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THE ECONOMICS OF TELECOMMUTING: THEORY AND EVIDENCE

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Abstract

While there has been considerable research on the effect of telecommuting on worker's productivity and quality of work life, there is considerably less work on the managerial problems associated with selecting, monitoring, and compensating workers involved in telecommuting. We propose a model based on contract theory to analyze the managerial decisions on telecommuting, focusing on (1) how managers should decide which workers will have the opportunity to telecommute and (2) how managers should monitor and provide incentives to workers who participate in telecommuting programs. Based on the model, we find that managers' willingness to allow telecommuting is related to the amount of information they have about their employees and that employees who telecommute should have incentives based both on subjective evaluations and objective measures. Using data from the 1998 Workplace Employment Relationship Survey (WERS98), we test these predictions and find that they are supported by the data.

Keywords: Telecommuting, distributed work arrangements, information technologies, multitasking agent, subjective measurement, contract theory

Introduction

The concept of telecommuting (or telework) was coined by Nilles (1975, 1994) to describe a work arrangement in which employees work outside the conventional workplace (e.g., home) and interact with their managers and coworkers by way of computer-based technology. There has been considerable research on telecommuting over the last 25 years, initially spawned by the oil embargo of the mid-1970s and the desire to substitute communications for transportation (Nilles et al. 1976). Telecommuting has been linked to overall societal benefits such as reduced traffic congestion, reduced transport costs, and decreased real-estate costs (see Bailey and Kurland 2002), and benefits to workers that participate in telework programs such as higher job satisfaction and decreased interference between work and family life (Duxbury et al. 1998; Igbaria and Guimaraes 1999). Recent developments in information technology (IT) have accelerated the trend toward telecommuting, expanding the range of firms and industries where telecommuting is viable. Currently, more than 16.5 million people in the United States telework at least one day per month of their normal work schedule (International Telework Association 2000).

While considerable work has been done examining the implications of telecommuting for workers, significantly less research has examined the managerial decision to support telework programs and how telework arrangements should be designed (Bailey and Kurland 2002). Recent studies of telecommuting arrangements have found that managerial support is critical for both the existence and success of telework programs (Anderson et al. 2002; Mannering and Mokhtarian 1995; Mokhtarian and Salomon 1997; Powell and Mainiero 1999). However, studies have suggested that support for these programs is far from overwhelming with a survey of 4000 European managers reporting limited interest (Huws et al. 1990, p. 173) and other research showing that managers have significant concerns about the difficulties in monitoring employee behavior remotely (Hamblin 1995; Kurland and Egan 1999; Olson 1982) and the potential for telecommuting to compromise job performance (Pearlson and Saunders 2001). Earlier research on telecommuting from the firm's perspective has focused on descriptive case studies or statistical studies

involving correlations between specific telework practices and outcomes (Belanger and Collins 1998). While these studies have helped understand telecommuting in practice, many researchers have noted that these studies have been hampered by the lack of an appropriate theoretical foundation upon which to base hypotheses (Bailey and Kurland 2002; Hartman et al. 1992; McCloskey and Igbaria 1998). This has limited the abilities of these studies to gain insights into the process by which telecommuting causes various organizational outcomes and limited managerial prescriptions to studies of observed best practice.

In this paper, we present a formal economic model of telecommuting focusing specifically on two types of managerial decisions identified in the previous literature: (1) Which workers should be permitted to participate in telework programs? (2) How should workers involved in telecommuting be monitored and compensated? While there are a variety of arrangements for working outside the conventional workplace (Davenport and Pearlson 1998), to facilitate modeling and empirical testing, we focus specifically on telecommuting where workers with fixed offices occasionally work at home. This is by far the dominant means of telecommuting, does not have some of the more serious issues (isolation, difficulty of mentoring) associated with purely virtual firms or some of the other alternative work arrangements (Cooper and Kurland 2002), and is a relatively well-defined decision that is presumably faced by most managers. Using contract theory, we derive a set of relationships among manager's information about worker type, worker's individual characteristics, worker selection criteria for telecommuting programs, the intensity of incentives, and the balance between subjective (e.g., managerial review) and objective (e.g., piece rates) incentive systems. We then test these relationship using the 1998 Workplace Employment Relationship Survey (WERS98), a large survey dataset that captures both workers' and managers' perspectives on telework arrangements. Overall, we find both empirical and theoretical support for the argument that managers will be more likely to support telework arrangements when they are better informed about workers' characteristics and that telecommuting employees should and do receive a higher proportion of subjectively determined incentive compensation in their overall pay.

Model

Modeling Approach and Description

The theory of contracts is a widely used collection of approaches for examining interactions between a small number of economic agents (see descriptions in Hart [1989] or Salanie [1997]). The most common model within contract theory is the principal-agent model, which in its most stylized form involves a setting in which a principal (e.g., a manager) seeks to elicit costly effort from an agent (e.g., a worker), but cannot measure effort directly. As a result of this imperfect measurement, the principal must typically rely on various means to align the interests of the principal and the agents such as incentive contracts, monitoring, or selection mechanisms.

The telecommuting decision problem discussed in the introduction naturally lends itself to a principal-agent formulation. In our model, a manager is facing a decision as to whether to allow a worker to work at home.[1] The manager, however, faces two uncertainties. First, she may not be sure of the worker's propensity to engage in nonwork activities during work time if allowed to work at home. This may be due to personality, family situation, or other factors which may be only partially observable to the principal. Second, she may not be able to observe how much effort the agent exerts on work-related tasks. Clearly, the principal can better monitor effort and does not have to contend with alternative nonwork activities by her employees when they work in the office. However, disallowing telecommuting may not be optimal as it can be less costly to the agent (either explicitly or implicitly) to accomplish the same amount of work with some telecommuting.

The manager has two instruments that she can use to obtain the optimal level of effort from her employees.[2] First, she can choose which workers to trust to telecommute. Workers with a low inherent propensity to engage in outside activities can be allowed to work at home with a relatively low cost in terms of lost productivity. Thus, the manager faces a selection problem in deciding which workers should be permitted to telecommute. Second, the manager can provide incentives to workers to telecommute so that they are more likely to engage in work-related activities. The efficacy of these incentives depends on the information the manager has about performance and therefore must be considered jointly with the issue of monitoring and observability of effort.

[1]In the description of the model, we will follow the convention of referring to manager as she and worker as he.

[2]Note that, as with most principal-agent models with voluntary agent participation, the objective is to maximize overall value since the agents' overall utility is governed by their outside alternatives. We are not considering the issue of whether telework can be used to redistribute value between the managers and the workers—only the issue of whether more value can be created by such an arrangement.

If effort is highly observable (either directly or through measurable surrogates such as worker output), the principal can contract specifically on these observable outcomes (e.g., x% per sale made for a salesperson). However, if the manager can perceive worker effort, even if she cannot measure it explicitly, she can utilize subjective incentives, such as a bonus based on a managerial review. Thus, the manager faces a decision problem as to how strong incentives should be and the optimal balance between subjective and objective incentives.

Our model draws on insights from the multi-task principal agent model (e.g., Holmstrom and Milgrom 1991), which captures how incentives alter the division of effort between work and nonwork tasks modified to account for varying agent characteristics. We also utilize an approach based on the Baker et al. (1994) model of subjective measurement in determining the mixture of subjective versus objective incentives.

Model Formulation

We model the interaction between a principal (P) and an agent (A) in which there is a decision as to whether the agent should be allowed to work at home. If the agent works at home, he can receive additional private benefits of working at home with a monetary value designated by *b*. Workers have different types, which correspond to how much time they must devote to capturing *b* if allowed to work at home. A worker of type $\theta \in [\underline{\theta}, \overline{\theta}]$ will spend $t_1 = b/\theta$ to capture private benefits if allowed to work at home—high values of θ correspond to good types of workers. In addition, workers may have different productivity levels (independent of their time allocation) when working in the office as compared to working at home. Let p_1 be the productivity of working in the office and p_2 be the corresponding productivity of working at home (we make no assumptions about which is larger).[3] If the agent spends time *t* on the job, he creates value of $p_1 t$ for the principal working in the office, and $p_2 t$ working at home. The agent bears a private cost given by $C(t + t_1)$ (where $C(0) < 0$, $C'(\cdot) > 0$, $C''(\cdot) > 0$). Note that these assumptions imply that there is some positive number *t**, where $C(t^*) = 0$, and thus agents will exert some effort for a fixed wage. We also assume that $\underline{\theta}$ is not so small so that $b/\underline{\theta} < t^*$ and that the agent works voluntarily and thus must earn a reservation utility of u_0.

The principal faces a decision problem as to whether to allow the agent to work at home and therefore capture his private benefits, and what type of compensation structure to offer the agent to maximize her profit. We first consider two benchmark models, one in which the principal is constrained to pay a fixed wage (a case where effort is totally unobservable), and the other where the principal can observe effort completely and offer an effort (time) based contract. Then we study the case where the worker's performance at home can only be partially observed. Finally, we consider whether including subjective incentives can improve performance over the above case.

Case 1 (Unobservable Agent Action/Fixed-Wage Contract). Without telecommuting, the principal solves the following optimization program:

$\underset{w}{Max}\ \pi_1 = p_1 t - w$, where *w* is the fixed wage.

s.t. (IR) $w - C(t) \geq u_0$

(IC) $t = \arg\max_t (w - C(t))$

This is the standard formulation of the principal agent problem where a principal maximizes her profit subject to the agent's individual rationality (or participation) constraint (IR) and the agent's incentive compatibility (IC) constraint, which ensures the agent to take the action the principal intended when he is free to choose any action. Given a fixed wage, the agent will always exert the "no incentive" effort $t = t^*$ to satisfy the IC condition. To satisfy the IR constraint, the principal will offer a wage $w = u_0 + C(t^*)$ and therefore receive a payoff of:

[3]Several researchers show that workers report that their productivity is higher at home (Bailey and Kurland 2002, Belanger and Collins 1998), although managers doubt this (Pearlson and Saunders 2001).

$$\pi_1 = p_1 t^* - u_0 - C(t^*) \quad (1)$$

If telecommuting is allowed, the principal must account for different types of agents. From incentive compatibility, the agent offered a wage *w* will exert effort *t* to satisfy:

$$\underset{t,t_1}{Max} \quad w - C(t + t_1) + \theta t_1 \qquad \text{s.t. } \theta t_1 \le b$$

Since we assume that if the agent works at home, he always obtain his outside benefit, $t = t^* - \frac{b}{\theta}$. The principal then must solve a program similar to the one before accounting for the productivity difference of working at home and the agent's modified IR constraint, which includes his outside benefit:

$$\text{P: } \underset{w}{Max} \quad \pi_2 = p_2 t - w$$
$$\text{s.t. (IR) } w - C(t + t_1) + \theta t_1 \ge u_0$$
$$\text{(IC) } t = t^* - \frac{b}{\theta}$$

Then we have P's maximal payoff:

$$\pi_2 = p_2 t^* - u_0 - C(t^*) + b - p_2 \frac{b}{\theta} \quad (2)$$

If the principal can observe θ, then she will offer telecommuting when it is more profitable (that is, $\pi_2 > \pi_1$). Comparing equations (1) and (2) we get we get $\theta \ge \frac{p_2}{1 - \frac{p_1 - p_2}{b} t^*}$.

$\theta^* = \frac{p_2}{1 - \frac{p_1 - p_2}{b} t^*}$ will be the threshold that P should offer the option of telecommuting.

From the above results, we have the following proposition:

> *Proposition1: Given either p_1 or p_2 fixed, θ^* increases with $p_1 - p_2$ under some mild constraints.[4] This means the higher the productivity in office, the less likely the principal will offer telecommuting to her workers. On the other hand, the higher the productivity at home, the more likely P will offer telecommuting.*

Proposition 1 is consistent with the observed telecommuting trends. As IT increases the relative productivity of working at home, through improved information processing and data transfer capability, there will be a greater number of workers engaging in telecommuting.

Case 2 (Fully Observable Effort/Time-Based Contracting). To simplify the problem and remove the issue of productivity differences, we will assume going forward that productivity is the same at home and at work, thus $p_1 = p_2 = p$. If effort (*t*) is

[4]When p_2 is fixed, there is no constraints; when p_1 is fixed, we need $(1 - \frac{p_1 t^*}{b})$ to be positive. That is, b is large enough.

observable, then the agent can implement the optimal action using a linear incentive contract where $w = s + at$ (s is the base salary, and a is the rate for the agent's time). Without telecommuting, the agent solves $\underset{t}{Max}\ s + at - C(t)$ to determine his optimal effort. The first order condition yields $C'(t) = a$ which we will rewrite as $t = T(a)$ [the conditions on $C(\cdot)$ guarantee it can be inverted to obtain $T(\cdot)$]. Since at optimum the agent's IR constraint always binds, the principal's problem then becomes $\underset{a}{Max}\,\pi_1 = pT(a) - C(T(a)) - u_0$, which yields an optimal solution for the principal of $\pi_1 = pT(p) - C(T(p)) - u_0$. As before, with telecommuting the agent's problem becomes slightly more complex: $\underset{t}{Max}\ s + at - C(t + \frac{b}{\theta}) + b$ with a solution $t = T(a) - \frac{b}{\theta}$. After imposing the agent's IR constraint, the principal's problem becomes $\underset{a}{Max}\,\pi_2 = p(T(a) - \frac{b}{\theta}) - C(T(a)) + b - u_0$, which has a solution $a^* = p$, the same as in the no-telecommuting example. Thus $\pi_2 \geq \pi_1 \Rightarrow \theta^* = p$.

Case 3 (Partial Observability/Objective Incentive Contracting). Suppose now that the agents' actions are fully observable in the office, but only partially observable at home. Following Baker et al. (1994), we assume that if the worker spends time t on his job, he generates an objective performance measurement μt, where μ is a random distortion factor with $E(\mu) = 1$. The worker can observe μ, but the manager can only observe μt. Thus, the worker will decide his optimal working time according to the realization of μ, giving rise to a moral hazard problem. We also extend our definition of type to include the variance in measured output; we assume a good worker has a lower $Var(\mu)$ than a bad worker and therefore will be less inclined to act opportunistically.

For tractability we assume the worker's cost function is $C(t) = \gamma t^2 - m$, where m is a positive number. Using this cost function, the solution to the no-telecommuting analysis in Case 2 earlier yields $a^* = p$ and $\pi_1 = \frac{p^2}{4\gamma} - u_0 + m$. We now consider the solution when the agent works at home. Because the agent observes μ, he will choose the best response according to the realization of μ. The agent's problem then becomes $\underset{t}{Max}\ s + \mu at - \gamma(t + \frac{b}{\theta})^2 + m + b$ with a solution of $t^* = \frac{\mu a}{2\gamma} - \frac{b}{\theta}$. The manager's problem is to choose the optimal a to maximize her expected payoff (where E is the expectation operator):

$$\underset{a}{Max}\, E\{pt - \gamma(t + \frac{b}{\theta})^2 + b + m - u_0\}$$

From the first order condition we get $a^* = \frac{p}{E(\mu^2)}$ which yields $E(\pi_2) = \frac{p^2}{4\gamma E(\mu^2)} - \frac{pb}{\theta} + b + m - u_0$. Comparing the profit in this scenario with telecommuting and no telecommuting yields $E(\pi_2) > \pi_1 \Rightarrow \theta^* = \frac{p}{1 - \frac{p^2}{4\gamma b}(1 - \frac{1}{E(\mu^2)})}$.

This result has a number of implications. First, when comparing the partial observability case to the full observability case, the manager is more reluctant to allow telecommuting when effort is imperfectly observable and thus requires workers to be of higher type before allowing telecommuting. Second, since $E(\mu^2) = 1 + Var(\mu)$, increased variance of μ (and thus the less precise the objective measurement), the higher the θ^* and fewer workers will be allowed to work at home. These results are consistent with arguments in previous research that to successfully adopt telecommuting, firms should try to make the output more structured and easier to measure (that is, they should structure work to increase the precision of objective measurement).

From the above, we can easily show that if two workers' θ are the same, the one who has a lower $Var(\mu)$ will be more likely to get the option of working at home. Similarly, if two workers' $Var(\mu)$ are the same, the one who has higher θ is more likely to reach the threshold of θ^*. This suggests our first hypothesis:

H1: Workers with high θ or low $Var(\mu)$ are more likely to have the privilege of working at home.

The information of θ and $Var(\mu)$ are valuable to the manager, in that it enables managers to give the privilege of working home to the right person. Without this information, the manager will face a more difficult decision problem and thus may be more inclined to limit telecommuting. In fact, in the Appendix we show that in the absence of this information, even if the manager knows the average θ is above the threshold θ^*, she will not offer the telecommuting option to her workers.

From the above we draw our second hypothesis:

H2: Managers who know more about their workers are more likely to support telecommuting.

One way in which managers learn about the characteristics of their workers is through formal communications policies as well as informal interaction. Therefore, we would expect that:

H1a: Workers with more communication with managers are more likely to get the option of working at home.

Case 4 (Partial Observability/Subjective and Objective Incentive Contracting). In this section, we assume that besides the objective measurement, both managers and workers can observe a subjective measurement of effort. In this case, we analyze whether this subjective measurement can be used to reach a more efficient outcome.

Following Baker et al. (1994), we assume that this subjective measurement takes the form of εt, where ε is a positive random variable with $E(\varepsilon) = 1$. In this way we allow the subjective measurement to be imperfect if $Var(\varepsilon) > 0$. The worker can observe ε, which means the worker may be able to exploit suspected biases in the manager's evaluation technology. The manager can only see εt and will use this measure to offer a bonus of $\varepsilon t\beta$, where β is the bonus rate.

Because εt is the subjective perception of the manager, she can not put this in an explicit contract (and this is the difference between εt and μt). However, under certain conditions (when both sides are patient enough, which means the discount rate is small enough, or the manager can commit to award the bonus through some mechanism such as reputation; see Baker et al. 1994), contracting based on this subjective measurement can be feasible. We assume that the manager can credibly commit to pay a bonus based on her subjective performance assessment.

When working at home, the worker's problem becomes: $\underset{t}{Max}\ s + \mu ta + \varepsilon t\beta - C(t + \frac{b}{\theta})$ which has an optimal solution of $t = \frac{\mu a + \varepsilon\beta}{2\gamma} - \frac{b}{\theta}$. The principal's problem is to set the hourly rate (a) and bonus rate (β). Intuitively, we can see that if $Var(\mu) = 0$ (perfect objective measures), then the manager would set $a = p$ and $\beta = 0$ to achieve the optimal outcome with no subjective incentive component. Similarly, if $Var(\varepsilon) = 0$, she will set $a = 0$ and $\beta = p$ to use only the subjective measurement. If neither of them is perfect, the manager will use both and achieve a better result, which is shown below.

The principal's problem is $\underset{a,\beta}{Max}\ E_{\mu,\varepsilon}\left[pt - C(t + \frac{b}{\theta}) + b - u_0 \right]$.

That is, to maximize $E_{\mu,\varepsilon}\left[p(\frac{\mu a + \varepsilon\beta}{2\gamma} - \frac{b}{\theta}) - \gamma(\frac{\mu a + \varepsilon\beta}{2\gamma})^2 + b + m - u_0 \right]$.

F.O.C. $\Rightarrow a^* = \frac{p\left[E(\varepsilon^2) - 1\right]}{E(\mu^2)E(\varepsilon^2) - 1}$ and $\beta^* = \frac{p\left[E(\mu^2) - 1\right]}{E(\mu^2)E(\varepsilon^2) - 1}$.

This yields a maximum expected payoff of

$$E\pi_2 = \frac{p^2}{2\gamma}\frac{\left[E(\varepsilon^2)+E(\mu^2)-2p\right]}{E(\mu^2)E(\varepsilon^2)-1} - \frac{pb}{\theta} - \frac{1}{2\gamma}\frac{p^2\left[E(\varepsilon^2)-1\right]\left[E(\mu^2)-1\right]}{\left[E(\mu^2)E(\varepsilon^2)-1\right]^2}$$
$$- \frac{E(\mu^2)p^2\left[E(\varepsilon^2)-1\right]^2 + E(\varepsilon^2)p^2\left[E(\mu^2)-1\right]^2}{4\gamma\left[E(\mu^2)E(\varepsilon^2)-1\right]^2} + b + m - u_0$$

Comparing the results of Case 3 (only objective measures) and this case, we find that profits are increased by $\frac{p^2}{4\gamma}\frac{\left[E(\mu^2)-1\right]^2}{E(\mu^2)\left[E(\mu^2)E(\varepsilon^2)-1\right]}$ by using subjective incentives. Because $E(\mu^2) = 1 + Var(\mu)$, and $E(\varepsilon^2) = 1 + Var(\varepsilon)$, this quantity is always positive, unless $Var(\mu) = 0$. Thus, when objective and subjective measures are both imperfect, the principal can do better by using both, and thus is more likely to offer telecommuting to her workers. This yields our final hypothesis:

H3: Managers who use more subjective evaluations are more likely to support telecommuting.

Data and Empirical Results

Data Introduction

We use data from the 1998 Workplace Employment Relationship Survey (WERS98) to test our hypotheses. The WERS98 dataset is a collection of surveys performed by personnel from a stratified sample of over 2,000 British establishments with 10 or more employees (Cully et al. 1999). WERS98 comprises three sources of data, all collected between October 1997 and June 1998: interviews with 2,191 managers with day-to-day responsibilities for personnel matters in the establishment; 947 interviews with worker representatives from a recognized trade union or consultative committee for the establishment; and 28,237 completed questionnaires from a sample of employees working at each participating establishment. For clarity, all references to specific variables are written in italics and we keep their *initial variable names* from WERS98. Please refer to Table 1 for variable definitions, description, and coding.

Manager Survey (Workplace/Establishment Level)

There are three key constructs needed to test our hypotheses. First, the dependent variable in our analysis is the option of telecommuting, which is explicitly asked in the survey.

Second, we need some measure of how well managers can assess the type of worker (as per our theoretical model). While there are no direct measures of worker type in the survey, there are two general categories of activities that would enable a manager to assess worker type: information gathering and communications. For information gathering, the survey asks whether any of the following nine records is kept for this establishment, like labor costs, productivity, quality of product or service, labor turnover, absenteeism, and workforce training. We create a variable KRECPER_SUM, which is the count of all kinds of records kept for the establishment to measure the information endowment of the manager. The manager is also asked the ways the quality of work is monitored at this workplace. Variable KHOWMON_SUM is generated as the count of ways of monitoring. Our assumption is that the more ways of monitoring, the better information the manager would have about the work quality of her workers. For communications, the survey includes measures on the use of quality circles (DCIRCLES), whether the firm has a system of briefings for workers (DBRIEF), and whether there are joint consultative committees including managers and workers (DJOINT). The manager is also asked whether she regularly gives employees or their representatives any information about the following items such as internal investment plans, the financial position of the establishment, and staffing plans. This can partly reflect the manager's attitude to information sharing and communication (these constructs are captured by variables DINVPLAN, DFINANCE, and DSTAFFIN; see Table 1 for definitions).

Overall, although the measurements are far from perfect, combined as a group, they do seem to provide an objective measurement of how much information the manager has about her workers. We therefore factor analyze these measures and construct a composite variable (F_INFO) as proxy for the manager's information endowment (for details, see Table 2). The lower the value of F_INFO means the better the manager knows her workers.

Table 1. Variable Definition and Descriptive Statistics

(Note: coding is as per WERS98 source data except as noted by *)

From the manager survey:

Variable Name	Definition	Coding	Mean	SD
IFAMILY_WORKHOME	Whether nonmanagerial employees are allowed to work at home in normal working hours	yes = 1;no = 0	.180	.384
KRECPER_SUM*	Count of types of workplace records	Count	7.046	1.964
KHOWMON_SUM*	Count of types of monitoring	Count	3.285	1.359
DCIRCLES	Whether have specific problem groups	yes = 1;no = 2	1.523	.499
DBRIEF	Whether have debriefing system	yes = 1;no = 2	1.106	.307
DJOINT	Whether there are joint consultative committees, works councils, etc	yes = 1;no = 2	1.544	.498
DINVPLAN	Whether manager regularly gives out information about investment, finance and staffing issues	yes = 1;no = 2	1.437	.496
DFINANCE		yes = 1;no = 2	1.284	.451
DSTAFFIN		yes = 1;no = 2	1.362	.480
FMEASPR	The portion of performance appraisal to workers	Rank of1-6, 1-most, 6-very few	2.097	1.736
EANYEMP	Any worker Unionized in the workplace	yes = 1, no = 2	1.341	.474

Please refer to Data ane Empirical Results section for the description of other control variables: CTEAM, CJOBDENEW_SUM, ASIC, KACTIVI, KERFIC, LOG_ZALLFTE and ZTOT_RATIO.

From the employee survey:

Variable Name	Definition	Coding	Mean	SD
B34	Whether working in or from home in normal hours is available to you	yes = 1;no = 0	.113	.316
B5A	I sharing the value of the organization	1-6, 1 means strongest	2.545	.911
B5D	I feel loyal to my organization	1-6, 1 means strongest	2.31	.937

How often do workers communicate with the manager about -

B7A	Future plans for the workplace	1-4. 1means frequently 4 means hardly	2.563	.959
B7B	Staffing issues		2.582	.941
B7C	Changes to work practices		2.558	.957
B7D	Pay issues		2.634	.917
B7E	Health and safety at work		2.482	1.00

Other variables

EDU_AVG*	The sample mean of education in this workplace	1-6 The bigger, the more education. Except 6	3.497	.701
OCU_AVG*	The sample mean of occupation in this workplace	1-9, The smaller, the more administrative and research occupation	4.666	1.693
SERNO	Workplace identifier			

Please refer to Data and Empirical Results section for the description of other control variables: D1, D2, D5, D9.

Table 2. Construction of F_INFO: Factor Analysis Summary

2. a: Eigenvalues

1	2	3	4	5	6	7	8
1.632	0.267	0.091	-0.025	-0.096	-0.127	-0.187	-0.219

2. b: Factor loadings of the eight IT measures

KNOWMON	KRECPER	DCIRCLES	DBRIEF	DJOINT	DINVPLAN	DFINANCE	DSTAFFIN
-0.489	-0.344	0.452	0.354	0.383	0.538	0.569	0.432

Note: Conventional criteria applied to the results in Table 2a suggest that the first factor is the only non-noise factor.

Finally, we require some measures of the use of subjective evaluation. In the survey, the manager is asked what proportion of nonmanagerial employees at the workplace have their performance formally appraised, which is measured by variable FMEASPR. We use this variable as proxy of subjective evaluation.

We also add several control variables. It has been argued that teamwork may adversely influence the manager's attitude to telecommuting. We include CTEAM, the proportion of workers' work in formally designated teams. The structural nature of the job may also be a factor that influences the manager's decision on telecommuting. Managers are asked the main methods by which employees are made aware of their job responsibilities. We use the count of these methods, CJOBDENEW_SUM, to control for this effect. We also include additional controls for type of activities in the workplace (KACTIVI), the industry (ASIC), whether it is a cost or profit center (KERFIC), establishment size (LOG_ZALLFTE), and gender composition (ZTOT_RATIO) of the workplace. These are all variables that commonly appear in empirical studies of strategic human resource practices. Upon data completion, the observations we use in the regression range from 1,152 to 1,775 due to missing data on some variables.

Employee Survey (Individual Level)

The second part of our data is an employee survey in the WERS98 data. In each workplace, a random sample of 25 workers are selected. If there are fewer than 25 employees, then all workers are sent a questionnaire. Workers are asked a similar question about whether working at home is available to them, which is coded in variable B34. To test H1, we need measurements of the type of worker. One advantage of the employee survey is that workers are asked to put a score of 1 to 6 on the following questions: "*I share many of the values of my organization*" and "*I feel loyal to my organization*." We believe the corresponding variables B5A and B5D are good measurements of the employee's attitude to his job, and thus a good proxy for the type of the worker.

Workers are also asked how their managers communicate with them on issues like future plans, staffing, changes to work practice, payment issues, and health, which is captured by variables B7A through B7E. We use these variables as proxies of the communication effect in manager's information endowment.

We also use education (D5) and occupation (D9) as control variables for individual employee-level tests. Because these measurements are not available at the workplace level in the manager survey, we use the sample average of education and occupation, EDU_AVG and OCU_AVG, as corresponding measurements at workplace level. Other variables that we use as controls are gender D1 and age D2, and the unique number (SERNO) assigned to each establishment in the survey data (this implicitly controls for all workplace-specific characteristics that were included in the manager survey analysis). Descriptive statistics of our data can be found in Table 1.

Econometric Models and Results

Hypotheses H1 and H1a are from the worker's perspective and tested at employee individual level, using data from employee survey. H2 and H3 are from manager's perspective and tested at workplace level, using data from the manager survey.

Since we are predicting a 0/1 variable, we employ logit model in our regressions. Specifically, H1 and H1a are tested at employee level using the following model:

$$Ln(\Pr/(1-\Pr)) = \beta_0 + \beta_1 X_{type} + \beta_2 X_{Communicat\ ion} + Controls + \varepsilon$$

where Pr is the probability of having the option of working at home. X_{type} includes variables B5A and B5D, which reflect worker type; $X_{communication}$ includes variables B7A-B7E, which measure communication with managers. Control variables are education (D5), occupation (D9), gender (D1), and age (D2). SERNO is used to control the heterogeneity among workplaces.

H2 and H3 are tested at manager level using the following model:

$$Ln(\Pr/(1-\Pr)) = \beta_0 + \beta_1 * F\_INFO + \beta_2 * FMEASPR + Controls + \varepsilon$$

where Pr is the probability of offering telecommuting to workers. H2 corresponds to the sign and significance of β_1, and H3 corresponds to β_2. As detailed in the section on the manager survey, controls include industry, the degree of structure of the job, and sample average of education and occupation (EDU_AVG and OCU_AVG) at the working place. Other controls are industry, size, and gender composition.

Employee Data: Testing H1 and H1a

We first test hypotheses H1 and H1a using data from the employee survey. We limit our analysis to employees from a random subset of about 800 establishments due to constraints on the size of nonlinear fixed effects models in our regression software (results are similar with other random subsets). The regression results are reported in Table 3. Standard errors are also reported. In column 1, we test only the effects of worker's type to telecommuting. Two variables that depict worker's type, B5A (the degree of sharing the value of the organization) and B5D (the degree of feeling loyal to the organization), are both significant at the 1 percent level. Due to the coding of the scale, the negative coefficients imply that employees who report being more committed to the organization are more likely to telecommute.

We then add variables of communication with manager to the regression (B7A through B7E). The effects of discussing future plans (B7A), changes to work practice (B7C) and payment issues (B7D), are significant at the 1 percent to the 10 percent level. The other two variables, discussion of staffing issues and health/safety issues are not significant. The results are quite reasonable, because the former three variables are closely related to working at home, while the later two are not. In this way, H1a is supported by the data.

It is possible that employees in a higher skill occupation or with a higher education are more loyal to the organization, and communicate more with the manager. So our results might be driven by occupation and education. To test this, we add them in the regression and results are reported in column 3. They are both significant at the $p < .01$ level. The change in the coefficient of B5A is not substantial, and it remains significant at $p < .01$.

B5D is not significant in columns 2 and 3. This appears to be due to collinearity between B5A and B5D (the correlation coefficient between them is 0.579 and they are jointly significant). If we drop B5A and run the logit regression again, B5D is significant at the 1 percent level, while coefficients of other variables remain unchanged.

Overall, the above regression results provide strong empirical support on H1 and H1a. Although we cannot rule out other possibilities, we believe that the worker's type and communication with the manager do influence whether he is allowed to work at home.

Manager Data: Testing H2 and H3

Now we use data from the manager survey to test the effects of information endowment and subjective measurement on managers' telecommuting decisions. First, we test only the effect of information endowment. Results from our baseline regression are listed in column 1 of Table 4. As expected, the information endowment factor is significant at a 5 percent level. Because of the way this factor is constructed, the observed negative coefficient is consistent with our expectation. When we add the subjective measurement variable (FMEASPR) (column 2, Table 4), this variable is significant at the 1 percent level, while the coefficient of F_INFO remains almost unchanged (from –.254 to –.268) and still significant. FMEASPR is coded such that a low value means more use of subjective measurement, so the negative coefficient of FMEASPR means that subjective measurement is positively correlated to managers' willingness of offering telecommuting.

Table 3. Testing for H1 and H1a

Logit regression dependent variable: *B34* (Whether working in or from home in normal hours is available to the employee)

Independent Variables	Col(1)	Col(2)	Col(3)	Col(4)
D5			0.099*** (.0319)	.116*** (.0309)
D9			-.427*** (.0280)	-.453*** (.0273)
B5A	-.621*** (0.0595)	-.621*** (0.0619)	-.478*** (.0650)	
B5D	-.109** (0.0536)	-.064 (.0553)	-.064 (.0582)	-.301*** (.0481)
B7A		-.209*** (.0523)	-.128** (.0547)	-.158*** (.05388)
B7B		-.077 (.0547)	-.069 (.0568)	-.054 (.0560)
B7C		-.168*** (.0515)	-.105* (.0538)	-.102* (.0530)
B7D		.196*** (.0509)	.142*** (.0531)	.130** (.0522)
B7E		.000 (.5682)	-.004 (.0476)	-.013 (.0468)
Other Controls	Workplace Dummies, Gender, Age	Workplace Dummies, Gender, Age	Workplace Dummies, Gender, Age	Workplace Dummies, Gender, Age
N	5906	5583	5455	5685
Pseudo R2	.1949	.2062	.2601	.2508

*p < .1, **p < .05, ***p < .01, standard error in parentheses

Table 4. Testing H2 and H3

Logit regression dependent variable: *IFAMILY_WORKHOME* (whether nonmanagerial employees are allowed to work at home in normal working hours)

Independent Variables	Col (1)	Col (2)	Col (3)
F_INFO	-.254** (.1062)	-.268** (.1212)	-.331** (.1431)
FMEASPR		-.242*** (.0536)	-.162*** (.0614)
ZTOT_RATIO	.649* (.3526)	.890** (.3962)	1.145** (.4748)
LOG_ZALLFTE	.358*** (.0534)	.413*** (.060)	.311*** (.0691)
EDU_AVG			.045 (.1594)
OCU_AVG			-.538*** (.0760)
EANYEMP	.393** (.1809)	.437** (.1971)	.309 (.2381)
Other Controls	Industry Dummies and Major Activity Dummies, Team, Job Structure	Industry Dummies and Major Activity Dummies, Team, Job Structure	Industry Dummies and Major Activity Dummies, Team, Job Structure
N	1775	1401	1152
Pseudo R2	.1206	.1377	.1889

*p < .1, **p < .05, ***p < .01, standard error in parentheses

These analyses support our argument in H2 and H3. Other interesting findings are unionization and the proportion of female workers at the establishment are also positively correlated with telecommuting.

One simple explanation of our results is that information intensive workplaces or occupations are more likely to be subjectively measured, have high information sharing, and utilize telecommuting. To determine whether our results are driven by this alternative explanation, we repeat our analyses controlling for education (EDU_AVG) and occupation (OCU_AVG). We find that education is not significant (possibly because of the correlation with occupation), but occupation has a significant effect on telecommuting. It shows that if a workplace mainly consists of knowledge workers and administrative employees, it is more likely that the manager will offer telecommuting. One explanation is that information work can be done more easily at home than physical work. However, even in this modified specification, the main results continue to hold, consistent with H2 and H3.

Conclusion and Limitations

Overall, based on our theoretical modeling, we conclude that managers will be more likely to offer telecommuting to workers that are less likely to shirk at home and those for which they have good information about their propensity to shirk. In addition, we show that subjective incentives can often complement objective measures, especially when objective measures are more difficult to utilize (or unavailable) for home work settings. Using WERS98 data, we find support for these hypotheses at the worker and workplace (manager) level. Managers with better information about their workers allow more telecommuting and use a higher proportion of subjective incentives. Workers that are more committed to the firm are more likely to be able to telecommute. We believe this work complements existing research on telecommuting by extending the results to two critical managerial problems in telecommuting (worker selection and incentives), developing a formal model of telework, and testing this model using empirical data. While the data is not perfect, especially since we do not observe worker motivations for engaging in telework and cannot directly observe worker type, and our model clearly abstracts away some important issues, such as how telework combines with office work, we believe our analysis adds new insights into how firms should manage their workers when telecommuting is a viable option.

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Appendix

For simplicity, we use fixed wage contract presented in Model 1 and assume that $p_1 = p_2 = p$. This yields a threshold of $\theta^* = p$. We now show that even when the manager knows that her workers' average type equals to p, that is, $E(\theta) = p$, the manager may still not want to offer the option of telecommuting to her workers due to lack of information of individual worker type. For simplicity, suppose that θ is uniformly distributed at $[p - \frac{l}{2}, p + \frac{l}{2}]$, with a density $\frac{1}{l}$. From model 1, we get $\pi_2 - \pi_1 = b - p\frac{b}{\theta}$, so if the manager offers telecommuting to all of her workers, her expected payoff would be $E(\pi_2 - \pi_1) = \int_{p-\frac{l}{2}}^{p+\frac{l}{2}} (b - p\frac{b}{\theta})\frac{1}{l} d\theta$. Let $l = \lambda p$, then we have $E(\pi_2 - \pi_1) = b(1 - \frac{1}{\lambda}\ln\frac{2+\lambda}{2-\lambda})$. Thus if $\frac{1}{\lambda}\ln\frac{2+\lambda}{2-\lambda}$ > 1, the manager will not offer telecommuting to her workers, even half of her workers qualify for this policy. And we see that this always holds as long as $\lambda \in (0,2)$.