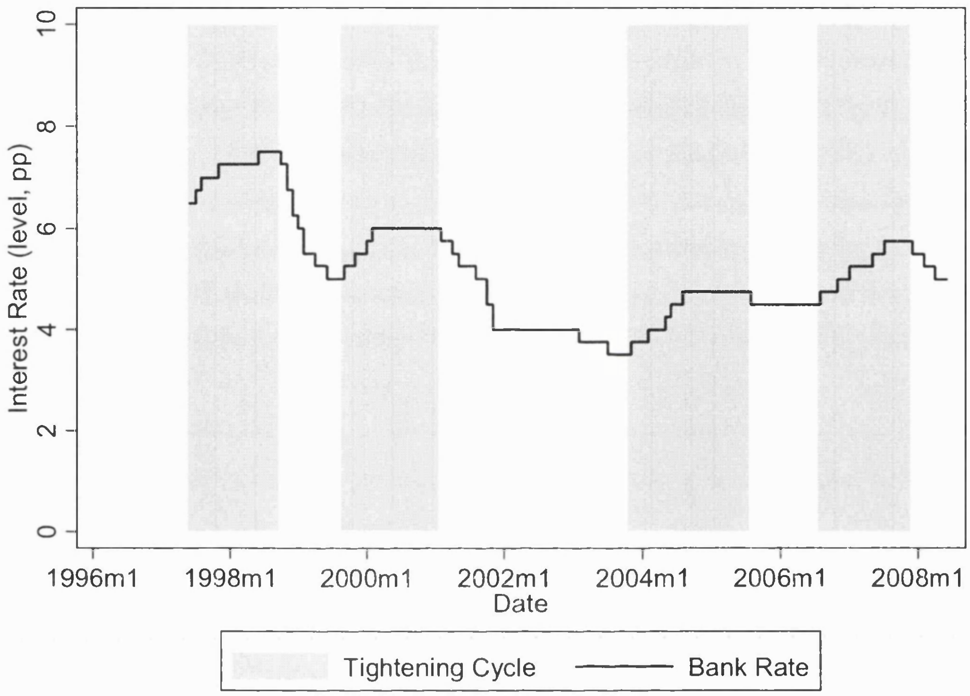

Figure 3.6: Interest Rate Cycles in the UK

In order to test whether the behavior of MPC members differs over the phases of the interest rate cycle, we run a regression similar to equation (3.6) but instead of distinguishing between academics and non-academics, we use the variable $loosen_t$ to distinguish between the phases of the interest rate cycle. Thus, we estimate:

$$\begin{aligned} y_{it} &= \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \psi_4.loosen_t \\ &\quad +\beta_1.\left(INT_i.exp_{it}\right) + \beta_4.\left(INT_i.loosen_t\right) + \beta_5.\left(exp_{it}.loosen_t\right) \\ &\quad +\mu_2.\left(INT_i.exp_{it}.loosen_t\right) \\ &\quad +\sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \nu_i + \eta_{it} \end{aligned} \tag{3.7}$$

Table 3.9: Estimates of "Experience-Effect" by Member Type:

	Members		Experience Effect	P-Value	95% Confidence Interval	
(1)	External	Tighten	-0.02	0.20	-0.04	0.01
(2)	External	Loosen	-0.04	0.01	-0.07	-0.01
(3)	Internal	Tighten	0.02	0.18	-0.01	0.05
(4)	Internal	Loosen	0.01	0.44	-0.02	0.04

The results for the estimated experience effect, analogous to the results in Table 3.8, are displayed in Table 3.9. The evidence is not conclusively for or against the asymmetric preferences story. While the experience effect is only significantly different from zero for external MPC members in a loosening phase, we cannot reject the null hypothesis that the experience effect is the same in tightening and loosening cycles for externals. Therefore, while it is likely that the effect is larger in the loosening cycle, and we cannot reject the null hypothesis that there is a different experience effect for internals and externals, the fact that there is an experience effect in tightening cycles, weakens the evidence for recession-aversion as driving our experience result.

3.7.3 Testing both together

One concern may be that the two explanatory variables may not be orthogonal. The results for the cycle could be driven by the academics; most inexperienced academics in our sample (who would be building a reputation under our story), cast their votes in tightening cycles.

Also, it is not clear that career concerns would be symmetric over the cycle. A member who is trying to build a reputation for being tough on inflation in order to get reappointed may require more evidence of falling inflationary pressures to cut rates, than an optimally-behaving member would require to increase rates.

Therefore, as we could not conclusively eliminate one story, we test for both the stories together in a combined regression given by equation (3.8), where the variables are as defined before. If we find that the importance of either the academics, or the loosening cycle, disappears, then it may be the smoking-gun that we are looking for in determining which of our stories is most likely to explain the behavior.

Table 3.10: Estimates of "Experience-Effect" by Member Type: Combined Career Concerns and Asymmetric Preferences Regression

	Members			Experience Effect	P-Value	95% Confidence Interval	
(1)	External	Tighten	Non-academic	-0.01	0.67	-0.03	0.02
(2)	External	Tighten	Academic	-0.02	0.27	-0.05	0.01
(3)	External	Loosen	Non-academic	0.00	0.88	-0.02	0.03
(4)	External	Loosen	Academic	-0.12	0.00	-0.17	-0.08
(1)	Internal	Tighten	Non-academic	0.02	0.30	-0.01	0.04
(2)	Internal	Tighten	Academic	0.03	0.37	-0.02	0.08
(3)	Internal	Loosen	Non-academic	0.01	0.62	-0.02	0.04
(4)	Internal	Loosen	Academic	0.01	0.58	-0.03	0.05

$$\begin{aligned}
y_{it} = {} & \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \psi_3.Acad_i + \psi_4.loosen_t \\
& +\beta_1.(INT_i.exp_{it}) + \beta_2.(INT_i.Acad_i) + \beta_3.(exp_{it}.Acad_i) \\
& +\beta_4.(INT_i.loosen_t) + \beta_5.(exp_{it}.loosen_t) + \beta_6.(Acad_i.loosen_t) \\
& +\mu_1.(INT_i.exp_{it}.Acad_i) + \mu_2.(INT_i.exp_{it}.loosen_t) + \mu_3.(INT_i.Acad_i.loosen_t) \\
& +\mu_4.(exp_{it}.Acad_i.loosen_t) \\
& +\phi_1.(INT_i.exp_{it}.Acad_i.loosen_t) \\
& +\sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \nu_i + \eta_{it} \qquad (3.8)
\end{aligned}$$

The results in Table 3.10 for the estimated experience effect, are reported as before. It is now the case that the experience effect can be attributed solely to external, academic members during the loosening phase of the business cycle. Thus, we are no closer to eliminating either explanation as both are consistent with this result; either the academics have recession averse preferences, or the other members are affected by a career concern that keeps them voting for higher interest rates.

3.8 A Natural Experiment

Ideally we would have an exogenous variation in the extent of career concerns which would help us to disentangle these two effects and determine which is driving the behavior. Fortunately, we have one such natural experiment. The Act that created the MPC allows for the reappointment of all members, internal and external. When the first group of externals and internals served on the MPC, they thus operated under the assumption that reappointment to the committee was possible, although uncertainty still existed about how the reappointment system would function. Then, on 18 January 2000, Willem Buiter wrote an open letter to then Chancellor Gordon Brown that laid down forceful arguments for not reappointing external members (Buiter 2000). To quote from this letter:

> With the end of my term approaching, I have given considerable thought to whether I should be a candidate for re-appointment. I have come to the conclusion that both the appearance and the substance of independence of the external members of the MPC are best served by restricting their membership to a single term - three years as envisaged in the Bank of England Act 1998.

It seems that this letter swayed Brown's decision; he did not reappoint a single external member from the original group, even though some were still among the most prominent monetary policy experts in the UK. A clear precedent was set: external members would find reappointment difficult, most likely extremely so. All external members served for only one term until February 2003 (almost 6 years since the first MPC meeting), when Brown unexpectedly reappointed Stephen Nickell to the MPC (HM Treasury 2003). Since then, Kate Barker has also been reappointed twice.

If career concerns play a role, one would expect different voting patterns between external members serving from February 2000 to February 2003 and those serving at other times, since the rewards to reputation presumably changed when reappointment was and was not possible. There are 322 votes cast during this period in which reappointment of external members was not possible. Of course, there is no reason to expect that this lack of reappointment opportunities for external member to affect internal member voting; during this period many external members were reappointed to the committee. To this end, we define a dummy variable $reappoint_{it}$ which equals 1 before February 2000 and after February 2003. We then estimate the following career concerns regression:

Table 3.11: Estimates of "Experience-Effect" by External Type: Career Concerns Regression from Natural Experiment

	Members			Experience Effect	P-Value	95% Confidence Interval	
(1)	External	$reappoint_{it} = 0$	Non-academic	-0.05	0.04	-0.09	0.00
(2)	External	$reappoint_{it} = 0$	Academic	-0.06	0.01	-0.11	-0.02
(3)	External	$reappoint_{it} = 1$	Non-academic	0.01	0.55	-0.02	0.04
(4)	External	$reappoint_{it} = 1$	Academic	-0.07	0.00	-0.10	-0.03
(5)	Internal	$reappoint_{it} = 0$	Non-academic	-0.01	0.69	-0.06	0.04
(6)	Internal	$reappoint_{it} = 0$	Academic	0.03	0.31	-0.03	0.09
(7)	Internal	$reappoint_{it} = 1$	Non-academic	0.01	0.36	-0.01	0.04
(8)	Internal	$reappoint_{it} = 1$	Academic	0.00	0.98	-0.06	0.06

$$\begin{aligned} y_{it} = {} & \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \psi_3.Acad_i + \psi_5.reappoint_t \\ & + \beta_1.(INT_i.exp_{it}) + \beta_2.(INT_i.Acad_i) + \beta_3.(exp_{it}.Acad_i) \\ & + \beta_7.(INT_i.reappoint_t) + \beta_8.(exp_{it}.reappoint_t) + \beta_9.(Acad_i.reappoint_t) \\ & + \mu_1.(INT_i.exp_{it}.Acad_i) + \mu_5.(INT_i.exp_{it}.reappoint_t) + \mu_6.(INT_i.Acad_i.reappoint_t) \\ & + \mu_8.(exp_{it}.Acad_i.reappoint_t) \\ & + \phi_2.(INT_i.exp_{it}.Acad_i.reappoint_t) \\ & + \sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \nu_i + \eta_{it} \end{aligned} \tag{3.9}$$

The results in Table 3.11 lend support to the idea that this exogenous variation has led external members to behave differently, while internal members have been unaffected. Rows (1) and (2) shows that, when reappointment was not possible, the experience effect was the same across types of external member; there is no longer a differential effect between external academics and non-academics. The effect uncovered earlier in Table 3.8 is driven by the differential behavior when reappointment was possible.

We now attempt to distinguish between the preferences and career concerns story using our natural experiment and the combined effects equation given by (3.9). However, we now augment this equation with differential effects for when reappointment was possible; the resulting (large) equation is:

$$
\begin{aligned}
y_{it} &= \alpha + \lambda.z_i + \psi_1.INT_i + \psi_2.exp_{it} + \psi_3.Acad_i + \psi_4.loosen_t + \psi_5.reappoint_t \\
&+\beta_1.\,(INT_i.exp_{it}) + \beta_2.\,(INT_i.Acad_i) + \beta_3.\,(exp_{it}.Acad_i) \\
&+\beta_4.\,(INT_i.loosen_t) + \beta_5.\,(exp_{it}.loosen_t) + \beta_6.\,(Acad_i.loosen_t) \\
&+\beta_7.\,(INT_i.reappoint_t) + \beta_8.\,(exp_{it}.reappoint_t) + \beta_9.\,(Acad_i.reappoint_t) \\
&+\beta_{10}.\,(loosen_t.reappoint_t) \\
&+\mu_1.\,(INT_i.exp_{it}.Acad_i) + \mu_2.\,(INT_i.exp_{it}.loosen_t) + \mu_3.\,(INT_i.Acad_i.loosen_t) \\
&+\mu_4.\,(exp_{it}.Acad_i.loosen_t) + \mu_5.\,(INT_i.exp_{it}.reappoint_t) + \mu_6.\,(INT_i.Acad_i.reappoint_t) \\
&+\mu_7.\,(INT_i.loosen_t.reappoint_t) + \mu_8.\,(exp_{it}.Acad_i.reappoint_t) \\
&+\mu_9.\,(exp_{it}.loosen_t.reappoint_t) + \mu_{10}.\,(Acad_i.loosen_t.reappoint_t) \\
&+\phi_1.\,(INT_i.exp_{it}.Acad_i.loosen_t) + \phi_2.\,(INT_i.exp_{it}.Acad_i.reappoint_t) \\
&+\phi_3.\,(INT_i.exp_{it}.loosen_t.reappoint_t) + \phi_4.\,(INT_i.Acad_i.loosen_t.reappoint_t) \\
&+\phi_5.\,(exp_{it}.Acad_i.loosen_t.reappoint_t) \\
&+\iota_1.\,(INT_i.exp_{it}.Acad_i.loosen_t.reappoint_t) \\
&+\sum_t \tau_t.Time_t + \sum_T \delta_T.Q_T + \sum_j \kappa_j.COM_j + \nu_i + \eta_{it} \qquad (3.10)
\end{aligned}
$$

When we estimate the effect, two of the interaction terms are automatically dropped because of dependency among the independent variables; the dropped variables are fully explained by other variables in the regression. Given the number of interaction terms, this is perhaps not surprising. The variables dropped by Stata (the econometrics package we use) are $(INT_i.exp_{it}.Acad_i.reappoint_t)$ and $(INT_i.Acad_i)$ meaning that β_2 and ϕ_2 will not be separately identified. This means that we are unable to accurately identify the separate effects of experience on different types of internal members. However, as we would expect from our natural experiment, and as suggested by the results in Table 3.11 above, the reappointment period only affects external member behavior. We, therefore, use the estimates of this equation to examine their behavior only and present the "experience effect" results in Table 3.12.

The results when reappointment is possible mirror those of the estimations reported in Table 3.10 and Table 3.11 above. We reject the hypothesis that the experience effect is the same across different types of external members when reappointment is possible ($F(3, 983) = 0.38, Prob > F = 0.7638$). However, the results change markedly when we look at the behavior when reappointment was not possible (Columns (3) and (4)). In particular, the behavior of all externals is much more similar; we cannot reject the null hypothesis that all external types experience the same experience effect ($F(3, 983) =$

Table 3.12: Estimates of "Experience-Effect" by External Type: Combined Career Concerns and Asymmetric Preferences Regression from Natural Experiment

			$reappoint_{it} = 1$		$reappoint_{it} = 0$	
Members			Coefficient	P-Value	Coefficient	P-Value
			(1)	(2)	(3)	(4)
External	Tighten	Non-academic	0.00	0.84	-0.05	0.29
External	Tighten	Academic	-0.02	0.41	-0.03	0.47
External	Loosen	Non-academic	0.03	0.27	-0.04	0.10
External	Loosen	Academic	-0.18	0.00	-0.08	0.01

$3.58, Prob > F = 0.0136$).

These results suggest that it is only in the presence of career concerns that the interest rate cycle plays a role. In terms of distinguishing between the two potential explanations, it seems that career concerns play a larger role. In fact, it may be that the extent of career concerns is influenced by the cycle; it is easier to appear anti-inflation by keeping interest rates higher in a downturn. However, to examine the reasons for such interactions we would need to develop a model that explicitly considers career concerns and the economic cycle.

3.9 Conclusion

MPC members communicate their views (signals) about the state of the world, and they also have different views about the economic structure. Our model provides two justifications for appointing different types of committee members. First, if different members have different dimensions of expertise, then mixing them together can improve the outcome for the committee designer. Second, where the designer cannot observe member beliefs about the economic structure, drawing members from two distributions which are likely to lie at extremes of the distribution of possible views of the economy is more likely to generate a moderate median voter. The first benefit can be attained through a simple advisory role, whereas the second relies on external members having a vote.

We find that internals and externals only vote for different interest rates after a period of time on the committee. This is an important finding; if members are failing to moderate each other's views initially, then it fails to justify appointing externals in a voting capacity. We explore what might drive this behavior; we find evidence of career concerns as some external members vote differently in an attempt to be reappointed. Career concerns not only reduce the benefits of appointing members with different views about the economic structure, but, if there is less learning about the economic shocks, then the information sharing may be impeded also.

The systematic difference between internals and externals should be particularly surprising given the fact that internals are often appointed from very similar backgrounds to externals and, therefore, the two groups differ only in the sense that the internals are appointed to the staff of the Bank of England, taking on management roles in the day-to-day running of the Bank.

Our results suggest that career concerns may play a role in MPC voting (though they obviously cannot prove the existence of career concerns). This finding is of independent interest because papers such as Levy (2007) and Sibert (2003) have stressed the theoretical consequences of career concerns in committee voting, and Meade and Stasavage (2008) have uncovered patterns in the voting record of the FOMC that they interpret as identifying career concerns. These papers largely focus on voting differences when deliberation and voting is either transparent or secretive. These dimensions do not vary with regard to the MPC and yet we find evidence supporting career concerns.

As our model shows, the voting behavior of the Bank of England's MPC indicates that the gains to a mixed committee may be reduced or even made negative. The finding is particularly striking as the MPC is, otherwise, close to our ideal committee in terms of set-up; if optimal behavior fails on this committee, it is more likely to fail on other committees where differences in preferences are more acceptable. Exploring the benefits of a mixed committee in the context of career concerns is required in order to better understand the decision to appoint external experts to a committee. Nonetheless, the conclusion of this chapter is that mixed committees are not a panacea to ensuring optimal monetary policy decisions.

3.A Proofs

3.A.1 Proof of Proposition 3.1

Proof. The optimal strategy for each member i is to maximize (3.1) conditional on I_{it}, the information set of member i at time t. In the proof, we suppress I_{it} for notational simplicity; the expectations should be understood to be taken with respect to I_{it}. We decompose (3.1) in the following manner:

$$\begin{aligned} E\left[(\pi_t - \pi^*)^2\right] &= E\left[\pi_t^2\right] - 2\pi^* E\left[\pi_t\right] + (\pi^*)^2 \\ &= V\left[\pi_t\right] + E\left[\pi_t\right]^2 - 2\pi^* E\left[\pi_t\right] + (\pi^*)^2 \\ &= V\left[\pi_t\right] + \left(E\left[\pi_t\right] - \pi^*\right)^2, \end{aligned}$$

where

$$E\left[\pi_t\right] = g\left(r\right) + \widehat{\alpha}_{it} + \widehat{\theta}_{it}$$

and

$$V\left[\pi_t\right] = E\left[V\left[\pi_t \mid \alpha_t, \theta\right]\right] + V\left[E\left[\pi_t \mid \alpha_t, \theta\right]\right] = \sigma^2 + V\left[\alpha_t + \theta\right].$$

The interest rate only affects $E\left[\pi_t\right]$, not $V\left[\pi_t\right] =$. Clearly, utility is highest when $r_t = r_{it}^*$, where r_{it}^* satisfies

$$g\left(r_{it}^*\right) + \widehat{\alpha}_{it} + \widehat{\theta}_{it} = \pi^*.$$

Also, since g is strictly increasing, utility is strictly increasing when $r_t < r_{it}^*$ and strictly decreasing when $r_t > r_{it}^*$. So, expected utility is continuous and single peaked.

Member i is indifferent between a given $\underline{r}_t$ and $\overline{r}_t$ when $\widehat{\alpha}_{it} = \alpha_{it}^*$, where

$$\alpha_{it}^* + \widehat{\theta}_{it} - g\left(\underline{r}_t\right) = g\left(\overline{r}_t\right) - \alpha_{it}^* - \widehat{\theta}_{it},$$

which implies

$$\alpha_{it}^* = \frac{g\left(\overline{r}_t\right) - g\left(\underline{r}_t\right)}{2} - \widehat{\theta}_{it}. \tag{3.11}$$

Since preferences are single-peaked with the bliss point depending positively on $\widehat{\alpha}_{it}$, member i votes for $\underline{r}_t$ for all $\widehat{\alpha}_{it} < \alpha_{it}^*$ and for $\overline{r}_t$ for all $\widehat{\alpha}_{it} \geq \alpha_{it}^*$. From (3.11) one can see that α_{it}^* is decreasing in $\widehat{\theta}_{it}$. ■

3.A.2 Proof of Proposition 3.2

Proof. Suppose the game is in period 1, and that there is an equilibrium in which Θ_{i1}^d and Θ_{i1}^s are non-empty. Moreover, without loss of generality, suppose that $\overline{\theta}_1 < \overline{\theta}_2$. For this equilibrium to exist, it must be that case that member 1's expected utility is higher from withholding than disclosing $\forall \widehat{d}_{11} \in \Theta^{d}_{11}, \widehat{s}_{11} \in \Theta^{s}_{11}$.

Using standard results in Bayesian decision theory (Greene 2003, p.871-2), one can construct two separate beliefs for member 2:

$$\begin{aligned} \widehat{\alpha}'_{21} &= E\left[\alpha_1 \mid \widehat{d}_{11}, \widehat{s}_{11}, \widehat{d}_{21}, \widehat{s}_{21}\right] \\ &= \lambda_1 \widehat{d}_{11} + \lambda_2 \widehat{s}_{11} + \lambda_3 \widehat{d}_{21} + \lambda_4 \widehat{s}_{21}; \end{aligned}$$

and

$$\begin{aligned} \widehat{\alpha}''_{21} &= E\left[\alpha_1 \mid \widehat{d}_{11} \in \Theta^{d}_{11}, \widehat{s}_{11} \in \Theta^{s}_{11}, \widehat{d}_{21}, \widehat{s}_{21}\right] \\ &= \lambda_1 E\left[\widehat{d}_{11} \mid \widehat{d}_{11} \in \Theta^{d}_{11}, \widehat{d}_{21}\right] + \lambda_2 E\left[\widehat{s}_{11} \mid \widehat{s}_{11} \in \Theta^{s}_{11}, \widehat{s}_{21}\right] \\ &\quad + \lambda_3 \widehat{d}_{21} + \lambda_4 \widehat{s}_{21}. \end{aligned}$$

In these equations, the λ terms are linear weights that depend on the variance terms of the underlying signals. $\widehat{\alpha}'_{21}$ is member 2's belief on α when he observes member 1's signals, and $\widehat{\alpha}''_{21}$ is his belief when he does not, in which case he knows that they lie in the sets Θ^{d}_{11} and Θ^{s}_{11}.

Define $\Theta^{d\varepsilon}_{11} \equiv \left\{ \widehat{d}_{11} \mid \widehat{d}_{11} \in \Theta^{d}_{11}, \left(\widehat{d}_{11} - \inf \Theta^{d}_{11}\right) > \varepsilon \right\}$, and define $\Theta^{s\varepsilon}_{11}$ analogously. For the rest of the proof, we suppose that ε is small enough so that

$$\begin{aligned} E\left[\widehat{d}_{11} \mid \widehat{d}_{11} \in \Theta^{d}_{11}, \widehat{d}_{21}\right] &> \widehat{d}_{11} \ \forall \widehat{d}_{21}, \forall \widehat{d}_{11} \in \Theta^{d\varepsilon}_{11} \text{ , and} \\ E\left[\widehat{s}_{11} \mid \widehat{s}_{11} \in \Theta^{s}_{11}, \widehat{s}_{21}\right] &> \widehat{s}_{11} \ \forall \widehat{s}_{21}, \forall \widehat{s}_{11} \in \Theta^{s\varepsilon}_{11}. \end{aligned}$$

Now, fix some $\widehat{d}_{11} \in \Theta^{d\varepsilon}_{11}$ and $\widehat{s}_{11} \in \Theta^{s\varepsilon}_{11}$. One can define the following sets:

$$\begin{aligned} R_1 &= \left\{ \left(\widehat{d}_{21}, \widehat{s}_{21}\right) \mid \widehat{\alpha}''_{21} < \alpha^*_{21} \right\} \\ R_2 &= \left\{ \left(\widehat{d}_{21}, \widehat{s}_{21}\right) \mid \widehat{\alpha}''_{21} \geq \alpha^*_{21}, \widehat{\alpha}'_{21} < \alpha^*_{21} \right\} \\ R_3 &= \left\{ \left(\widehat{d}_{21}, \widehat{s}_{21}\right) \mid \widehat{\alpha}'_{21} \geq \alpha^*_{21}, \widehat{\alpha}'_{21} < \alpha^*_{11} \right\} \\ R_4 &= \left\{ \left(\widehat{d}_{21}, \widehat{s}_{21}\right) \mid \widehat{\alpha}'_{21} \geq \alpha^*_{11} \right\} \end{aligned}$$

These sets are all non-empty since $\widehat{\alpha}'_{21} < \widehat{\alpha}''_{21}$ whenever $\widehat{d}_{11} \in \Theta^{d\varepsilon}_{11}$ and $\widehat{s}_{11} \in \Theta^{s\varepsilon}_{11}$.

For some fixed $\widehat{d}_{11} \in \Theta^{d\varepsilon}_{11}$ and $\widehat{s}_{11} \in \Theta^{s\varepsilon}_{11}$, let

$$U^1\left[r_{11}\left(\widehat{d}_{21}, \widehat{s}_{21}\right), r_{21}\left(\widehat{d}_{21}, \widehat{s}_{21}\right)\right]$$

be the expected utility of member 1 when member 2 has drawn $\left(\widehat{d}_{21}, \widehat{s}_{21}\right)$, member 1 votes for r_{11}, and member 2 votes for r_{21}. The payoff for member 1 from withholding his information from member 2 in the proposed equilibrium is

$$E\left\{U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\underline{r}_1\right] \mid \left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_1\right\}\Pr\left[\left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_1\right]$$
$$+\sum_{i=2}^{4}E\left\{U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\overline{r}_1\right] \mid \left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right\}\Pr\left[\left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right],$$

while his payoff from disclosing information is

$$\sum_{i=1}^{2}E\left\{U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\underline{r}_1\right] \mid \left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right\}\Pr\left[\left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right]$$
$$+\sum_{i=3}^{4}E\left\{U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\overline{r}_1\right] \mid \left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right\}\Pr\left[\left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_i\right],$$

which is strictly larger his payoff from withholding since

$$U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\underline{r}_1\right] > U^1\left[r_{11}\left(\widehat{d}_{21},\widehat{s}_{21}\right),\overline{r}_1\right]$$

whenever $\left(\widehat{d}_{21},\widehat{s}_{21}\right)\in R_2$. Thus, there cannot exist an equilibrium in the first period in which member 1 withholds information. Similar arguments show that there also cannot exist an equilibrium in which member 2 withholds information in the first period. Thus, the equilibrium of the communication game in the first period features full disclosure.

Now consider the communication game in period 2. Since all information in period 1 continues to be public information, the game is isomorphic to the game in period 1. Therefore, the equilibrium of the period 2 communication game is also full disclosure. Repeating this argument ad infinitum gives the result. ■

3.A.3 Proof of Proposition 3.3

Proof. In the proof, all expectations taken at time t are understood to depend on $\{\widehat{\pi}_\tau\}_{\tau=1}^t$ as well as the variables explicitly noted. Suppose that $\overline{\theta}_i=\overline{\theta}_d$ for all possible appointees. Let

$$\underline{R}_t=\left\{\{d_\tau,s_\tau\}_{\tau=1}^t \mid \begin{array}{c} E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t,\underline{r}_t\right]\geq \\ E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t,\overline{r}_t\right]\end{array}\right\}$$

and

$$\overline{R}_t=\left\{\{d_\tau,s_\tau\}_{\tau=1}^t \mid \begin{array}{c} E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t,\overline{r}_t\right]> \\ E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t,\underline{r}_t\right]\end{array}\right\}.$$

Now, the expected utility of the committee designer at time t computed in the first period is equal to

$$
\begin{aligned}
&E\left[(\pi_t-\pi^*)^2\right]= \\
&\left\{\begin{array}{l}
E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t, \underline{r}_t\right] \times \\
\Pr\left[r_t=\underline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t\right]+ \\
E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t, \overline{r}_t\right] \times \\
\Pr\left[r_t=\overline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t\right]
\end{array}\right\} \Pr\left[\{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t\right]+ \\
&\left\{\begin{array}{l}
E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t, \underline{r}_t\right] \times \\
\Pr\left[r_t=\underline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t\right]+ \\
E\left[(\pi_t-\pi^*)^2 \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t, \overline{r}_t\right] \times \\
\Pr\left[r_t=\overline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t\right]
\end{array}\right\} \Pr\left[\{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t\right]
\end{aligned}
$$

Expected utility reaches a maximum when there is at least one member for whom $\gamma_i^d \to \infty$ and one member for whom $\gamma_i^s \to \infty$ because in this case $\Pr\left[r_t=\overline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \underline{R}_t\right] \to 0$ and $\Pr\left[r_t=\underline{r}_t \mid \{d_\tau,s_\tau\}_{\tau=1}^t \in \overline{R}_t\right] \to 0$. This follows from the fact that members share their private information with each other prior to voting. The result follows from the continuity of $E\left[(\pi_t-\pi^*)^2\right]$ in $\overline{\theta}_i$, γ_i^d, and γ_i^s. ■

3.A.4 Proof of Proposition 3.5

Proof. Let $\widehat{\alpha}_t$ be the members' shared belief about α_t at time t. By (3.11)

$$
\Pr\left[r_{1t} \neq r_{2t}\right] = \Pr\left[\frac{g(\overline{r}_t)-g(\underline{r}_t)}{2} < \widehat{\alpha}_t < \frac{g(\overline{r}_t)-g(\underline{r}_t)}{2} + \left|\widehat{\theta}_{1t}-\widehat{\theta}_{2t}\right|\right]
$$

Since $\widehat{\alpha}_t$ has a continuous distribution for all t, a sufficient condition for the result to hold is $\left|\widehat{\theta}_{1t}-\widehat{\theta}_{2t}\right| \xrightarrow{p} 0$.

By standard results in Bayesian decision theory, the conditional distributions of $\theta \mid \{d_\tau, s_\tau, \widehat{\pi}_{\tau-1}\}_{\tau=1}^t$ for both members are normal with means $\widehat{\theta}_{1t}$ and $\widehat{\theta}_{2t}$. Let $\tilde{f}_t^1(\theta)$ and $\tilde{f}_t^2(\theta)$ be the associated probability density functions.

Now, since both members' prior distributions on θ assign positive probability to all subsets of $\mathbb{R}$, they are absolutely continuous with respect to each other; so, one can apply Proposition 1 in Kalai and Lehrer (1994), which implies

$$
1-\varepsilon \geq \frac{\tilde{f}_t^1}{\tilde{f}_t^2} \geq 1+\varepsilon \tag{3.12}
$$

for large enough t for all $\varepsilon > 0$. Since $\tilde{f}_t^i(\theta)$ are unimodal, (3.12) implies that $\left|\widehat{\theta}_{1t}-\widehat{\theta}_{2t}\right| < \delta$ for all $\delta > 0$ for large enough t. So, $\left|\widehat{\theta}_{1t}-\widehat{\theta}_{2t}\right| \xrightarrow{p} 0$, establishing the result. ■

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