Does Size Really Matter? Empirical evidence on group incentives.

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Abstract

The paper empirically analyzes the economic theory and intuition that the "free rider" problem will overwhelm firm-wide incentives in large firms. Kandel and Lazear (1992) claim that in a simple model of an equitable partnership, Nash equilibrium effort levels fall with the number of partners - the $\frac{1}{N}$ problem. The paper shows that this result is crucially dependent on a unstated assumption on the production function. In particular, if worker effort levels are complementary, effort levels can increase with the number of partners. This difference may explain the empirical finding that the $\frac{1}{N}$ problem is substantial in medical and legal practices (where effort levels are independent), but less important in manufacturing (where effort levels are complementary). The empirical results suggest that the use of firm-wide incentives increases with firms size, at least for smaller firms. The results do *not* support the claim that the use of other human resource practices, like self-managed work teams, allows the firm to mitigate the $\frac{1}{N}$ problem.

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1 Introduction

The use of profit sharing amongst production line workers in large manufacturing firms, seems to defy economic logic. According to Kandel and Lazear (1992), 'the idea that joint ownership can do much for incentives when the number of workers is large seems wrong on the face of it. After all, each worker bears the full cost of his own effort, but reaps at most $\frac{1}{N}$ of the benefit in an N-worker firm' (pp. 801-2). Despite the general incredulousness of economists, these types of incentives schemes are used in large firms and moreover such schemes have been found to improve firm performance.[1] This paper takes a closer look at why firm-wide incentives should or should not be used in large firms, and tests the explanations on a data set based on a large survey of production line workers and the manufacturing establishments that they work for.

In their seminal work, Kandel and Lazear (1992) argue that without peer pressure, Nash equilibrium effort levels will fall as the number of workers is increased. However, this is not generally true in the model analyzed by the authors.[2] The analysis presented below shows that if effort levels are complements (in the sense that the marginal value of effort increases in other people's effort), then Nash equilibrium effort levels may increase as the number of workers increase. The empirical section estimates the probability that an individual production worker receives either profit sharing or employee share ownership. The section estimates a number of different specifications, the results suggest that the use of profit sharing increases in firm size, at least for smaller firms.

Despite the empirical results presented below, there exists compelling empirical evidence in support of the $\frac{1}{N}$ problem. It seems that at least for legal and medical partnerships, the $\frac{1}{N}$ problem is real (Gaynor and Gertler

[1]See for example, Knez and Simester (2001) and their analysis of the productivity improvements achieved at Continental Airlines after the introduction of a firm-wide bonus scheme for the airline's 35,000 hourly workers, or Ichniowski et al. (1997) and Boning et al. (2001) and their analysis of the productivity improvements attributed to profit sharing amongst production workers in the steel industry.

[2]It is true if effort levels are independent of each other, which is probably the case the authors had in mind.

(1995); Prendergast (1999)). Gaynor and Gertler (1995) shows that proxies for doctor's effort decrease as the number of doctors in the practice increases. However, the empirical evidence on the relationship between firm size and the use of profit sharing in manufacturing (and other industries) is not nearly so clear. As stated above, a number of studies have found that firm-wide incentives schemes lead to productivity improvements, even after accounting for the selection problems inherent in such measures (Boning et al. (2001); Knez and Simester (2001)). Boning et al. (2001) point out that this result suggests the free rider problem is not overwhelming, at least not in steel mini-mills.

Studies on the adoption of profit sharing using establishment and firm level data are inconclusive. Using Canadian firm level data, Jones and Pliskin (1997) find that larger firms are *more* likely to offer employee share ownership to all non-managerial employees and profit sharing to production workers, contradicting the standard intuition. Drago and Heywood (1995) analyze the adoption of incentive schemes in Australian establishments. The authors do find that profit sharing schemes are less likely to be used by larger firms, although the estimated coefficient is not statistically significantly different from 0. Heywood et al. (1998) analyzes the use of profit sharing in German establishments. The authors find that larger firms are again *more* likely to use profit sharing, although the coefficient is not statistically significantly different from 0. The analysis presented below aims to complement these papers by analyzing individual employee level data. Such data is likely to provide more accurate information on the adoption of such a schemes, and the relationship between the use of profit sharing and the adoption of other human resource management practices.

The analysis presented below may help to explain the divergent empirical results. If effort levels are (more or less) independent in medical practices and legal partnerships, then the model predicts effort levels will decrease with partnership size. It seems likely that the effort level choice of one doctor has little or no effect on the productivity of the other doctors in the practice. Doctors generally form partnerships in order to share costs (building, nurses, receptionists) and to reduce risk.[3] In manufacturing, on

[3]This is the subject of the Gaynor and Gertler (1995) paper.

the other hand, it seems likely that effort levels are complementary. For example, on a production line, if one worker is shirking or becoming careless, the productivity of workers further down the line will be adversely affected. It seems likely that the size of a manufacturing firm is intimately related to the degree with which worker's efforts are complements. The analysis of the bonus scheme at Continental suggests that interdependence is important. The scheme introduced by Continental gave all workers in the firm a bonus if a firm-wide target of on-time departures was achieved. According to Knez and Simester (2001)

> A flight cannot depart until the entire ramp and gate activities have been performed, so that poor performance by one employee can negate good performance by the rest of the group. For example, maintenance or fueling delays will prevent a flight from leaving on time, even if passengers and baggage are loaded... (p. 766)

It is also the case that breakdowns at one airport will affect the ability of other airports to contribute to achieving the company wide target (especially in a hub-spoke system).

There are two other arguments made in the literature regarding why the $\frac{1}{N}$ problem is not overwhelming for firms using profits sharing plans. The first is that there are economies of scale in adopting incentive schemes such as profit sharing or employee share ownership. This would occur if there were substantial fixed costs or large overhead in implementing these schemes. It seems reasonable to expect that only larger firms are going to offer employee share ownership. Jones and Pliskin (1997) suggest that at least part of the explanation for their results lies with the existence of scales economies, particularly given the administrative costs of employee share ownership schemes.

The second is that firms use human resource management practices, such as self-managed work teams that allow for "mutual monitoring" (Knez and Simester (2001); Pliskin (2000)). According to Knez and Simester (2001),

> To explain why the [group incentive] scheme may have been effective we argue that the organization of employees into autonomous

> work groups[4] enabled Continental [Airlines] to induce mutual monitoring among employees within each group. (p. 743)

Che and Yoo (2002) present a theoretical model of group incentives in a repeated game that formalizes the argument made in Weitzman and Kruse (1990). The authors show that the implicit incentives generated by perfect (within group) monitoring and repeated interaction allow the free rider problem to be solved. However, the authors do not model the exact situation discussed by Knez and Simester (2001), where there is perfect monitoring within the self-managed work team but imperfect monitoring between teams. Kandel and Lazear (1992) argue that such mutual monitoring cannot work in a large firm with a firm-wide incentive scheme. The authors argue that the mutual monitoring equilibrium unravels when there is imperfect monitoring between groups. I am not aware of any theoretical analysis of the situation. Rather than taking a stand one way or another, this paper will simply test the hypothesis that self-managed work teams solve the free rider problem, allowing profit sharing to be used in large firms.[5]

There exists a parallel discussion of group size and free riding in the charitable giving literature. Andreoni (1988) shows that the standard model of charitable giving, voluntary contributions to a public good, imply a free rider problem. The author shows that the standard model suggests that there are "limits to altruism." In an economy with uncertainty, as the number of people in the economy grows large, the free rider problem becomes overwhelming. There has been some work in the experimental literature to determine whether there is a relationship between group size and free riding. However, no clear relationship has been found. Isaac and Walker (1988) show that the free rider problem does increase with group size, but only if the value of the marginal contribution is allowed to decrease with group size. If the value of the marginal contribution is held constant, then size has no

[4]The terms self-managed work teams and (semi) autonomous work groups are used in the literature to refer to the human resource management practice of giving decision making power to a small group of production workers (Levine (1995); Eaton et al. (1997)).

[5]Knez and Simester (2001) and Che and Yoo (2002) also point out that in firms with complementary effort levels, incentives can be further improved as co-workers can implement harsher punishments by reducing effort levels.

effect on the free rider problem. This argument is similar to the argument made below that the relationship between group size and free riding is dependent on the relationship between group size and the production function. Other experimental evidence suggests that average giving actually *increases* in group size (Isaac et al. (1994)).

The rest of the paper proceeds as follows. Section Two presents a simple theoretical analysis of the relationship between firm size and worker effort choice. The section presents the empirical implications of this model. The section also presents the empirical implications of the economies of scale hypothesis and the mutual monitoring hypothesis. Section Three presents the empirical evidence. The section discusses the data and tests the hypotheses. Section Four concludes.

2 Theoretical Analysis of Group Incentives

This section has three parts. The section presents a theoretical model to illustrate how the number of employees is related to individual effort choices under a simple firm-wide incentive scheme. The implications of this model are illustrated using a linear latent profit model of the firm's decision to use firm-wide incentives. The implications of economies of scale are also illustrated using this model. The section also analyzes the value of using firm-wide incentives conditional upon the use of other human resource management practices such as self-managed work teams, that allow for mutual monitoring. A linear latent profits model is used to illustrate the implications of the mutual monitoring hypothesis.

2.1 A Simple Model of Group Incentives

Consider a firm with N workers.[6] Each worker chooses an effort level $e_i \in \Re$, where $i \in \{1, 2, ..., N\}$, in order to maximize their utility, $u(m, e_i)$, such that $u : \Re^2 \to \Re$. The utility function for each worker is separable in money, such that $u(m, e_i) = m - C(e_i)$, where m is money, and C is the cost of effort,

[6] The model and notation follow Kandel and Lazear (1992).

such that $C(0) = 0$, $C' > 0$ and $C'' > 0$.[7]

The production function is $f : \Re^{\infty} \rightarrow \Re$. For a firm with N workers $f(e_1, e_2, ..., e_N, ...)$ is such that for all $i > N$, e_i is a constant such that $\exists M \in \Re$ such that $f < M$. The partial derivative on i's effort is positive ($f_i > 0$), and there is diminishing returns in i's effort ($f_{ii} < 0$). Assume that the incentive scheme is an "equitable partnership". That is, worker i receives $\frac{f}{N}$. Given the assumptions on f and C, for any N, worker i's effort choice ($e_i^*(N)$) is the solution to the following first order condition,

$$\frac{f_i}{N} - C'(e_i) = 0 \tag{1}$$

Equation (1) is equivalent to Equation (2) in Kandel and Lazear (1992). The authors seem to believe that this equation implies that effort choice decreases in N.[8] This, however, is not obvious and depends on how f_i changes with N. If f_i is constant in N, as would be the case if $f = e_1 + e_2 + ... + e_N$, then the authors are correct.[9] If however, $f_{ij} > 0$, for $i \neq j$, then the opposite may be true.

What does this mean? If the production function is such that each worker's marginal productivity (f_i) is increasing in the number of workers (N), then this is *sufficient* for e_i^* to be increasing in N.[10] Does such a production function exist? Is it a reasonable representation of a manufacturing firm? Consider a Cobb-Douglas production function, $f = \Pi_{i=1}^{\infty} e_i^{\alpha}$, where $e_i = 1$ for all $i > N$, and $\alpha \in (0, 1)$. The following proposition shows that if α is large enough, then effort levels increase with N.

Proposition 1 *Let* $C(e_i) = \frac{e_i^2}{2}$,

1. *If* $\alpha < \frac{2}{N+1}$, *then* $e_i^*(N+1) < e_i^*(N)$.
2. *If* $\alpha > \frac{2}{N}$, *then* $e_i^*(N+1) > e_i^*(N)$.

[7] These are the standard assumptions of the incentive literature (Holmstrom (1979); Kandel and Lazear (1992)).

[8] According to Kandel and Lazear (1992), 'The standard argument, as illustrated by (2), is that effort falls as firm size increases' (p. 815).

[9] More precisely the production function is $f = e_1 + e_2 + ... + e_N + 0 + 0 + ...$

[10] The necessary condition is that $\frac{f_i}{N+1} > \frac{f_i}{N}$.

Proof. From Equation (1), $e_i^*(N)$ is the solution to

$$\frac{\alpha e_i^{\alpha-1}\Pi_{j\neq i}e_j^{\alpha}}{N} - e_i = 0 \tag{2}$$

By symmetry, the Nash equilibrium is such that $e_i^* = e_j^* = e^*$ for all $i, j \leq N$. Therefore $e^* = \left(\frac{N}{\alpha}\right)^{\frac{1}{N\alpha-2}}$. QED.

If for some range of N, α is large enough, then Nash equilibrium effort levels will increase as more workers are hired. How "large" α needs to be depends on the cost of effort function. But in general, the more complementary effort levels are the more likely that effort levels will increase with N.

Note that the Cobb-Douglas production function presented above has the property that for a given α, the "equilibrium" production function $(f(e^*))$ will increase unboundedly as N gets large. In order to mitigate this, α must decrease at a "fast enough" rate as N gets large. In the example, presented above, if $\alpha = \frac{A}{N^2}$, for some large A, then equilibrium effort levels will increase for small N, but eventually they will go to 0 as N gets large.

The Cobb-Douglas function is an example of a production function that is supermodular in worker effort levels (Milgrom and Roberts (1990)). That is, worker effort levels are complements to each other. If someone else in the firm works a little harder, then every other worker's marginal productivity increases. I would argue that complementarities in effort levels are a reasonable characterization of a modern manufacturing plant, in fact the size of the firm itself must be closely related to the existence of such complementarities. Consider the task of authoring a paper. This paper is authored by one person. It reasonable to believe that if another economist was willing to coauthor the paper, then my effort level would actually increase because the marginal returns of my effort would increase. The coauthor and my effort levels would be complementary. In economics, these complementarities are such that two or three economists and 1 or 2 research assistants are optimal to author a paper. In other disciplines the number can be much larger.

Analysis of this simple model shows that the intuition of the $\frac{1}{N}$ problem is not straight forward. If there are complementarities in the production process, effort levels of individual workers may not decrease in firm size.

It is therefore not obvious that the value of using profit sharing decreases monotonically in firm size.

2.2 A Model of Firm Choice of Profit Sharing

In a simple linear latent profit model there exist two possibilities, the latent value of each is presented below. Let V_P be the latent value to the firm, where $P \in \{0, 1\}$ indicates whether the worker is provided with profit sharing. First, the value of not using profit sharing is denoted by A_{ij} for worker i and firm j. The latent profits of the other contract will be compared to this one.

$$V_0 = A_{ij} \tag{3}$$

The value of using profit sharing is V_1.

$$V_1 = A_{ij} + g(N_j) + X_i\beta_{iP} + X_j\beta_{jP} + \epsilon_{ijP} \tag{4}$$

where N_j is the number of workers in firm j, g is some function of N_j, X_i is a vector of observable characteristics of the worker, X_j is a vector of observable characteristics of the worker's firm, and ϵ_{ijP} represents unobservable characteristics that affect the relative value of using profit sharing. If $g(N_j) = \beta_N N_j$ or $g(N_j) = \beta_N \log(N_j)$, then the $\frac{1}{N}$ problem exists if $\beta_N < 0$. A result that $\beta_N > 0$ would be consistent with the hypothesis that there are complementarities in the production process and effort levels increase with firm size. This result would also be consistent with the existence of economies of scale.

2.3 A Model of Firm Choice of Profit Sharing and Teams

Consider the linear model presented above. Now assume that the firm can choose to use two human resource management practices, profit sharing ($P \in \{0, 1\}$) and teams ($T \in \{0, 1\}$), where are either self-managed work teams or quality circles or both. The value of these two practices is denoted V_{PT}. First, the value of neither using profit sharing nor groups is denoted by A_{ij}. The latent profits of the other contracts will be compared to this one.

$$V_{00} = A_{ij} \tag{5}$$

The value of using profit sharing but not using teams is V_{10}. The variables are defined in the previous section.

$$V_{10} = A_{ij} + \beta_{NP}\log(N_j) + X_i\beta_{iP} + X_j\beta_{jP} + \epsilon_{ijP} \tag{6}$$

The value of using teams but not profit sharing is V_{01}. The value of using teams may also be a function of firm size as well as other observable characteristics of the worker and the firm.

$$V_{01} = A_{ij} + \beta_{NT}\log(N_j) + X_i\beta_{iT} + X_j\beta_{jT} + \epsilon_{ijT} \tag{7}$$

where ϵ_{ijT} represents unobservable characteristics that affect the relative value of the contract with teams only. The value of using profit sharing and teams is V_{11}.

$$V_{11} = A_{ij} + \beta_{NPT}\log(N_j) + X_i\beta_{iPT} + X_j\beta_{jPT} + \epsilon_{ijPT} \tag{8}$$

Note that with out loss of generality Equation (8) can be rewritten in a form that is more conducive to representing the particular hypothesis test of interest.

$$\begin{aligned} &V_{11} = A_{ij} + \beta_{NP}\log(n_j) + X_i\beta_{iP} + X_j\beta_{jP} + \epsilon_{ijP} \\ &+\beta_{NT}\log(N_j) + X_i\beta_{iT} + X_j\beta_{jT} + \epsilon_{ijT} \\ &+\beta^*_{NPT}\log(N_j) + X_i\beta^*_{iPT} + X_j\beta^*_{jPT} + \epsilon^*_{ijPT} \end{aligned} \tag{9}$$

where the "*" variables represent the "extra" value of using both practices together.

The mutual monitoring hypothesis is, conditional on the use of teams, the value of profit sharing is not affected by the size of the firm, and conditional on not using teams, the value of profit sharing decreases with size. For the first part the appropriate difference is

$$\begin{aligned} &V_{11} - V_{01} = \beta_{NP}\log(N_j) + X_i\beta_{iP} + X_j\beta_{jP} + \epsilon_{ijP} \\ &+\beta^*_{NPT}\log(N_j) + X_i\beta^*_{iPT} + X_j\beta^*_{jPT} + \epsilon^*_{ijPT} \end{aligned} \tag{10}$$

For the second part of the hypothesis the appropriate difference is

$$V_{10} - V_{00} = \beta_{NP}\log(n_j) + X_i\beta_{iP} + X_j\beta_{jP} + \epsilon_{ijP} \tag{11}$$

Using these two equations the hypothesis to be tested is.

Hypothesis 1 *Mutual Monitoring*
i) $\beta_{NP} + \beta^*_{NPT} = 0$
ii) $\beta_{NP} < 0$

Part (i) of Hypothesis 1 follows the reasoning of **?**) and states that if teams are used by the firm, then the value of profit sharing will be unaffected by the size of the firm. Part (ii) is the same as the traditional $\frac{1}{N}$ problem, but now with the condition that the firm does not use teams.

3 Empirical Evidence on Group Incentives

3.1 Data

The empirical analysis presented below uses data from the Canadian Workplace and Employee Survey (WES) 1999. WES 1999 surveyed management and up to 12 employees at 6,358 establishments with a response rate of around 95 %. There are 24,938 employee surveys, which is a response rate of 83 %. It is important to realize that this is establishment level data, and that there may be more than one establishment per firm. There are two concerns. First, the measure of size may be not be accurate. This issue is discussed further below. Second, the standard errors may be larger than shown because it is not possible to tell whether two establishments are actually members of the same firm, and thus not independent observations. For a more detailed discussion of this issue see Jones and Pliskin (1997).

In order to reduce the variation in the type of establishments and workers that are analyzed, the samples are limited to full-time production workers[11] in non-government manufacturing establishments. This restriction substantially reduces the sample size.[12] The restriction is particular important for understanding what is meant by the use of "teams" or "circles". In a broader sample that includes non-production workers or non-manufacturing firms, it is often difficult to understand what is meant by these types of human resource management practices.

[11] A production worker is either a skilled tradesperson or an unskilled production worker.
[12] The actual sample sizes are listed with the results.

The dependent variable, PROFIT SHARING, is 1 if the worker receives profit sharing or is involved in a share ownership plan. PROFIT SHARING is 0 if the worker does not have profit sharing and is not involved in a share ownership plan.[13] The use of profit sharing is determined by a direct question of the worker. The other dependent variable is TEAM. TEAM is 1 if the worker if they are either in a self-managed work team or a circle, TEAM is 0 if neither is true. Again, the definition is based on a direct question to the worker.

The measure of the size of the firm is the number of full-time employees in the establishment. Note that this measure only tells us how many workers there are at the establishment, not the total number of full-time employees of the firm. This is a concern because the profit-sharing plans and the share ownership schemes may be firm wide rather than establishment wide.

The analysis uses six measures of employee characteristics. The first, EXPERIENCE is the number of years since the worker started her particular job (not necessarily when she started at the firm). This measure is meant to capture the worker's knowledge and experience with the production process. The second, UNION, is 1 if the employee is a member of a union and 0 otherwise. It has also been argued that unions tend to be opposed to profit sharing (Gregg and Marchin (1988)). The third characteristic, MALE is 1 if the employee is male and 0 if the employee is female. The fourth characteristic of the employee, SKILLED is 1 if the employee is a skilled trades person and 0 if the employee is an operator or assembly worker. CANADIAN BORN IS defined as you would expect. HIGH SCHOOL is 1 if the worker completed high school, HIGH SCHOOL is 0 if the worker did not complete high school.

There are two measures to describe the establishment's product market. CUSTOM which is 1 if the relative importance of improving coordination with customers and suppliers is "very important" or "crucial." CUSTOM is 0 if the relative importance of improving coordination with customers and suppliers is "not applicable" or "not important." Note, observations that state

[13] Profit sharing and share ownership are two different schemes that are combined in the analysis. For a discussion and analysis of the differences between the two schemes see Jones and Pliskin (1997).

Variable	*Mean*
PROFIT SHARING	.13
TEAM	.54
Full-Time Workers	374 (660)
MALE	.78
EXPERIENCE	7.49 (7.91)
SKILLED	.81
UNION	.53
CUSTOM	.87
QUALITY	.96
CANADIAN BORN	.84
HIGH SCHOOL	.68
Number of Observations	1,580

Table 1: Sample Means (standard deviation)

coordination is "important" and "slightly important" are dropped. This is done in order to increase the accuracy of the measure. The second measure of the establishment's product market is QUALITY. QUALITY is 1 if the relative importance of improving quality is "very important" or "crucial." QUALITY is 0 if the relative importance of improving quality is "not applicable" or "not important." Note observations that report quality as "important" and "slightly important" are dropped. Again, this is done in order to increase the measure's accuracy. The incentive literature suggests that it will be more difficult to monitor the worker's actions when those actions include quality margins as well as quantity margins (Drago and Heywood (1995)).

Table 1 presents the sample means (frequencies) of the variables used in the analysis. These are the unweighted means, while the regression results are for the weighted sample. Just over 10 % of production workers have profit sharing or share ownership, while over half are members of teams or quality circles.[14]

[14] Because different observations are dropped during the regression analysis, these means may not be exactly the same as for actual sample analyzed in any particular regression.

3.2 Results

Table 2 presents the main empirical results of the paper. The table shows that the traditional $\frac{1}{N}$ problem is not supported by the data. The hypothesis implies that the coefficient on the log of the number of employees is negative. From Column 2, the coefficient is,

$$\beta_{NP} = .15 > 0 \tag{12}$$

and statistically significantly different from 0. This result indicate that production workers in large establishments are (if anything) *more* likely to receive profit sharing than workers in small establishments. This is consistent with the claim that there are complementarities in the production function and with the argument that there are economies of scale.

Column 4 presents the results with the assumption that $g(N_j) = \beta_N N_j + \beta_{N^2} N_j^2$. The coefficient is

$$\beta_{N2P} = -.0000002 < 0 \tag{13}$$

which is negative and statistically significantly different from 0. The results suggest that for Canadian establishments with over 4,000 full time workers, the free rider problem becomes overwhelming and the probability of using profit sharing decreases in establishment size. A possible explanation for this result is that there is a free rider problem and there are also economies of scale in the adoption of profit sharing. For smaller firms, economies of scale dominate free riding, and for larger firms, free riding dominates economies of scale. Alternatively, it seems reasonable that complementarities will diminish with firm size, and eventually the addition of new workers is not enough to induce greater effort.[15]

The last hypothesis to be tested in this section is the mutual monitoring hypothesis. The estimator used to test this hypothesis accounts for the endogeniety in the decision of the firm to give a worker both profit sharing and place that worker in a self-managed work team or quality circle. The estimator is discussed in detail in Adams (Forthcoming, 2002). The estimator allows the firm's choice on giving a worker profit sharing and teams to be

[15] It seems that for academic papers in economics, this number is around 2.

Profit Sharing	*Model 1* β	% Δ	*Model 2* β	*Model 3* β
Log(N)	.15	.02	-	-
	(.07)	(.01)	-	-
N	-	-	-.00004	.0008
			(.00008)	(.0002)
N^2	-	-	-	-.0000002
			-	(.00000005)
Male	.18	.02	.25	.25
	(.16)	(.02)	(.16)	(.15)
Experience	.02	.002	.02	.01
	(.01)	(.001)	(.01)	(.01)
Skilled	.23	.03	.08	-.07
	(.23)	(.03)	(.21)	(.19)
Quality	-.05	-.01	.10	-.04
	(.50)	(.08)	(.55)	(.51)
Union	-.33	-.05	-.08	-.26
	(.24)	(.04)	(.21)	(.21)
Custom	.09	.01	.19	.21
	(.30)	(.04)	(.34)	(.30)
Canadian Born	.62	.07	.64	.63
	(.21)	(.02)	(.20)	(.21)
High School	-.07	-.01	.06	.00
	(.15)	(.02)	(.16)	(.15)
Constant	-2.97		-2.52	-2.38
	(.48)		(.50)	(.48)
Log Likelihood	-389.77		-401.20	-382.38
Sample Size	1,390		1,400	1,400

Table 2: Probit Regressions on Profit Sharing (Robust Standard Errors)

made simultaneously, and it allows the two choices to interact. The model's key characteristics is that it allows this interaction to vary from worker to worker in observable and unobservable ways.

Table 3 presents the estimates from the complementary Probit. From the data, the equations are respectively (from column 2, row 3 and 19)

$$\beta_{NP} + \beta^*_{NPT} = .14 + .01 = .15 > 0 \tag{14}$$

which is positive rather than 0, and (from column 2, row 3)

$$\beta_{NP} = .14 > 0 \tag{15}$$

which is also positive and statistically significantly different from 0. That is, for workers not in teams, larger establishments are *more* likely to receive profit sharing the workers in smaller establishments. These results are *not* consistent with the Mutual Monitoring Hypothesis. This hypothesis posits that $\beta_{NP} < 0$ and $\beta_{NP} + \beta^*_{NPT} = 0$, neither of which is supported. The results do however give further support for both the claim that there are complementarities in the production process as well as for the argument that there are economies of scale, both of which posit that $\beta_{NP} > 0$.

These results also highlight the importance of the QUALITY variable. Not only is QUALITY an important determinant of the use of profit sharing it is also an important indicator of whether profit sharing and teams are complements. It should be noted that "teams" includes the use of quality circles and problem solving groups, both of which seem to be very important for firms that produce high quality products (Boning et al. (2001); Ichniowski et al. (1997)).

4 Conclusion

The $\frac{1}{N}$ problem states that as firms get large, workers will be more likely to free ride and firm-wide incentive schemes will breakdown. This paper shows that the intuition from the simple model is not as straight forward as we have been led to believe. Whether effort levels decrease or increase, as the number of workers increase, is crucially dependent on the production function. If the

Model 3	β	*Robust SE*
Profit Sharing(β_P)		
Log(N)	.14	(.05)
Male	-.07	(.18)
Quality	.87	(.29)
Experience	.01	(.01)
Skilled	.19	(.21)
Candian Born	.59	(.21)
Constant	-3.59	(.47)
Team(β_T)		
Log(N)	-.06	(.05)
Male	.23	(.12)
Quality	-.29	(.25)
Experience	.0135	(.0076)
Skilled	.61	(.17)
Candian Born	.22	(.12)
Constant	-.29	(.30)
Both(β^*_{PT})		
Log(N)	.01	(.05)
Quality	2.28	(.21)
Constant	-4.12	(.30)
ρ_{12}	.12	
ρ_{13}	-.20	
ρ_{23}	-.28	
Log Likelihood	-646443.65	
Sample Size	1,918	

Table 3: Conditional Estimates from a complementary Probit (Robust Standard Errors)

production function is separable in the effort level of each worker, then the intuition holds. However, if there are complementarities, more workers may *increase* effort levels under equitable partnership incentive schemes. This difference in production functions, may explain why the $\frac{1}{N}$ problem seems to hold in legal and medical partnerships, but does not seem to hold in manufacturing firms. Empirical results from a recent Canadian survey of production workers and their establishments, does not support the notion that firm size is negatively related to the adoption of firm-wide incentive schemes. The results suggest that (at least for smaller firms), as firm size increases the adoption of profit sharing and employee share ownership also increases.

Another possible explanation is that large firms use human resource management practices that allow for mutual monitoring and thus mitigate the free rider problem (Knez and Simester (2001); Pliskin (2000)). The argument (formalized by Che and Yoo (2002)) is that if workers are able to perfectly observe each other's actions, then the Nash equilibrium of the repeated game allows profit sharing to implement the Pareto optimal effort levels. It is argued that human resource management practices such as self-managed work teams and quality circles allow workers to mutual monitor (or perfectly observe) each other's actions. Kandel and Lazear (1992) point out that workers may not be able to perfectly monitor workers in other teams. The authors suggest that the argument unravels under such circumstances. I am not aware of any theoretical analysis of this situation. This paper tests the two empirical implications of the mutual monitoring hypothesis. First, establishments that use teams will not suffer from the free rider problem and so size will not affect the value of profit sharing. Second, establishments that don't use teams will suffer from the free rider problem and so size will decrease the value of profit sharing. The empirical findings do not support the hypothesis. The results suggest the workers in larger establishments are more likely to receive profit sharing, irrespective of their participation in teams.

The paper finds that in manufacturing, the use of profit sharing increases in firm size (at least for small firms). The results are consistent with two explanations. The first is that effort choices between workers in manufacturing are complementary. If this is true then it may be the case that effort choices would increase with the number of workers and profit sharing may be more profitable for larger firms. The second is that there are economies of scale in the use of profit sharing and employee share ownership plans.

References

Adams, Christopher P., "Selection of "High Performance Work Practices" in U.S. Manufacturing," March 2002. FTC Working Paper 247.

_ , "The Use of Profit Sharing When Workers Make Decisions: Evidence from a Survey of Manufacturing Workers," in Jeffrey Pliskin and Takao Kato, eds., *Advances in the Economic Analysis of Participatory and Labor Managed Firms*, Elsevier, Forthcoming.

Andreoni, James, "Privately provided public goods in a large economy: the limits of altruism," *Journal of Public Economics*, 1988, *35*, 57–73.

Boning, Brent, Casey Icniowski, and Kathryn Shaw, "Opportunity Counts: Teams and the Effectiveness of Production Incentives," May 2001. NBER Working Paper 8306.

Che, Yeon-Koo and Seung-Weon Yoo, "Optimal Incentives for Teams," *American Economic Review*, June 2002, *91* (3), 525–541.

Drago, Robert and John Heywood, "The Choice of Payment Schemes: Australian Establishment Data," *Industrial Relations*, 1995, *34*, 507–531.

Eaton, Adrienne, Paula Voos, and Dong-one Kim, "Voluntary and Involuntary Aspects of Employee Participation in Decision Making," in David Levine, Daniel Mitchell, and Mahmood Zaidi, eds., *The Human Resource Management Handbook (Part 1)*, JAI Press, 1997, pp. 63–85.

Gaynor, Martin and Paul J. Gertler, "Moral Hazard and Risk Spreading in Partnerships," *Rand Journal of Economics*, 1995, *26* (4), 591–613.

Gregg, P. A. and S. J. Marchin, "Unions and the incidence of performance linked pay schemes in Britain," *International Journal of Industrial Organization*, 1988, *6*, 91–107.

Heywood, John S., Olaf Hubler, and Uwe Jirjahn, "Variable Payment Schemes and Industrial Relations: Evidence from Germany," *Kyklos*, 1998, *51* (2), 237–257.

Holmstrom, Bengt, "Moral Hazard and Observability," *Bell Journal of Economics*, 1979, *10* (1), 74–91.

Ichniowski, Casey, Kathryn Shaw, and Giovanna Prennushi, "The Effects of Human Resource Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review*, 1997, *87*, 291–313.

Isaac, R. Mark and James M. Walker, "Group Size Effects in Public Goods Provision: The Voluntary Contributions Mechanism," *Quarterly Journal of Economics*, 1988, *103* (1), 179–199.

_ , _ , and Arlington Williams, "Group Size and the Voluntary Provision of Public Goods: Experiments Utilizing Very Large Groups," *Journal of Public Economics*, 1994, *54*, 1–36.

Jones, Derek and Jeffrey Pliskin, "Determinants of the Incidence of Group Incentives: Evidence from Canada," *Canadian Journal of Economics*, November 1997, *30* (4b), 1027–1045.

Kandel, Eugene and Edward Lazear, "Peer Pressure and Partnerships," *Journal of Political Economy*, 1992, *100*, 801–817.

Knez, Marc and Duncan Simester, "Firm-Wide Incentives and Mutual Monitoring at Continental Airlines," *Journal of Labor Economics*, October 2001, *19* (4), 743–772.

Levine, David, *Reinventing the Workplace: How Business and Employees Can Both Win*, The Brookings Institution, 1995.

Milgrom, Paul and John Roberts, "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *The American Economic Review*, June 1990, pp. 511–528.

Pliskin, Jeffrey, "The Incidence of Profit Sharing and Flexible Workplace Practices," July 2000. Conference Paper for the 10th Conference of the International Association for the Economics of Participation, Trento Italy.

Prendergast, Canice, "The Provision of Incentives in Firms," *Journal of Economic Literature*, 1999, *37*, 7–63.

Weitzman, Martin L. and Douglas L. Kruse, "Profit Sharing and Productivity," in Alan S. Blinder, ed., *Paying for Productivity*, Washington, D.C.: The Brookings Institution, 1990, pp. 95–142.