Title

Individual, Collective, and Systems Rationality in Work Groups: Dilemmas and Solutions

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Title

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Abstract

In formal organizations and particularly in work teams within organizations, the following two situations often arise. In the first, one can observe or measure only the output of the work group, not the contributions of each member. In the second, the output of each member depends not only on her own effort but also on the efforts of other workers. The problem that arises in both situations is how to construct reward or incentive schemes. In the first case, one cannot tie individual rewards to individual outputs. In the second, one can do so, but the connection between individual effort and output is blurred by the interdependencies between the workers. Group piece-rate schemes are suggested remedies in both situations. However, it is wellknown that group piece-rate schemes are susceptible to free-rider problems. The classic solution to the free-rider problem and to the problem of team interdependencies in general is to substitute a market-type relationship, such as a group piece-rate scheme, with an authority relationship, in which a supervisor keeps free riders in line. In this paper, I discuss an alternative solution to the free-rider problem, a solution that retains the market-type character of the piece-rate scheme but in which the relationship between output and reward is highly nonlinear. I show that a so-called target-rate scheme, either individual or group based, in which pay is high if a production target is reached and low otherwise, can solve the free-rider problem. I use evidence from establishment-level data on several thousand production workers in two U.S. industries to support this claim.

1 Introduction

In formal organizations and particularly in work teams within organizations, the following two situations often arise. In the first, one can observe or measure only the output of the work group, but not the contributions of each member. In the second, the output of each member depends not only on her own effort but also on the efforts of the other workers.

The problem that arises in both situations is how to construct reward or incentive schemes. In the first case, one cannot tie individual rewards to individual outputs. In the second one may do so, but the tie between individual effort and output is blurred by the interdependencies.

Group piece rates are suggested remedies in both situations (see, e.g., Balderston 1930, p. 10; Miller and Hamblin 1963; Dessler 1984, p. 377; ILO 1984, p. 15; Hills 1987, p. 370). However, it is well known that group piece-rate schemes are susceptible to free-rider problems, as pointed out in the sociological, psychological, managerial, economics, and industrial engineering literature (Stinchcombe and Harris 1969; Granovetter and Tilly 1988; Hechter 1987, p. 136; Marriott 1949; Lawler 1981, p. 81; Dessler 1984, p. 377; Aft 1985, pp. 241, 247; Holmstrom 1982; Miyazaki 1984; ILO 1984, p. 16; Sellie 1982). Under a group piece-rate scheme each worker has an incentive not to work hard, since her contribution to the group output is of order $1/n$, where n is the group size. Increased effort is reflected in increased pay only to the order of $1/n$, since all other workers also benefit from the effort of a single worker, a problem that is exacerbated with the size of the group. A group piece-rate scheme is therefore likely to lead to low effort levels, low output levels, and hence low pay for all members of the work group. In the case of interdependencies when individual outputs are observable, even an individual piece-rate scheme is susceptible to free-rider problems. The mechanism is then that each worker knows that her own output depends not only on her own effort, but also on the efforts of her coworkers. She therefore has an incentive to take it easy and let the others work hard. But again, if everyone acts according to this logic, outputs and hence rewards will be low.

In both situations, when either a group piece-rate scheme or an individual piece-rate scheme is applied, individually rational behavior leads to collective irrationality or poor systems functioning. It is individually rational not to work hard, irrespective of the actions of the other workers. But everyone would prefer a situation in which everyone works hard to one in which everyone does not. The situation belongs to the class of problems that has become known as the micro-macro problem (see Coleman 1986).

The classic solution to the problem of team interdependencies and to free-rider problems in work groups in general was sketched by Stinchcombe and Harris (1969), was later fully developed by Alchian and Demsetz (1972), and was to some extent elaborated in Jacobs (1981). It substitutes a market-type relationship, such as the group piece-rate scheme, with an authority relationship, in which a supervisor keeps free-riders in line (see also Williamson 1985, pp. 210, 244–246; Hechter 1987, pp. 136, 141).[1]

In this paper, I discuss an alternative solution to the free-rider problem, a solution that retains the market-type character of the piece-rate scheme but in which the relationship between output and reward is highly nonlinear. It is shown that a so-called target-rate scheme, either individual or group based, in which pay is high if a production target is reached and low otherwise, can solve the free-rider problem.[2] I also present empirical evidence to support the claim.

Besides solving free-rider problems, a market-type relationship is in many respects preferable to an authority relationship, on economic and ethical grounds. It saves the costs of remunerating a supervisor (a point already observed by Marx [(1867) 1967, p. 521]), although it incurs the costs of measuring output at the individual or group level (a cost that is usually incurred even in the absence of an output-related scheme). From an ethical viewpoint, a market-type relationship facilitates work-group autonomy, a feature workers might find desirable: Workers decide the pace of work rather than the supervisor. (For example, in the British mining industries, supervisors were almost eliminated when group incentives were introduced in 1977–1978 [see Heery 1984]).

From a more empirical point of view, group incentive schemes are used in several industries in the U.S. and other countries, and about half of group incen-

[1]Alchian and Demsetz (1972) take an extreme point of view, claiming that the need to alleviate free-rider problems under team production is the cause of authority relationships and even of capitalist employment relationships in general (for a critique, see Perrow 1986, chap. 7).

[2]Holmstrom (1982) showed that when only group outputs are observable, group target-rate schemes can solve free-rider problems. He does not discuss the perhaps equally important case in which team interdependencies exist. In that case, both an individual target-rate scheme and a group target-rate can solve the free-rider problem (see Section 3 below).

tive workers in the U.S. are paid according to target-rate schemes (see Section 2 below). Most well known are probably the target-rate schemes frequently used in the construction and building industries, where team interdependencies are important (see, e.g., Hills 1987, p. 352): A penalty, often called liquidated damages, is imposed if a project is not finished by a certain date (see, e.g., Stinchcombe 1985, p. 161). It is unknown whether such target-rate schemes were introduced to alleviate free-rider problems or for other reasons.[3]

The remainder of the paper is organized in six sections. In Section 2 I present some descriptive material on the prevalence of target-rate schemes and of group incentive schemes in the U.S., Britain, Sweden, and Norway. My primary objective is to illustrate the relevance of the problem. In Section 3 I develop a formal model to compare the reward schemes, piece-rate and target-rate schemes under two scenarios: in the first, only group outputs are observable; in the second, interdependencies exist between workers. I draw four conclusions and summarize them in Propositions 1 and 2. In Section 4 I discuss alternative solutions to the free-rider problem, namely those relying on social rewards (i.e., social control mechanisms that operate at the work group level), altruistic preferences, and moral commitment. These three mechanisms may operate as alternatives or supplements to market-type and authority relationships. In Sections 5 and 6, I present the empirical evidence, based on establishment-level data on two industries in the U.S. In Section 7 I present concluding remarks.

Before proceeding to these tasks, it may be useful to explicate the methodology to be followed. In Section 3, the core theoretical part of the paper, I state the baseline model, in which all actors are assumed to be egoistic. There, I show that a target-rate scheme can overcome the free-rider problems of a piece-rate scheme. As is often the case, other factors are also at play, but I delay their introduction until Section 4, where the description of the social setting is made

[3]The substantive setting of the current research is the factory. Target rate schemes have relevance beyond the factory. Most interestingly, they are found in Chinese population policies. Each village has a maximum number of children that can be born, and each family within the village is enjoined to have no more than one child (see Greenhalgh 1986). If the village and each family within the village stays within the centrally specified limits, rewards ensue. Otherwise the sanctions are severe. Not only are the families that bear two or more children penalized, the entire village may be punished for the adversive actions of a few. In this manner China attempts to curtail free-rider problems in population growth. The enforcement of the target relies partly on the material incentives provided but also on the social and political sanctions imposed on offenders and would-be offenders. Indian fertility policies rely on similar target-rate schemes; in each village in India, a given number of sterilizations are to be performed (see Weisman 1988).

more complex and realistic. There, I bring in three additional institutions: social rewards, altruistic preferences, and moral commitment. Throughout this conceptual analysis there is a conflict between the relevance and the usefulness of the ideas. In Section 3 I push, as far as my data allow, the latter aspect. In Section 4, the relevance aspect dominates and the relationship of the ideas to the quantitative data is more tangential, relying instead on ethnographic and anecdotal evidence. Although the material in Section 4, in contrast to that of Section 3, is less relevant to the empirical analysis that follows in Section 6, it deserves space. Work groups appear to be hotbeds for social rewards, social norms, and ethical codes (see, e.g., Montgomery 1987, chap. 1). Ignoring these yields a needlessly partial view of the mechanisms that likely operate. Fifty years of research in sociology and neighboring disciplines documents the existence and importance of these alternative social institutions.

2 The Prevalence of Group Incentive Schemes

In this section I place the issues of the paper in their broader empirical context, leaving the clarification and development of the concepts to the following two sections. For now, the objective is to document the prevalence of group incentive schemes among incentive workers in four countries: the U.S., Britain, Sweden, and Norway. For the U.S., I also present a breakdown of incentive workers by the type of incentives, piece and target rates.

Table 1 gives the distribution of incentive workers in the U.S within each of 21 manufacturing industries among four types of incentives: individual piece and target rates and group piece and target rates. The industries are presented in descending order by the percentage of incentive workers paid by group incentives. The data pertain to production workers and were taken from the Industry Wage Surveys conducted by the Bureau of Labor Statistics (U.S. Department of Labor), to be discussed in greater detail in Section 5.

(Table 1 about here)

Table 1 shows that group incentive schemes are quite common among incentive workers but that there are considerable interindustry differences. In the cotton, footwear, and clothing industries— historically the classical piece-rate industries—96 to 100 % of the incentive workers are paid according to individual incentives, predominantly individual piece rates. The factories in these industries, particularly in clothing and footwear, are equipped with machines that are controlled by individual operators; hence, individual incentive schemes are feasible (see, e.g., Lokiec 1966, p. 314). In contrast, in the woodhousehold furniture, corrugated and solid fiber boxes, and meatpacking industries, 60 to 70 % of the incentive workers are paid according to group incentives. In these industries, individual outputs are harder to identify and team production is more widespread.

By comparing columns 1 and 2 and columns 3 and 4, we see further that target-rate schemes are more common among group incentive workers than among individual incentive workers. In 9 of the 18 industries using group incentives, group target rates are more important than group piece rates, whereas in only 5 of the 21 industries using individual incentives, individual target rates are more important than individual piece rates. This makes sense. Free-rider problems are most severe among group incentive workers and group target rates may alleviate these.

The last column of Table 1 gives the percentages of workers paid by any type of incentive, which range from a low of 10 % in meatpacking to a high of 78 % in men's and boys' shirts. By comparing the last column with the sum of columns 1 and 2 we see that as the percentage paid on incentives increases, the percentage of those workers paid on individual incentives also increases, attesting indirectly to the conjecture, often found in the literature, that when individual outputs are hard to measure and assess other forms of control may take the place of output assessment (see Hechter 1987, chap. 7). The correlation between the percentage of incentive workers in an industry and the percentage of those workers being paid by individual piece or target rates is .74.

Table 2 gives a similar breakdown of incentive workers in Britain by type of incentive scheme: individual, group, and company. The distributions pertain to full-time employed male production workers in 21 manufacturing industries. The first line, which pertains to all manufacturing industries, shows that about 40 % of the incentive workers are remunerated according to group incentives and that another 8 % are remunerated according to company or plant incentives, again revealing that group incentive schemes are quite common among incentive workers. The distribution of women among the three types of incentive schemes is almost identical to that of men (see U.K. Department of Employment 1977,

p. C44). Moreover, these distributions remained more or less unchanged over a ten year period (for data from the identical 1968 survey, see Bowey and Thorpe 1986, Table 1, p. 25). As in the U.S., there are considerable differences between the industries in the use of group incentives. The classical piece-rate industries at the bottom of the table rely on individual incentives more often than the other industries. As shown in the last column, the percentage of workers paid by incentives appears to be higher in Britain than in the U.S.

(Table 2 about here)

I finally consider Sweden and Norway. Table 3, panel A, gives the distribution of incentive paid working time between group incentive schemes and individual incentive schemes, for several years in the Swedish manufacturing industries. Starting with the last column, we see that the proportion of working time paid by incentives declined from about 70 % to about 50 % between 1965 and 1980. Most striking, for working time remunerated by incentives, is the steady shift over time from individual to group incentives, the latter covering 57 % of incentive paid working time in 1965 and 78 % only fifteen years later.

Panel B gives a similar breakdown for Norway, by individual, group, and plant incentive schemes. The last column reveals that incentive schemes are less prevalent in Norway than in Sweden and that the percentage of remunerated working time paid by incentives declined from 49 to 31 % between 1976 and 1985. Among incentive workers, group and plant incentives are far more important in Norway than in Sweden. Individual incentives account for less than 20 % of the working time remunerated by incentives, about half as much as in Sweden. This may reflect the strongly egalitarian trade union and government policies in Norway (see, e.g., Esping-Andersen 1985, pp. 176, 323); group incentives are likely to generate fewer plant-level inequalities than individual incentives.

(Table 3 about here)

Although the materials presented in Tables 1–3 address no specific theoretical issues they attest to the relevance of concepts and theories addressing the operation of group incentive schemes, which were shown to be important in four Western societies, and the operation of target-rate schemes as opposed to traditional piece-rate schemes.[4]

[4]For non-Western societies, such a theory may be even more relevant. In China, group

3 Individual and Collective Rationality: Piece Versus Target Rates

In this section I show that a target-rate scheme may overcome the free-rider problems of a piece-rate scheme in the two situations described at the beginning of the paper: when only group outputs are observable and when there are team interdependencies. The two situations are discussed separately, starting with the latter. Following a four-step procedure, I first define the production technology and the preferences of workers. Then, I derive the collectively rational solution. Third, I characterize individually rational behavior under a piece-rate scheme and under a target-rate scheme. Finally, I compare the individually and collectively rational solutions, establishing whether the reward schemes can align the two interests, individual and collective.

Interdependencies Between Workers

The interdependencies considered take the following form: The output of a worker is identifiable and measurable, but it depends not only on her own effort but also on the efforts of the other workers. What worker i produces depends on how hard she works, but it also depends on how hard her coworkers work, and vice versa. In Thompson's terminology (1967, pp. 54–55), the interdependence is reciprocal. Such interdependence is found in research groups, on sports teams (Keidel 1984), and in a variety of jobs in the manufacturing industries (Stieber 1959, pp. 29, 216–217; Dore 1973, p. 113; Kornblum 1974, pp. 37–43; Frank 1985, pp. 58, 76; Gartman 1986, pp. 176, 217; Hills 1987, pp. 352, 370; Montgomery 1987, pp. 12, 29, 44).

To formalize the concept of reciprocal interdependence, let x_i and a_i denote the output and effort levels of worker i. Let a_{-i} denote the effort levels of all the other workers, where a_{-i} is a vector of dimension $n-1$ and n is the size of the work group. Worker i produces output x_i according to a function

$$x_i = f(a_i, a_{-i}) \qquad \text{for each } i, \tag{1}$$

incentives have been in almost universal use (see Walder 1986, chap. 3; and for Japan see Dore 1973, chap. 3).

where

$$f_1 \equiv \partial x_i/\partial a_i > 0, \qquad f_{11} \equiv \partial^2 x_i/\partial a_i^2 < 0, \tag{1.b}$$

$$f_2 \equiv \partial x_i/\partial a_j > 0, \qquad f_{22} \equiv \partial^2 x_i/\partial a_j^2 < 0, \qquad \text{for } j \neq i, \tag{1.c}$$

$$f_{12} \equiv \partial^2 x_i/\partial a_i \partial a_j > 0, \quad f_{122} \equiv \partial^3 x_i/\partial a_i \partial a_j^2 < 0, \quad \text{for } j \neq i, \tag{1.d}$$

$$f_1 > f_2 \qquad \text{when } a_i = a \text{ for all } i. \tag{1.e}$$

The first derivatives of $f(\cdot)$ formalize the idea that output x_i depends not only on a_i but also on a_{-i}, that is, on how hard the other workers work. The second and third derivatives rule out some forms of increasing returns to scale with respect to effort. The last condition, $f_1 > f_2$, says that worker i has more control over her own output than any single other worker has, without which the output of worker i could not be meaningfully observed and measured.

The worker's preferences are over the effort expended and the wage earned, as follows:

$$U(a_i, w_i) = P(w_i) - V(a_i), \qquad \text{with } P' > 0,\ P'' < 0,\ V' > 0,\ V'' > 0, \tag{2}$$

where w_i is the wage earned and P' and P'' denote the first and second derivatives of P (and similarly for V). Equation (2) says that preferences increase with the wage but at a decreasing rate and that preferences decrease with effort at an increasing rate. The more money one already has, the less desirable an extra dollar becomes, and the harder one already works, the harder it becomes to expend even more effort, all other things constant.

Before proceeding to the analysis proper I shall give an account of the behavioral concept underlying the analysis here. First, the model does not distinguish between individuals of different types: Workers are identical in productive capabilities and in type of position occupied. In this section, I vary only the reward schemes faced; in the following section I vary preferences and moral commitments. Since the model assumes that workers are identical, all workers facing the same reward rule will behave in the same way, choosing the same actions.[5] Second, in choosing her actions each worker will, because of the interdependencies, take into account what everyone else does. The choice of each depends on

[5] This symmetrical solution can be justified by strategic arguments; it satisfies the condition for Nash's bargaining solution (see Nash 1950). But it can also be justified by normative arguments, as in Hart (1955).

the choice of all, because the reward of each depends on the choice of all. Third, if each worker, after having chosen her action and having observed the actions of everyone else, has no incentive to change her action, then all the workers are in mutual equilibrium, known as a Nash equilibrium for noncooperative games (Moulin 1982, chap. 3). I study behavior and compare outcomes that satisfy the Nash equilibrium solution.

We can now introduce the reward scheme. An individual piece-rate scheme takes the form

$$\begin{aligned} w_i &= \beta(x_i - x_0) + w_0 && \text{if } x_i \geq x_0, \\ &= w_0 && \text{if } x_i \leq x_0, \end{aligned} \tag{3}$$

where x_0 is a quota that must be reached before the worker starts earning the piece rate, β is the piece rate (i.e., the pay per unit of output above x_0), and w_0 is the baseline wage or guaranteed minimum.[6]

A group piece-rate scheme takes the same form as (3), but the individual output x_i gets replaced with the average output per group member, namely

$$x = (1/n)\sum_{i=1}^{N} x_i. \tag{4}$$

A graphical illustration of the piece-rate scheme is given in Figure 1a.

(Figure 1 about here)

The condition for collective rationality can be derived by performing a simple thought experiment. Suppose the work group were able to decide and act as a unified body. If so, it would choose effort and hence output levels for each worker so that noone could be made better off without hurting someone else by changing effort and output levels. This amounts to finding the collectively rational solution. For both individual and group piece-rate schemes we derive the condition for collective rationality as

$$V'/P'[f_1 + (n-1)f_2] = \beta \qquad \text{for each } i. \tag{5}$$

The condition takes into account the interdependencies between the workers, saying that each worker in deciding her effort level should consider the effects

[6]Piece-rate schemes of this type are common and are described in Burawoy (1979, pp. 48–51), Edwards and Scullion (1982, pp. 181–182), and ILO (1984, p. 86).

her own actions have not only on her own output but also on the outputs of the other workers. A proof of (5) is given in Appendix A.

Having defined what would be collectively rational, we can turn to the behavior of the work group. To understand its functioning we must analyze the behavior of its constituent members.

Each member, under the egoistic preferences assumed in this section, is interested in maximizing her own preferences, taking the *actions* of the other workers as given. Under both individual and group piece-rate schemes her preferences over outcomes are as follows, ranked from most to least preferred (alternatives A to D):

A. I take it easy, everyone else works hard.
B. I work hard, everyone else works hard.
C. I take it easy, everyone else takes it easy.
D. I work hard, everyone else takes it easy.

In this formulation, each worker plays a strategic game against everyone else. In game-theoretic terminology, outcome A represents the free-rider solution, and outcome D represents the "sucker" solution (Elster 1979, p. 22).

Consider first the group piece-rate scheme. Each worker may think as follows. It is in my best interest to take it easy, because if the others work hard I will reap the benefits of their labors, and if the others take it easy my own effort will affect the group output only negligibly, and hence I will exert myself to no avail. Taking it easy is thus a dominant strategy: No matter what the others do, I am best off taking it easy.

As is often the case, what each can achieve individually, all cannot achieve simultaneously (Hirsch 1976, p. 5). If everyone acts according to the logic in the preference ordering above, effort and hence output levels will be low and, by (3), little will be earned. Individually rational behavior leads to collective irrationality: Outcome C is implemented, but everyone would have preferred outcome B. The workers face the famous Prisoners' Dilemma game. Outcome C is a so-called Nash equilibrium in dominant strategies (for definition of a dominant strategy, see Moulin 1982, pp. 14–15).

In individual piece-rate schemes, the argument runs much the same. Each worker has an incentive to take it easy, because each, through the interdependencies, will reap benefits from the efforts of the other workers. The incentive to take it easy is weaker than it is under a group piece-rate scheme, but it is still present, and free-rider problems emerge.

In formal terms, the argument is as follows. Under a group piece-rate scheme each worker chooses her effort level according to the condition

$$V'/P'[f_1/n + f_2(n-1)/n] = \beta, \tag{6}$$

whereas under an individual piece-rate scheme the condition for individual rationality is

$$V'/P'f_1 = \beta. \tag{7}$$

Proofs of (6) and (7) are given in Appendix A.

By comparing the individually rational solutions (6) and (7) to the condition for collective rationality (5), we can conclude that less effort is expended in the former. Under the group or individual piece-rate scheme, outcome C is implemented, but outcome B is collectively rational.

Further, by comparing (6) and (7), we see that workers take it less easy under the individual piece-rate scheme than under the group piece-rate scheme, because f_1 is greater than f_2 at the point where everyone works equally hard [see eq. (1.e)]. The mechanism is that the tie between individual effort and reward is blurred more under the group piece-rate scheme than under the individual piece-rate scheme.

The results of this analysis can be summarized in the following well-known proposition:

Proposition 1: Under team interdependencies, group and individual piece-rate schemes are both subject to free-rider problems. Each worker has an incentive to take it easy, hoping the others will work hard.

I turn now to the individual and group target-rate schemes, in which a high wage is paid if a production target is reached and a low wage is paid otherwise. An individual target-rate scheme, has this structure:

$$\begin{aligned} w_i &= \beta(x_i - x_0) + w_0 && \text{if } x_i \geq x_t, \text{ where } x_t > x_0, \\ &= \beta(x_i - x_0) + w_0 - c && \text{if } x_0 < x_i < x_t, \text{ where } c > 0, \\ &= w_0 - c && \text{if } x_i \leq x_0, \end{aligned} \tag{8}$$

where x_0 is a quota that must be reached before the piece rate is earned, x_t is the production target, and c is a penalty imposed if the target is not reached. If β equals zero, we have a pure target-rate scheme. The workers then face a two-tiered system: A high wage w_0 is paid if the target is reached, and a low wage $w_0 - c$ is paid otherwise. Figures 1b and 1c illustrate both cases, that is, in which β equals and differs from zero.[7]

Under a group target-rate scheme, x_i is replaced with the average output per group member, namely x as defined in (4).

It is now always possible to choose the baseline wage w_0, the penalty c, and the target x_t, so that the rank ordering of outcomes A and B in the Prisoners' Dilemma game is reversed:

B. I work hard, everyone else works hard.
A. I take it easy, everyone else works hard.
C. I take it easy, everyone else takes it easy.
D. I work hard, everyone else takes it easy.

The mechanism behind the reversal in the ranking is this. Under a group targe-rate scheme, each worker might reason as follows. If the others work hard it is in my best interest also to work hard, otherwise we might not hit the group target, and I would rather work hard and hit the target than take it easy and miss it. The central point is that a very small drop in output from, say, x_t to $x_t - \epsilon$, will cause a very large drop in the wage; under a pure target-rate scheme, wages will drop from w_0 to $w_0 - c$. Each worker has an incentive not to be the cause of a drop in output below the target (see also van de Kragt, Orbell, and Dawes 1983; on step-function payoffs, see Hardin 1982, pp. 55–61).

In an individual target-rate scheme, the argument is much the same. If the others work hard it is in my best interest also to work hard, otherwise I might not hit my individual target, and I would rather work hard and hit the target than take it easy and miss it. Therefore, when everyone else is industrious it is also in my best interest to be industrious. Everyone working hard becomes a mutually self-enforcing outcome.

Conversely, when the others take it easy, it is in my best interest also to take it easy. Under a group target-rate scheme, one hardworking member will not

[7] Crozier (1964, p. 68) describes a target-rate scheme. Organizational psychologists refer to target-rate schemes as goal setting. In experiments they tend to perform better than continuous reward schemes (see Locke 1968; Guzzo and Katzell 1987, p. 114).

enable the group to reach the target. And each worker would rather take it easy and miss the target than be industrious and still miss it. Under an individual target-rate scheme, it will still be difficult for one hardworking member to reach the target if the others take it easy, because the interdependencies cause the output of that member to be low even though she works hard.

We can conclude, then, that under a target-rate scheme, individual and collective rationality may coincide. Choosing to work hard under a target-rate scheme, though, is not a dominant strategy as choosing to take it easy was under the piece-rate scheme. It is rational to work hard only when the others also work hard. Outcome B is one equilibrium point of the game in the Nash sense, outcome A is another. The former is collectively rational, the latter is collectively irrational.[8] Whether a worker will choose to work hard will depend on whether she expects and trusts other workers also to work hard. As experiments have shown, the level of trust may be crucial for eliciting cooperation in these types of games (see Tyzka and Grzelak 1976; Dawes, McTavish and Shaklee 1977; Yamagishi and Sato 1986).

I summarize this analysis in proposition 2:

Proposition 2: A group or an individual target-rate scheme may overcome the free-rider problem of a group or individual piece-rate scheme.

In concluding the preceeding analysis, it may be instructive to compare what I will call the target-rate game of this section to two other similar and wellknown games, the Assurance Game and the Chicken Game.

In the Assurance Game, extensively studied by Amartya Sen, the ranking of alternatives A–D is identical to the ranking found in the target-rate game above (see Sen 1974; Elster 1979, p. 22). There is a crucial difference between the two games, though. In the Assurance Game, the ranking of outcome B over outcome A occurred through a *change* in the actors' *preferences*, which originally were of the Prisoners' Dilemma type, in which outcome A is preferred over outcome B (see Sen 1974). The change may, for example, have been caused by concern for coworkers arising out of repeated interactions (see, e.g., Elster 1985, p. 362). In the target-rate game the actors' preferences are unchanged. The reversal in the ranking of alternatives is produced by a *change* in the *structure of interaction*,

[8] In fact, the target-rate game possesses an infinity of Nash equilibria, in which some workers are lazy and others work hard to make up for them.

namely, in the reward rules the work group faces, from a piece-rate scheme to a target-rate scheme.

In the present analysis, the collective action problem under the target-rate scheme is solved by everyone working hard. There are other solutions. For example, some fraction of the work group may shirk their duties and the remaining workers may work a bit harder to make up for them. The workers then face the so-called Chicken Game, in which each would prefer to be among the lazy (see Taylor 1987, chap. 2). But if the choice is between (a) taking it easy and missing the target and (b) working hard and hitting the target, each prefers the latter. The issue, for each worker, is whether there is a sufficient number (i.e., a critical mass) of workers who will work hard (Oliver, Marwell, and Teixeira 1985). Conceivably, bargaining among the workers as well as norms of fairness would then determine who gets to work hard and who gets to take it easy (for the importance of rules of fairness, see, e.g., Kerr 1983; Stark 1988). The current conceptual framework, in which all workers are assumed to be homogeneous, is ill-equipped to address these issues. Introducing heterogeneity in preferences and productive capabilities would probably allow one to predict the allocation of workers to the two groups, those who work hard and those who get to take it easy. Norms of fairness most likely also bear on the issue (see Elster 1988, chap. 5).

Only Group Outputs Observable

The case in which there are no interdependencies between workers but only the group output can be observed, differs in only two ways from the case just considered. First, there are no interdependencies to be taken into account; that is, the technology in (1) satisfies $f_2 = f_{12} = 0$. Second, individual incentive schemes are no longer feasible, since individual outputs are unobservable. We need therefore only consider the two group incentive schemes.

It is immediately clear that the argument used to compare group piece-rate and target-rate schemes under the interdependent technology can be repeated. A group piece-rate scheme will be subject to free-rider problems, whereas a group target-rate scheme may overcome these. The arguments differ in one respect only. When interdependencies are absent, each worker should, in the collectively rational solution, act as if she faced an individual piece-rate scheme; whereas when interdependencies are present, she should take into account the positive effects of her own actions on the outputs of the other workers. The structure of interdependencies should be reflected in the choice rules.

The mathematical argument is as follows. Under collective rationality each worker should choose her effort level so that

$$V'/P'f_1 = \beta, \tag{9}$$

which is identical to the choice rule under an individual piece-rate scheme (see eq. [7]). When the workers face a group piece rate the condition for individual rationality becomes

$$V'/P'(f_1/n) = \beta. \tag{10}$$

Comparing (10) and (11) reveals that too little effort is expended under a group piece-rate scheme, since the denominator in (11) is divided by n: Each worker attempts to get a free ride. A proof of (10) and (11) is given in Appendix A.

As a corollary, one can also show that the larger the group, the less effort it becomes individually rational to expend under the group piece-rate scheme, because the larger the group, the less effect one's effort has on the group output and hence on the wage.[9] This is formally seen by taking the second derivative of the reward rule (3) with respect to effort a_i and the group size n, yielding

$$\partial^2 w_i/\partial a_i \partial n = -f\beta/n^2 < 0. \tag{11}$$

This says that the effect of increased effort on one's wage decreases with the group size (a corollary made famous by Olson 1965, pp. 28, 35). The corollary will in general not hold when there are interdependencies; hence, the group size need then not impede collective action (a proof is given in Petersen 1987, Appendix 4B; see also Oliver and Marwell 1988).

When a group target-rate scheme is used, in contrast, individual and collective rationality may coincide, the mechanism being the same as in the case of interdependencies.[10]

[9] For some, albeit limited, empirical evidence on this point, see Marriott (1949, 1951), Campbell (1952), Shimmin (1955), Buck (1957), Edwards and Heery (1985, p. 362, n. 10). See also the experimental literature (e.g., Harkins, Latane, and Williams 1980).

[10] One may further show that the size of the group under a target-rate scheme does not influence the decision to work hard or to be lazy, at least not in the formal statement of the problem. If the others work hard, it is in my best interest also to work hard, whereas if the others take it easy, it is in my best interest also to take it easy, irrespective of the group size (see also Oliver and Marwell 1988).

Again, the problem of collective irrationality may be overcome by an appropriate target-rate scheme. This scheme may operate as an alternative to the solution sketched by Stinchcombe and Harris (1969), in which a supervisor keeps free riders in line. The target-rate scheme may align individual and collective interests, thereby leading to systems rationality. Under a group piece-rate scheme, the two interests, individual and collective, diverge, and systems irrationality or malfunctioning ensues.

Discussion of the Nash Equilibrium Concept

Throughout the preceeding analysis I have relied extensively on the so-called Nash equilibrium concept for noncooperative games, which is as follows: If each worker, having chosen her own action and having observed the actions of everyone else, has no incentive to change her action, then all the workers are in mutual equilibrium. Each person's choice is the best possible response to the actions of everyone else.

The Nash equilibrium concept suffers from a wellknown drawback. For worker i to choose her Nash strategy, she must first know the actions of the other workers, but each of the latter cannot choose their Nash strategies before they know the action of worker i. An endless circularity ensues: Noone can act before she knows what all the others have done. The concept has nevertheless proved useful, and two alternative justifications have been proposed. The first relies on a dynamic specification of the game, in which the Nash equilibrium is seen as a stationary point towards which successive moves converge, an avenue utilized by Przeworski (1985, pp. 185–200); for technical details see Moulin (1982, pp. 115–136).

In the second justification, the Nash equilibrium emerges as the solution to a cooperative game. The workers get together before choosing their effort levels and communicate their intentions. Through this preplay communication each can promise or commit herself to play the collectively rational Nash strategy, provided the others also do so. If everyone sticks to their promise, noone will have regrets when the game is over (under the target-rate scheme). The importance of commmunication for eliciting cooperation in Assurance-type games has been demonstrated in several experiments (see, e.g., Dawes, McTavish, and Shaklee 1977; van de Kragt, Orbell, and Dawes 1983; Bornstein and Rapoport 1988).

The justification of the Nash equilibrium in terms of preplay communication seems reasonable in the present context. Workers may get together, say, each morning at coffee break and agree upon the efforts to be expended by each member, thereby facilitating the collectively rational outcome. Before starting the workday, the workers face a coordination game, which can be resolved through such preplay communication. Working hard may become a convention, which it is individually rational to abide by, provided the others also do so (see Lewis 1969, chap. 1; Leibenstein 1987, chap. 7). The first justification, in terms of a dynamic adjustment process, seems less relevant for the current purpose. A trial and error process in which each worker silently chooses her action, observes the actions of everyone else, then chooses a new action, and so on until the process converges, appears artificial in a context in which direct cooperation through communication is possible.

4 Alternative Solutions to the Free-Rider Problem

The specification of the social makeup of the work group has so far been simple: Each worker, being egoistically rational, cares only about her own effort and wages. In this section, I describe the work group in richer and more realistic terms, introducing three alternative or additional mechanisms that may alleviate the free-rider problem: namely, social rewards, altruistic preferences or sympathy, and moral commitment. The central feature of these mechanisms, in contrast to those treated up to this point, is that they pertain to relationships between workers, not to the relationship between management and the collective of workers.

There are of course other ways in which the description of the work group can be made more realistic. In particular, one may choose to drop the assumption of individual rationality, either the egoistic or the altruistic kind. Instead, one may introduce cognitive distortions—for example, of the type unraveled by experimental psychologists (see, e.g., Tversky and Kahneman 1974)—which may prevent actors from choosing rationally. However, in the present context I believe that cognitive distortions are relatively unimportant, though they are important elsewhere. The reward schemes discussed are simple and can be readily understood by workers, as reported in several ethnographic accounts and as often claimed in the managerial literature (see Edwards and Scullion 1982, pp.

181–182; Aft 1985, pp. 241, 247). The assumption of individual rationality will therefore be retained.[11]

Social Rewards

The crowning achievement of industrial sociology has been to document how various informal social rewards within work groups operate alongside and modify the functioning of material reward structures (for post-World War II research, see Roy 1953; Whyte 1955; Burawoy 1979; Edwards and Scullion 1982, chap. 7; Edwards 1986, chap. 6).

From the perspective of the workers, social rewards and punishments— such as praise and inclusion and exclusion from social groups—can be understood as an addition to or a second element of the reward structure. It now consists of two parts: (a) the material rewards, pertaining to the relationship between management and workers, and (b) the social rewards, pertaining to the relationships between workers. Social rewards can then be analyzed with the same formal apparatus as material rewards (see Pencavel 1977, pp. 239–241), even though their meanings differ.

For social rewards and sanctions to be feasible, workers must be able to observe the actions of each other; otherwise, there are no observables upon which to base sanctions. This point was convincingly illustrated by Edwards and Scullion (1982, p. 182). They report that group piece-rate systems work poorly when workers operate in isolation and hence social sanctions againts shirkers are infeasible. When social pressures can be exerted, such systems work better (see also Gartman 1986, p. 217; Walder 1986, pp. 208, 211).

The extent to which social rewards may solve free-rider problems depends on their strengths and on how the workers weigh them relative to the material rewards. The evidence provided by industrial sociologists is that social rewards can be quite important in regulating behavior. In the particular and wellknown case of quota restriction, social sanctions keep free riders (that is, rate busters) in line. The crucial point is that it may be individually rational to produce above the quota set by the collective of workers, but if everyone does so, the piece rate is likely to be adjusted downwards and hence everyone will be worse

[11]The picture could also be complicated by taking into account factors often discussed in the organizational psychology literature, such as the need for affiliation, group membership, and so on (see Schein 1980, chap. 9). While I do not dispute the relevance of these factors, I do not consider them in the present analysis.

off (see, e.g., Whyte 1955, pp. 39–49; Burawoy 1979, p. 86; Schatz 1983, p. 43). Although the social rewards discussed in this literature curtail rate busting, there is also evidence that they may induce effort rather than restrict it, as in group-based reward systems (see Edwards and Scullion 1982, p. 182; Dessler 1984, p. 377).

Altruistic Preferences

A second mechanism that may alleviate free-rider problems is so-called altruistic preferences. It seems obvious that actors in general care about other actors and that workers in particular care about coworkers (see, e.g., Margolis [1982, chap. 4]; for work groups see the poignant narrative in Whyte [1955, p. 14]). Formally, altruistic preferences (or in Sen's [1974] terminology other-regarding preferences) can be incorporated into the argument by letting the preferences of each worker depend not only on her own actions and rewards but also on those of her coworkers, as follows for worker i (see, e.g., Taylor 1987, pp. 111–112):

$$U^i = U[w_i; a_i; w_{-i}; a_{-i}], \tag{12}$$

with

$$\begin{aligned}
&U_1 \equiv \partial U/\partial w_i > 0, && U_2 \equiv \partial U/\partial a_i < 0, && \\
&U_{11} \equiv \partial^2 U/\partial w_i^2 < 0, && U_{22} \equiv \partial^2 U/\partial a_i^2 < 0, && \\
&U_3 \equiv \partial U/\partial w_j > 0, && U_4 \equiv \partial U/\partial a_j < 0, && \text{for } j \neq i, \\
&U_{33} \equiv \partial^2 U/\partial w_j^2 < 0, && U_{44} \equiv \partial^2 U/\partial a_j^2 < 0, && \text{for } j \neq i,
\end{aligned}$$

where U_1, U_{11}, U_2, and U_{22} have the same interpretations as P', P'', V', and V'' in equation (2) of Section 3, and U_3 and U_4 indicate that worker i cares about the other workers; that is, she likes them to take it easy and earn a lot, given her own effort and earnings. w_{-i} denotes the vector of wages for all the other workers. The second derivatives rule out some increasing returns to scale in the altruistic preferences, thereby ensuring a solution to the problem and avoiding, metaphorically, a situation in which hugging leads to more hugging, which again leads to even more hugging, and so on without end. The assumption that U_3 and U_4 are the same for all $j \neq i$ means that each worker treats each of the other workers identically. Her sympathy towards others is impartial.

Contrary to widely held beliefs, altruistic preferences provide no automatic remedy to free-rider problems, as demonstrated below. The important point is that not only does individually rational behavior differ under egoistic and altruistic preferences, but the content of collective rationality differs. Therefore, the two modes of rationality may still diverge. The individually rational solution under altruistic preferences should be compared to the collectively rational solution under altruistic preferences, not to the collectively rational solution under egoistic preferences.

For simplicity, but with no loss in generality of the conclusions, I consider the case in which there are no technological interdependencies. Under altruistic preferences and a group piece-rate scheme, the condition for collective rationality is

$$-[U_2 + (n-1)U_4]/(U_1 + U_3)f_1 = \beta, \tag{13}$$

whereas the condition for individual rationality is

$$-n\,U_2/(U_1+U_3)f_1 = \beta. \tag{14}$$

Comparison of (14) and (15) reveals that the two modes of rationality coincide only if each actor puts as much weight on the welfare of the other actors as she puts on her own, that is, when $U_2{=}U_4$ and $U_1{=}U_3$, which corresponds to a utilitarian moral code. I state this as a proposition:

Proposition 3: Only when each actor cares as much about others as she cares about herself will altruism align individual and collective interests under a group piece-rate scheme.

I prove equations (14) and (15), from which the proposition is derived, in Appendix B. I present a verbal outline below.

Consider first the case in which each worker puts more weight on her own effort and rewards than on her coworkers', that is, $U_2 < U_4$ and $U_1 > U_3$. Each worker then has an incentive to take it easy and let the others work hard. The incentive is weaker than it is under egoistic preferences, but the nature of collective rationality now also requires workers to expend more effort than they spend under egoistic preferences. The opposite case occurs when each worker cares more about her coworkers' efforts and rewards than about her own. Then, each worker ends up spending more effort than is collectively rational.

Everyone can be made better off if everyone relaxes more. Only when there is no distinction between her coworkers' needs and her own needs, will individual and collective rationality coincide. This occurs when $U_2 = U_4$ and $U_1 = U_3$. The absence of a conflict between the individual's needs and her coworkers' needs is caused by the structure of the workers' preferences, not by the structure of interaction, as in the case of the target-rate scheme.[12]

Experience tells us that people tend to favor their own interests over others' interest. As Weber ([1922] 1978, p. 203) stated: "It is of course true that economic action which is oriented on purely ideological grounds to the interests of others does exist. But it is even more certain that the mass of men do not act in this way, and it is an induction from experience that they cannot do so and never will." We are unfortunately forced to conclude that free-rider problems are also likely to emerge under altruistic preferences.

Moral Commitment

Altruism as analyzed above has often been interpreted as a sophisticated form of egoism or enlightened self-love that arises out of sympathy for other actors (see, e.g., Sen 1977; Kant [1785] 1964, pp. 66, 74). The actor derives pleasure (displeasure) from the contentment (discontentment) of others (see also Becker 1976, chaps. 12 and 15). It is the conception of the *source* or *motive* of moral behavior found in utilitarianism, as proposed by Hume ([1740] 1978, pp. 499–500), where the motive of moral behavior derives from self-interest, specifically from sympathy or benevolence towards others (see, e.g., Brandt 1979, pp. 138–148).

A different form of nonselfish behavior arises not from sympathy for others but out of a sense of moral duty or commitment (Sen 1977; Etzioni 1986). Moral actions or actions generated by commitment are done because they are right, not because they cause personal displeasure or remorse if not done. In moral philosophy, this is known as Kantianism.[13]

[12] Putting equal weight on everyone's preferences is taking what Harsanyi (1977, Sect. 4.1, p. 48) calls the moral point of view. An extended discussion follows below. Determining whose actions and rewards are to be given the most weight is sometimes referred to as the problem of dominant loyalties (see Harsanyi 1977, Sects. 2.3, 4.1–4.3). Elster (1979, pp. 22, 146; 1985, pp. 361–365) discusses how altruistic preferences may arise from repeated interactions.

[13] Habermas (1983, pp. 76–77) has developed a moral theory that mixes utilitarian and Kantian ideas. In his theory, as in utilitarianism, the motive of moral behavior is self-interest. In opposition to utilitarianism, the self-interest is of the egoistic kind. The rules of moral behavior are, however, distinctly Kantian. They are based on generalization arguments: Moral

In work situations, commitments, or less abstractly, attitudes towards work that supersede pure self-interest are undoubtedly present. Examples are many, but a work ethic that promotes the idea that one should carry one's part of the common load is probably one of the more important.

Of particular interest are commitments in the form of a Kantian Categorical Imperative: "Act only on that maxim through which you can at the same time will that it should become a universal law" (Kant [1785] 1964, p. 88). Under a group piece-rate scheme each worker, given the egoistic preferences, prefers alternative A: I take it easy, everyone else works hard. But this preference cannot be willed into a universal law, since each worker prefers that everyone else works hard. Thus, each worker should decide to work hard herself, because that is the only maxim that would be acceptable as a universal law. Therefore, if everyone acts according to a Categorical Imperative, alternative B is implemented and the free-rider problem is solved.

A restricted version of the imperative, which in some situations is socially superior (see Hardin 1980, pp. 585–586; Elster 1985, p. 364), is a so-called Conditional Imperative: Act according to the maxim through which you can at the same time will that it should become a universal law, provided everyone else also acts according to the maxim. Thus a worker might think, I will work hard if my coworkers also work hard. This is the conditional preference for cooperation which was encountered in the Assurance Game discussed in Section 3.[14]

If the hallmark of industrial sociology is to have documented the existence of informal norms and social rewards at the workplace, the hallmark of theoretical sociology, in opposition to theoretical economics, is to insist on the importance of moral commitments and of internalized norms in regulating behavior, as stated by Parsons (1937, pp. 85–125).[15]

acts are the only acts that one could rationally wish everyone to do.

[14] Hart (1955, pp. 461-462) has discussed this particular form of morality, in which one feels a moral obligation to restrict one's behavior when others with whom one is engaged in a cooperative venture restrict their behaviors correspondingly.

[15] Under Kant's definition, actions dictated by internalized norms, would not count as moral, even though they may be good. They fail Kant's definition because they are performed out of inclination (see Kant [1785] 1964, pp. 65–66). In Kant's definition, a moral act is performed out of a sense of duty, following from rational deliberation. Parsons' point of view is closer to the Aristotelean view, currently known as virtue ethics, in which habituation, internalization, and socialization, as opposed to rational deliberation, are the sources of the moral person and moral behavior (see, e.g., Williams 1985, chap. 3).

Assessment of the Alternative Mechanisms

As I have attempted to show in this section, free-rider problems can be overcome by alternative mechanisms, namely, social rewards, altruistic preferences, and moral commitment. The success of the two first mechanisms in solving free-rider problems depends on their strength, and no firm conclusions can be drawn. Empirical evidence suggests that social rewards can be quite effective. The last mechanism, moral commitment, can solve free-rider problems if everyone acts according to the moral code. The scant empirical evidence on moral commitment in factories indicates that they may be quite fragile compared with material and social rewards, as was apparent in China in the years 1958–1959 and 1966–1979 (see Walder 1986, chaps. 3–4; but for a contrary view, cf. Riskin 1974).

In most situations, the alternative mechanisms operate alongside the material reward systems. The success of a group incentive scheme may then depend on and be reinforced by social rewards. Likewise, social reward systems may develop when group-based reward systems are introduced. I will discuss this further in the conclusion.

Table 4 summarizes the results of this and of the preceeding section.

(Table 4 about here)

5 Data and Methods

I use data from two Industry Wage Surveys conducted by the U.S. Bureau of Labor Statistics, in the woodhousehold furniture and the non-ferrous foundries industries (see U.S. Department of Labor 1976*b*, 1977*d*). These industries have codes 2511 and 336 respectively, as defined in the *Standard Industrial Classification Manual* (see U.S. Executive Office of the President 1987). The survey of the woodhousehold furniture was conducted in November 1974; the survey of the non-ferrous foundries industry was conducted in May 1975. The populations for the surveys and the sampling from the populations are described in U.S. Department of Labor (1976*b*, p. 51; 1977*d*, p. 39). Within each industry a sample of approximately 350 establishments was drawn. For each establishment, information was obtained both on establishment characteristics and on most of the production workers in the establishment, from establishment records.

Information on the establishment characteristics includes the following: size (i.e., number of employees); region and area within region; whether it is located in a standard metropolitan statistical area (henceforth SMSA); union status and if unionized the name of the union organizing the majority of the production workers; production technology and major products; the number of employees remunerated by each of ten different payment schemes; and provision of fringe benefits. For each employee surveyed, information was obtained on sex, occupation (an industry-specific code), method of wage payment (incentives or time-rated), and hourly earnings. No information is available on age, experience, or education. However, the occupational classification is unusually detailed, corresponding to nine digits in the *Dictionary of Occupational Titles* (see U.S. Department of Labor 1977*g*). Within an occupation there is probably little variation in productivity-related characteristics such as education. Hence, the omitted variable bias resulting from not controlling for education is likely to be small.[16]

The wage data pertain to straight-time hourly wages, excluding premium pay for overtime and work on weekends, holidays, and late shifts. Thus, we do not conflate pay earned on regular hours with pay earned on overtime and irregular hours. Nonproduction bonuses, such as year-end bonuses, are excluded. The wages of workers paid according to incentives were usually obtained as average hourly wages over a period of two to four weeks (see U.S. Department of Labor 1976*b*, p. 52; 1977*d*, p. 40).

Unfortunately, the data on the incentive schemes are less complete than desirable. For each worker, we know whether he or she is paid by the hour or by results, but for the latter we do not always know the type of incentive scheme used. However, we know the distribution of an establishment's employees among the different types of incentive schemes; that is, we know the number of workers paid according to individual piece rates, individual target rates, and so on.

Therefore, I selected the subsample of establishments in which only one type of output-related payment scheme was in use. For those establishments, we know the incentive scheme of each worker. We can therefore compare the effects of different incentive schemes across establishments, but can make no intra-establishment comparisons.

[16] In the case of salespersons in department stores, some limited evidence exists that supports such a claim. Petersen (1989, Table 2) shows that human capital variables have almost no effects on the wage earned once one controls for a set of detailed occupational dummy variables.

I stress that establishments were selected on the basis of an independent variable, the payment scheme. Thus, there should be no problem of observer sample-selection biases (as discussed in Manski and McFadden 1981, p. 10).

The main method used in the statistical analysis is linear regression analysis of the logarithm of the hourly wage rate on establishment and individual characteristics. I chose the semilogarithmic form of the wage equation for its ease of interpretation; a coefficient is interpretable (roughly) as the percentage change in the mean of the dependent variable resulting from a unit increase in the associated independent variable. Note that we need therefore not consider the general wage levels prevailing in 1974 and 1975 to make social sense of the results (for an extended discussion, see Petersen 1989, Sect. 3).

Specification of Hypotheses for the Empirical Analysis

The analysis in Section 3 and the two propositions presented there are about productivity under different types of payment schemes. Productivity is not measured in the data sets used here, as it rarely is. However, we have a measure of another variable, wages, that may be correlated with productivity. In the following I justify my assumption that wages and productivity are correlated. The issues raised in Section 4 will not be pursued in the empirical analysis, except for by a comment on social rewards in the first part of Section 6.

Consider wages at the establishment or work-group level. For workers paid by results, wages are clearly a function of productivity. The more that is produced, the more that is earned. Under output-related payment schemes, high-productivity workers on the average earn more than low-productivity workers within the same establishment.

The question now becomes, Does this relationship between productivity and wages, which holds at the establishment level, also hold across establishments? Or phrased this way, Do high-productivity workers in one establishment earn more than low-productivity workers in another establishment? This relationship need only hold for the incentive-rated workers across establishments within the same industry. We need not assume a similar relationship across industries nor, for time-rated workers, across establishments within an industry. In Britain, there is strong evidence of such a relationship. Ball and Skoech (1981) studied interplant differences in wages and productivity in 15 British industries and reported a very strong relationship between the two in almost every industry.

Less research has been conducted on this topic in the U.S., but the evidence that exists confirms such a relationship (see Levine 1988).

The assumption of a relationship between productivity and wages for incentive-rated workers across establishments is crucial to the empirical analysis that follows. Although the required assumption is hard to *verify*, it is not unrealistic. The statistical tests reported are performed separately for each of two industries, woodhousehold furniture and non-ferrous foundries. The industries are narrowly defined; they correspond to four (2511) and three (336) digits in the *Standard Industrial Classification Manual* (see U.S. Executive Office of the President 1987, pp. 114, 180). Thus, there should be considerable homogeneity between establishments within the same industry.

Furthermore, it would be peculiar indeed if in the empirical analysis, where we control for as many as 64 variables, we were to find the relationship between the payment scheme and wages that follows from Propositions 1 and 2, if there were no relationship between productivity and wages across establishments among incentive-rated workers. The hypotheses are quite specific and their rationales are clear.

Assume now that there is a relationship between wages and productivity among incentive-rated workers across establishments within the same narrowly defined industry. Propositions 1 and 2 taken together suggest the following two hypotheses for the empirical analysis.

Hypothesis 1: Group target-rate workers will on the average earn more per hour than group piece-rate workers, since the latter are subject to free-rider problems.

Hypothesis 2: Under team interdependencies, individual target-rate workers will on the average earn more per hour than individual piece-rate workers, since the latter are subject to free-rider problems.

Note that Hypothesis 1 is correct even if team interdependencies are not present, whereas Hypothesis 2 holds only in their presence.

6 Empirical Analysis

Univariate Analysis

Descriptive statistics for the two industries—woodhousehold furniture and non-ferrous foundries—are presented in Table 5. The table gives the average hourly wages of incentive and time-rated workers by the type of incentive scheme used in their establishments: individual piece rates, individual target rates, group piece rates, and group target rates. Panel A, pertaining to the woodhousehold furniture industry, shows that group target-rate workers on the average earn 50 % more per hour than group piece-rate workers and that individual target-rate workers earn about 8 % more per hour than individual piece-rate workers. Of the four groups of incentive workers in panel A, group piece-rate workers earn the lowest average wages. Of the nine groups of workers in panel A, only two other groups earn lower average wages than group piece-rate workers.

Furthermore, it is important to note that establishments using group target-rate schemes are not necessarily high-paying establishments. Only the workers paid a group target rate earn high wages in those establishments, whereas the time-rated workers in the same establishments earn lower wages than any other group of workers in the table. Conversely, establishments using group piece-rate schemes are not necessarily low-paying establishments. Only the workers paid on group piece rates earn low wages in those establishments, whereas the time-rated workers in the same establishments earn higher wages than any other group of time-rated workers in the table. Therefore, it appears that the effect of being paid a group target rate is not primarily the effect of working in establishments that on the average pay high wages. It appears to be the effect of being remunerated by a group target rate. These considerations do not apply when we compare establishments using individual piece-rate schemes and individual target-rate schemes.

(Table 5 about here)

Panel B of Table 5, pertaining to the non-ferrous foundries industry, reveals a similar pattern. Group target-rate workers on the average earn more per hour than group piece-rate workers, but only about 14 % more. Individual target-rate workers also earn more per hour than individual piece-rate workers, about 6 % more. The effects of the target-rate schemes are weaker than in the woodhousehold furniture industry, but they are in the predicted directions. Group piece-rate workers on the average earn less than any other group of workers in the table, even less than those paid by the hour. In terms of earnings, being paid by the hour is better than being paid by a group piece rate.

In the non-ferrous foundries industry, in contrast to the woodhousehold furniture industry, there is a correlation between working in an establishment using group target rates and the general level of pay in the establishment, irrespective of the method of pay under which the employee works. Still, there appears to be an independent effect of working under a group target-rate scheme as opposed to a group piece-rate scheme. The difference in hourly pay between the two schemes is about 14 %. The difference in hourly pay between time-rated workers working in establishments using group target rates and time-rated workers working in establishments using group piece rates is only 5 %. Somewhat informally, we can therefore say that 5 % of the pay difference between group target-rate workers and group piece-rate workers is due to the fact that the former work in high-paying establishments (i.e., the group target-rate workers would have received 5 % more just because they work in those establishments). The remaining 9 % of the pay difference is, according to this line of reasoning, due to the different payment schemes. The same considerations do not hold when we compare establishments using individual target-rate schemes and individual piece-rate schemes.

In conclusion, the data support the hypotheses of Section 3. Under the interpretations developed there, free-rider problems are ubiquitous under group piece-rate schemes but may be overcome under a group target-rate scheme. Similarly, when there are interdependencies between workers but individual outputs are observable, individual target-rate schemes may overcome the free-rider problems of individual piece-rate schemes. The data, so far, support both theoretical conjectures: Group target-rate workers on the average earn more than group piece-rate workers and individual target-rate workers on the average earn more than individual piece-rate workers.

In the univariate analysis—and as we will see in the multivariate analysis—it appears that free-rider problems are more severe in the woodhousehold furniture than in the non-ferrous foundries industry. The wage difference between group piece-rate workers and group target-rate workers is much bigger in the former industry.

There is one piece of evidence, albeit circumstantial, that may explain this difference. Before submitting the evidence I state the theoretical principle making the evidence interesting. It is widely believed that the more cohesive a social group is, the more able it is to solve free-rider problems (Dion 1973), because social rewards and moral commitment have a higher probability of succeeding in cohesive groups. It is also commonly believed that the cohesiveness of a group may be a decreasing function of the turnover rate of its members: The lower the turnover rate, the higher the cohesiveness (see, e.g., Thernstrom 1970).[17]

Now to the evidence. In the months of and the months preceding the surveys in the two industries, the turnover rate was almost 100 % higher in the woodhousehold furniture industry than in the non-ferrous foundries industry, respectively 7.8 % and 4.1 % per month in the months of the interviews. Furthermore, the voluntary quit rate was almost 400 % higher in the woodhousehold furniture industry than in the non-ferrous foundries industry, respectively 3.8 % and 1.0 % per month in the months of the interviews (see *Employment and Earnings* 1975*a*, p. 122; 1975*b*, p. 122; 1975*c*, p. 124; 1975*d*, p. 114). Although these turnover rates cannot be tied to individual establishments, they nevertheless indicate that the woodhousehold furniture industry is less cohesive than the non-ferrous foundries industry. This in turn may explain why the woodhousehold furniture industry appears to have greater free-rider problems.

Regression Analysis

The objective of the regression analysis is to assess whether the differences in average pay between the four payment schemes hold when control variables are introduced. The control variables are sex, occupation, establishment size, presence of a union, SMSA status, production technology (only in non-ferrous foundries), major products (only in woodhousehold furniture), and, of course, the payment scheme. All variables are entered as sets of dummy variables: 63 dummy variables are used for the woodhousehold furniture industry, and 64 are used for the non-ferrous foundries industry.

The analysis focuses on the effects of the four output-related payment schemes. The other variables are for the present purpose not of substantive interest.

[17] This claim has a long history, starting, probably with Tocqueville ([1835] 1969, p. 557) and Marx ([1852] 1979, p. 111).

The theory developed speaks to the effects of the payment scheme, not to the effects of the other variables. For the sake of completeness, I report the estimates of the effects of the control variables, but I do not comment on these effects.

In each industry, I include only workers who are paid according to one of the four incentive schemes: individual piece rates, individual target rates, group piece rates, and group target rates. I report three different specifications of the wage equation. The first specification excludes the dummy variables for occupation, technology, and major products. The second specification excludes the dummy variables for occupation but includes the variables for technology and major products. The third specification includes all the variables.

Table 6 gives the results for the woodhousehold furniture industry. In all three specifications of the wage equation we see that the group target-rate workers on the average earn about 20 % more per hour than the group piece-rate workers, confirming the predictions of Hypothesis 1.[18] Individual target-rate and individual piece-rate workers earn more or less the same in all three specifications. The difference between the two latter groups becomes negligible—of about 0 to 3 % in hourly wages—when the additional variables in Table 6 are controlled for, but it is still in the predicted direction. The proportions of explained variance are high, ranging from .44 to .64.

There is a good reason for giving most weight to the results in the first column of Table 6, the results that are most consistent with the theory and that replicate the univariate differences in panel A of Table 5. The regressions are based on the wages of 5,573 workers (see the note in Table 6). We estimate 20, 32, and 64 effect parameters in the first, second, and third columns respectively. Formally there is therefore no problem with the degrees of freedom. However, these 5,573 workers are employed in only 77 establishments (see the note in Table 6). The group incentive workers are employed in only 28 establishments. There is much less variation in hourly wages within establishment than between establishments. Hence, in the third column we end up fitting a regression equation with 64 parameters to the data on wages from 77 establishments. With limited intra-establishment variation in wages, we practically have as many explanations (i.e., 64) as points of data to explain (i.e., 77), yielding potentially quite unreliable

[18]The effect of 18 % is computed as follows, as are the percentage differences reported below. The point estimates, for example, from column 2 of Table 6, for being paid on a group target-rate scheme and a group piece-rate scheme are $-.13$ and $-.30$ respectively. The relative difference between the two groups is therefore $\exp[-.13-(-).30]-1=.18$.

results. We face a problem of overfitting the data. Therefore, the results in the second and third columns are less reliable than those in the first. For that reason, we are well advised to put more confidence in the results from the first column. These square with the theory and with the univariate differences in panel A of Table 5.

(Table 6 about here)

Table 7 gives the corresponding results for the non-ferrous foundries industry. As in the woodhousehold furniture industry, in all three specifications of the wage equation, the group target-rate workers on average earn about 16–17 % more per hour than the group piece-rate workers. Again, the results are consistent with Hypothesis 1 of Section 3. Also, as in the woodhousehold furniture industry, the difference in hourly pay between individual target-rate and individual piece-rate workers is negligible. In column 1, the difference is in the predicted direction, but it is only 3/4 of a percent. In the two other specifications, individual target-rate workers earn less than individual piece-rate workers, but the differences are small, about 2–4 % in hourly pay. As in the woodhousehold furniture industry, the proportions of explained variance are high, ranging from .34 to .50.

Again, for the same reason as in Table 6, we are well advised to put more confidence in the results from the first column of Table 7. These results are most consistent with the theory and replicate the pattern of univariate differences found in panel B of Table 5. Specifically, once the control variables in the first column are introduced, individual target-rate workers on the average do not earn less than individual piece-rate workers, whereas according to the second and third columns, they earn less.

(Table 7 about here)

We can sum up the results of the regression analysis as follows. The data support the theory's predictions about the operation of the two group incentive schemes. Group target-rate workers on the average earn more than group piece-rate workers. The theory asserts that group piece-rate schemes are subject to free-rider problems, whereas group target-rate schemes may alleviate these, thereby leading to higher effort levels, higher output, and hence higher wages. Substantial differences in hourly pay between the two groups of workers were found both in the woodhousehold furniture industry and in the non-ferrous foundries industry.

The prediction (from Hypothesis 2) about the difference in hourly pay between individual piece-rate schemes and individual target-rate schemes was not borne out by the data. The difference in hourly pay between the two groups of workers is negligible, once the variables in Tables 6 and 7 are controlled for. It is important to note that the prediction was obtained under the condition of team interdependencies between the workers. Our data cannot tell us as to the extent to which this condition is satisfied. Our confidence in the theoretical implications of the results speaking to Hypothesis 2 is therefore less than our confidence in the implications of the results speaking to Hypothesis 1. The theory's prediction about group incentives holds irrespective of whether or not team interdependencies are present.

7 Concluding Remarks

At the most general level, the central conceptual issue addressed in the paper is this: How can actors construct social institutions so as to align individual and collective interests, thereby ensuring efficient systems functioning?

In the specific substantive context considered here—that of work-groups—the central task of the institutions was to solve the free-rider problems that individually rational behavior generates. Several institutions were considered.

The first institution considered relies on authority relationships, in which a supervisor keeps free riders in line (e.g., Stinchcombe and Harris 1969; Alchian and Demsetz 1972). The second type of institution discussed relies on market-type relationships. When only group outputs can be observed, group target-rate schemes were shown to provide a potential solution to the free-rider problems that plague group piece-rate schemes. When there are team interdependencies but individual outputs can be observed, individual target-rate schemes may alleviate the free-rider problems of individual piece-rate schemes.

Finally, I discussed three work-group internal mechanisms. First, I considered how social rewards that operate at the work-group level may alleviate free-rider problems under a group piece-rate scheme, as evidenced in Edwards and Scullion (1982, pp. 181–182) and Gartman (1986, p. 217). Then, I considered the two invisible institutions: altruistic preferences and moral commitment.

Altruistic preferences may alleviate free-rider problems in so far as actors care not only about their own welfare, but also about the welfare of others. Moral commitment may mitigate free-rider problems in so far as actors behave according to moral standards—for example, the standard dictated by a Kantian Categorical Imperative. In the present context, the imperative translates into the following rule: Do not take a free ride, because you cannot rationally want others to take a free ride.

In the empirical analysis, I compared several market-type relationships. In both univariate and multivariate analyses, I showed that group target-rate schemes on the average lead to higher wages than group piece-rate schemes. The data, therefore, as far as the operation of group incentive schemes goes, are consistent with the interpretation, developed in Section 3, that group piece-rate schemes are subject to free-rider problems, whereas group target-rate schemes may overcome these. In the multivariate analysis, I found no discernable difference in average pay between individual target-rate workers and individual piece-rate workers. However, in the univariate analysis, I found that individual target-rate workers earned about 6 and 8 % more in hourly pay than individual piece-rate workers, as predicted by the theory.

In most work-group situations, the institutions considered operate side by side. One may ask, Which institution provides the most efficient solution to the free-rider problem and which is preferable? From the viewpoint of workers, market-type relationships seem preferable to authority relationships. The former facilitate autonomy at the work-group level, a feature workers might find desirable. Additionally, market-type relationships make remuneration of supervisors superfluous, which on economic grounds may be desirable.

The importance of social rewards in regulating work-group behavior is documented in several impressive studies by industrial sociologists. In the present context, the extent to which social rewards can solve the free-rider problems depends on the strength of the rewards.

The existence of such invisible social institutions as altruistic preferences and moral commitment is difficult to dispute. However, the scant empirical evidence on their operation seems to attest that though potentially powerful, these institutions are often quite fragile. This fragility was most dramatically evident in the Chinese experience in the years 1967–1977, when material incentives were abandoned in favor of moral and political incentives, apparently with disastrous effects. The invisible social institutions rely, for their operation, on actors internally monitoring or policing themselves. The actors' willingness, ability, and compulsion to do so may stem from socialization and group-specific or more general moral codes. When strong and stable, the invisible social institutions are by far the most efficient and desirable. They waste few resources and rely on complete voluntary compliance. The other institutions—authority relationships, market relationships, and social rewards—all rely on actors monitoring and policing each other, either directly or through a market-type mechanism. They waste more resources and rely less on self-imposed compliance for solving the collective dilemma in question.

Although the invisible social institution of moral commitment is more efficient from a theoretical stance, we do not know how to create it. Hence, it may represent a forlorn hope for institutional design. Even so, in a few interesting settings we do know quite a bit about how actors attempt to bring about normative internalization. Most thouroughly studied are the ethical codes of professions (e.g., Friedson 1970, chap. 5; Larson 1977, chap. 5), of craftsmen (Montgomery 1987, chap. 1), and of factory institutions in Japan (Dore 1973, chap. 8; 1987, chap. 9), China (Walder 1986, chap. 4), England, and Russia (Bendix 1956, pp. 202–211).

However, except perhaps for Walder's study, all of this research has left two central issues unsettled. First, there is little empirical evidence of the degree to which members of a profession or social group believe in and comply with the moral code (see esp. Friedson 1970, pp. 81–82). Second, when members comply, do they do so primarily because of normative internalization and moral commitment or because of social sanctions by their peers?

In Walder's (1986, pp. 143–144) study, compliance obtains because of the economic, political, and social sanctions imposed, not because of normative internalization, as some previous studies of Chinese factory politics purport (e.g., Riskin 1974). More disturbingly, Walder claims that the moral and political factory apparatus creates individuals who are extremely calculative and exhibit no true commitment. Similarly, studies of work behavior in the U.S. show that codes of behavior are enforced primarily through social sanctions, both in the factory (Roy 1953) and in clerical bureaucracies (Blau 1963, chap. 10). Our conception of the moral person, however, requires that she will abide by the ethical code even in the absence of external sanctions and indeed even if the sanctions for behaving morally are negative (see Socrates' response to Glaucon's challenge in Plato's [1963] *Republic*, esp. Bk. II).

Appendix A: Proof of Equations (5)–(7) and (10)–(11) of Section 3

Define first

$$x_{-i} = (1/n)\sum_{j\neq i} x_j, \tag{A1}$$

and the general reward rule

$$w_i = g(x_i; x_{-i}), \tag{A2}$$

where $g_1 \equiv \partial w_i/\partial x_i > 0$ and $g_2 \equiv \partial w_i/\partial x_{-i} > 0$. An individual piece-rate scheme obtains when $g_1{=}\beta$ and $g_2{=}0$, which corresponds to equation (3). A group piece-rate scheme obtains when $g_1{=}\beta/n$ and $g_2{=}\beta$, which corresponds to equation (3) with the average group output x from (4) substituted for x_i.

The condition for collective rationality under group interdependencies, assuming either an individual or a group piece-rate scheme, obtains by solving the program

$$\underset{a_i,\, a_{-i}}{\text{Maximize}}\; P\{g[f(a_i, a_{-i}); (1/n)\sum_{j\neq i} f(a_j, a_{-j})]\} - V(a_i), \tag{A3}$$

subject to the $n-1$ constraints

$$P\{g[f(a_j, a_{-j}); (1/n)\sum_{k\neq j} f(a_k, a_{-k})]\} - V(a_i) \geq U_j^* \qquad \text{for all } j\neq i, \tag{A4}$$

where the relationships in equations (1), $x_i = f(a_i, a_{-i})$, and (A1) have been used when inserting the reward rule (A2) into the preferences of equation (2), that is, into $U(w_i, a_i) = P(w_i) - V(a_i)$.

The Lagrangian for the problem is

$$\begin{aligned} L(a_i, a_{-i}) \;&=\; P\{g[f(a_i, a_{-i}); (1/n)\sum_{j\neq i} f(a_j, a_{-j})]\} - V(a_i) \\ -\sum_{j\neq i}\lambda_j \cdot &P\{g[f(a_j, a_{-j}); (1/n)\sum_{k\neq j} f(a_k, a_{-k})]\} - V(a_i) \geq U_j^* \end{aligned} \tag{A5}$$

Since we consider n symmetrical workers, we get $f_d(a_i, a_{-i}){=}f_d(a_j, a_{-j})$ for $d{=}1,2$ (i.e., the derivatives f_1 and f_2) and all i, j. The n first-order conditions for a maximum are

$$\begin{aligned} \partial L/\partial a_i \;&=\; P' \cdot [g_1 f_1 + g_2 f_2 (n-1)/n] - V' \\ &\quad -\textstyle\sum_{j\neq i}\lambda_j P' \cdot [g_1 f_2 + g_2 f_1/n + g_2 f_2 (n-2)/n] \\ &=\; 0, \end{aligned} \tag{A6}$$

$$
\begin{aligned}
\partial L/\partial a_h &= P' \cdot [g_1 f_2 + g_2 f_1/n + g_2 f_2(n-2)/n] - V' \\
&\quad + \lambda_h \cdot \{P' \cdot [g_1 f_1 + g_2 f_2(n-2)/n] - V'\} \\
&\quad - \textstyle\sum_{j \neq i,h} \lambda_j P' \cdot [g_1 f_2 + g_2 f_1/n + g_2 f_2(n-2)/n] \\
&= 0 \qquad \text{for all } h \neq i.
\end{aligned} \tag{A7}
$$

Subtracting (A5.b) from (A5.a) yields

$$\lambda_h = -1 \qquad \text{for all } h \neq i. \tag{A8}$$

Then inserting (A6) into (A5.a) yields, after some rearrangement, the condition for collective rationality as:

$$V'/P' = g_1 f_1 + g_1 f_2(n-1) + g_2 f_1(n-1)/n + g_2 f_2(n-1)^2/n \quad \text{for all } i. \tag{A9}$$

Under a group piece-rate scheme, $g_1 = \beta/n$ and $g_2 = \beta$, whereas under an individual piece-rate scheme, $g_1 = \beta$ and $g_2 = 0$. In both cases the condition for collective rationality reduces to

$$V'/P' \cdot [f_1 + f_2(n-1)] = \beta \qquad \text{for all } i, \tag{A10}$$

which proves equation (5).

Note that the formulation in (A7) allows for mixed incentives, where part of the wage depends on the group output and another part on the individual contribution (e.g., as described in Lupton 1963, pp. 104–105).

The condition for individual rationality under either a group piece-rate scheme or an individual piece-rate scheme obtains by solving the program

$$\underset{a_i}{\text{Maximize}} \; P\{g[f(a_i, a_{-i}); (1/n) \sum_{j \neq i} f(a_j, a_{-j})]\} - V(a_i) \tag{A11}$$

where worker i, in solving (A8), takes a_{-i} as given.

The solution to the program yields the condition

$$V'/P' = g_1 f_1 + g_2 f_2(n-1)/n. \tag{A12}$$

Under a group piece-rate scheme—that is, when $g_1 = \beta/n$ and $g_2 = \beta$—(A9) reduces to

$$V'/P'[f_1/n + f_2(n-1)/n] = \beta, \tag{A13}$$

while under an individual piece-rate scheme—that is, when $g_1=\beta$ and $g_2=0$—(A9) reduces to

$$V'/P'f_1 = \beta. \tag{A14}$$

Equations (A9′) and (A9′′) prove equations (6) and (7) respectively.

When there are no interdependencies between workers—that is, $f_2=0$—the condition for collective rationality under a group piece-rate scheme follows as a special case of (A7′):

$$V'/P'f_1 = \beta. \tag{A15}$$

The condition for individual rationality under a group piece-rate scheme follows as a special case of (A9′):

$$V'/P'(f_1/n) = \beta. \tag{A16}$$

Equations (A10) and (A11) prove equations (10) and (11) respectively.

Appendix B: Proof of Equations (14)–(15) of Section 4

The preferences of worker i are given by

$$U^i = U[w_i; a_i; w_{-i}; a_{-i}], \tag{B1}$$

and her wage, under a group piece-rate scheme, is

$$w_i = (\beta/n)\sum_{i=1}^{n} x_i, \tag{B2}$$

where, assuming no interdependencies,

$$x_i = f(a_i). \tag{B3}$$

Inserting (B3) into (B2) and then the resulting expression into (B1) yields her preferences under a group piece-rate scheme:

$$U^i = U[(\beta/n)f(a_i) + (\beta/n)\sum_{j\neq i} f(a_j); a_i; (\beta/n)\sum_{j=1}^{n} f(a_j); a_{-i})]. \tag{B4}$$

The condition for collective rationality obtains by solving the program

$$\underset{a_i,\ a_{-i}}{\text{Maximize}}\ U[(\beta/n)f(a_i) + (\beta/n)\sum_{j\neq i} f(a_j); a_i; (\beta/n)\sum_{j=1}^{n} f(a_j); a_{-i}],$$

subject to the $n-1$ constraints (B5)

$$U[(\beta/n)f(a_j) + (\beta/n)\sum_{j\neq k} f(a_j); a_j; (\beta/n)\sum_{k=1}^{n} f(a_k); a_{-j}] \geq U_j^* \quad \text{for all } j\neq i.$$

The Lagrangian for the problem is

$$L(a_i, a_{-i}) = U[(\beta/n)f(a_i) + (\beta/n)\sum_{j\neq i} f(a_j); a_i; (\beta/n)\sum_{j=1}^{n} f(a_j); a_{-i}]$$

(B6)

$$-\sum_{j\neq i} \lambda_j \cdot \{U[(\beta/n)f(a_j) + (\beta/n)\sum_{k\neq j} f(a_k); a_j; (\beta/n)\sum_{k=1}^{n} f(a_k); a_{-j}] - U_j^*\}$$

The n first-order conditions are

$$\begin{aligned}
\partial L/\partial a_i &= U_1(\beta/n)f_1 + U_2 + U_3(\beta/n)f_1 \\
&\quad -\sum_{j\neq i} \lambda_j \cdot [U_1(\beta/n)f_1 + U_3(\beta/n)f_1 + U_4] \\
&= 0,
\end{aligned} \tag{B7}$$

$$\begin{aligned}
\partial L/\partial a_h &= U_1(\beta/n)f_1 + U_3(\beta/n)f_1 + U_4 \\
&\quad -\lambda_h \cdot [U_1(\beta/n)f_1 + U_2 + U_3(\beta/n)f_1] \\
&\quad -\sum_{j\neq h,i} \lambda_j \cdot [U_1(\beta/n)f_1 + U_3(\beta/n)f_1 + U_4] \\
&= 0 \quad \text{for all } h \neq i.
\end{aligned} \tag{B8}$$

Subtracting (B8) from (B7) yields

$$\lambda_h = -1 \qquad \text{for all } h \neq i. \tag{B9}$$

Inserting (B9) into (B7) yields, after some rearrangement, the condition for collective rationality:

$$-[U_2 + (n-1)U_4]/(U_1 + U_3)f_1 = \beta, \tag{B10}$$

which proves equation (14).

The condition for individual rationality obtains by solving the program

$$\underset{a_i}{\text{Maximize}} \; U[(\beta/n)f(a_i) + (\beta/n)\sum_{j\neq i} f(a_j); a_i; (\beta/n)\sum_{j\neq i} f(a_j); a_{-i}], \tag{B11}$$

where worker i, in solving (B11), takes a_{-i} as given. The solution to the program yields the condition for individual rationality under a group piece-rate scheme:

$$-nU_2/(U_1 + U_3)f_1 = \beta, \tag{B12}$$

which proves equation (15).

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Table 1
Distribution (Percentages) of Production Workers Paid by Incentives by Type of Incentive Scheme in a Selection of Manufacturing Industries in the U.S., 1973–1980

	Type of Incentive Scheme					
	Individual		Group			
Industry	Piece Rate	Target Rate	Piece Rate	Target Rate	Sum	Percentage Paid by Incentives
Meatpacking	0 %	30	20	50	100 %	10 %
Corrugated & solid fiber boxes	12 %	31	12	46	101 %	25 %
Clay sewer pipes	39 %	17	39		99 %	24 %
Woodhousehold furniture	25 %	17	25	33	100 %	17 %
Candy and other confectionary	36 %	9	9	46	100 %	11 %
Brick and structural clay	44 %	6	33	17	100 %	18 %
Other pressed or blown glass	14 %	38	29	19	100 %	21 %
Ceramic wall and floor tile	31 %	22	25	22	100 %	32 %
Glass containers	9 %	55	0	36	100 %	12 %
Iron and steel foundries	50 %	15	20	15	100 %	21 %
Clay refractories	52 %	14	24	10	100 %	20 %
Motor vehicles parts	43 %	25	14	18	100 %	27 %
Non-ferrous foundries	33 %	44	5	18	100 %	18 %
Textile dyeing and finishing	50 %	30	10	10	100 %	10 %
Leather taining and finishing	65 %	16	16	2	99 %	44 %
Wool yarn and handwoven fabrics	56 %	28	8	8	100 %	25 %
Cotton and manmade fiber	93 %	3	0	4	100 %	30 %
Men's and boys' shirts	98 %	1	1	0	100 %	78 %
Men's suits and coats	99 %	1	0	0	100 %	75 %
Footwear	97 %	3	0	0	100 %	73 %
Women's hoisery	100 %	0	0	0	100 %	63 %

Note: The numbers for the 21 industries are computed from several Industry Wage Surveys conducted by the U.S. Department of Labor, Bureau of Labor Statistics, Years 1973–1980, in this order from the following sources:
1. U.S. Department of Labor (1980*a*, Table 23, p. 69).
2. U.S. Department of Labor (1977*a*, Table 15, p. 44).
3. U.S. Department of Labor (1977*b*, Table 26, p. 35).
4. U.S. Department of Labor (1981*a*, Table 32, p. 68).
5. U.S. Department of Labor (1977*c*, Table 12, p. 21).
6. U.S. Department of Labor (1982*a*, Table 19, p. 41).
7. U.S. Department of Labor (1981*b*, Table 21, p. 26).
8. U.S. Department of Labor (1977*b*, Table 26, p. 35).
9. U.S. Department of Labor (1981*b*, Table 13, p. 20).
10. U.S. Department of Labor (1981*c*, Table 29, p. 48).
11. U.S. Department of Labor (1982*a*, Table 19, p. 41).
12. U.S. Department of Labor (1976*a*, Table 22, p. 48).
13. U.S. Department of Labor (1977*d*, Table 20, p. 25).
14. U.S. Department of Labor (1977*e*, Table 28, p. 57).
15. U.S. Department of Labor (1975, Table 21, p. 26).
16. U.S. Department of Labor (1982*b*, Table 46, p. 64).
17. U.S. Department of Labor (1982*b*, Table 28, p. 47).
18. U.S. Department of Labor (1982*c*, Table 28, p. 47).
19. U.S. Department of Labor (1980*b*, Table 23, p. 64).
20. U.S. Department of Labor (1982*d*, Table 27, p. 62).
21. U.S. Department of Labor (1977*f*, Table 12, p. 17).

Table 2
Distribution (Percentages) of Incentive Workers by Type of Incentive Scheme in the United Kingdom in 1977, Full-Time Employed Manual Male Workers

Industry	Type of Incentive Scheme: Individual	Group	Company	Sum	Percentage Paid by Incentives
All manufacturing industries[a]	49 %	43	8	100 %	40 %
Coal and petroleum products	4 %	52	44	100 %	27 %
Production of Man-Made Fibers	22 %	71	6	100 %	55 %
Iron and steel (general)	30 %	67	3	100 %	68 %
Glass	32 %	53	15	100 %	73 %
Steel tubes	36 %	50	14	100 %	14 %
Textile Finishing	40 %	41	19	100 %	40 %
Packaging products and paper	42 %	44	14	100 %	51 %
Paper and board	46 %	51	3	100 %	30 %
Bacon, meat and fish products	48 %	52	0	100 %	46 %
Iron castings, etc.	48 %	45	7	100 %	56 %
Electrical engineering	48 %	40	12	100 %	33 %
Timber	53 %	30	17	100 %	48 %
Mechanical engineering	56 %	35	9	100 %	42 %
Bricks, fireclay, etc.	58 %	39	3	100 %	67 %
Furniture and upholstery	65 %	25	10	100 %	49 %
Drink	69 %	30	1	100 %	40 %
Hoisery and knitted goods	70 %	28	2	100 %	31 %
Clothing	76 %	20	4	100 %	19 %
Footwear	87 %	11	2	100 %	42 %

Note: Computed from the U.K. Department of Employment (1978, Table 192, pp. F52–F54; 1977, Table 79, pp. C39–C41).

[a]The percentage of full-time employed manual women (in all the manufacturing industries) paid on incentives is also 40 (see U.K. Department of Employment 1977, Table 81, p. C44).

Table 3
Distribution (Percentages) of Incentive Paid Working Time on Type of Incentive Scheme Used by Year in Sweden and Norway

Panel A: Sweden[†]

Year	Type of Incentive Scheme: Individual	Group	Sum	Percent of Hours Worked Paid by Incentives
1965	62 %	38	100 %	70 %
1970	53 %	47	100 %	60 %
1973	53 %	47	100 %	61 %
1975	44 %	56	100 %	58 %
1977	47 %	53	100 %	54 %
1980	42 %	57	99 %	53 %

Panel B: Norway[‡]

Year	Type of Incentive Scheme: Individual	Group	Plant	Sum	Percent of Hours Worked Paid by Incentives
1976	19 %	66	15	100 %	49 %
1979	20 %	56	24	100 %	31 %
1982	15 %	53	31	99 %	30 %
1985	13 %	40	47	100 %	31 %

[†]Taken from ILO (1984, pp. 133 and 139).

[‡]Computed on the basis of the Norwegian Employer's Federation (NAF) survey on forms of remuneration (Norsk Arbeidsgiverforening, Oslo, Norway, unpublished memorandum of April 8, 1986, Table 1, p. 3 and Table 4, p. 5). The samples for the surveys consist of companies with 20 or more employees that are members of the Norwegian Employer's Federation.

Table 4
The Worker's Preference Ranking of the Outcomes (A–D) under Material Rewards and under the Alternative Mechanisms

Panel A: The Worker's Preference Ranking of the Outcomes (A–D) under the Material Reward Schemes

	Type of Material Reward Scheme	
Rank†	Group or Individual Piece Rate	Group or Individual Target Rate
1	A	B
2	B	A
3	C	C
4	D	D
Remarks:	Individual rationality leads to collective irrationality: Free-riders, Prisoner's Dilemma game. Everyone wants A, and the group ends up in C.	Individual rationality may coincide with collective rationality: Assurance Game. Everyone chooses B, *if* everyone else does so, and the group ends up in B.

Panel B: The Worker's Preference Ranking of the Outcomes (A-D) when Social Rewards, Altruism, and Commitment are Present

	Type of Alternative Mechanism			
			Commitment (i.e., morals)‡	
Rank†	Social rewards§	Altruistic Preferences¶	Kant's Categorical Imperative	Conditional Kant's Categorical Imperative
1	Depends on	Depends	B	B
2	the strength	on the	D	A
3	of the	degree of	A,C	C
4	rewards	altruism		D
Remarks:				Assurance game Collective rationality may ensue

NOTE.— The outcomes (A–D) are the following (see also Section 3):
A. I take it easy, everyone else works hard.
B. I work hard, everyone else works hard.
C. I take it easy, everyone else takes it easy.
D. I work hard, everyone else takes it easy.

†Outcomes are ranked from most (rank 1) to least (rank 4) preferred.

‡Commitment: workers follow rules of behavior that take into account the welfare of other workers, not because they care much about others, but because they feel obliged to behave according to certain moral standards. There are two versions of commitment: (1) Unconditional commitment; One follows one's moral obligation regardless of what others do (Kant's Categorical Imperative);
(2) Conditional commitment; One follows one's moral obligation if others also behave according to moral standards (Conditional Kant's Categorical Imperative).

§Social rewards: enforced by the workers themselves (e.g., group pressures).

¶Altruism: workers are concerned about the welfare of other workers.

Table 5
Means and Standard Deviations (in Parentheses) of Hourly Wages By Incentive Status of Workers and Type of Incentive Scheme in the Establishment

Incentive Scheme in the Establishment	Incentive Workers: Hourly Wages	Incentive Workers: N†	Time Rated Workers: Hourly Wages	Time Rated Workers: N†
Panel A: Woodhousehold Furniture Industry‡				
No Incentive Scheme			2.91 (.64)	25082 (222)
Individual Piece Rate	3.33 (.92)	2623 (36)	2.63 (.50)	1493 (35)
Individual Target Rate	3.58 (.90)	1185 (13)	2.93 (.45)	259 (11)
Group Piece Rate	2.74 (.42)	183 (6)	2.99 (.27)	207 (4)
Group Target Rate	4.05 (1.66)	1582 (22)	2.52 (.23)	362 (2)
Panel B: Nonferrous Foundries Industry§				
No Incentive Scheme			4.69 (1.32)	9665 (237)
Individual Piece Rate	4.82 (1.16)	1108 (54)	4.17 (.90)	1770 (54)
Individual Target Rate	5.12 (1.07)	1205 (38)	4.70 (.89)	1729 (38)
Group Piece Rate	3.93 (.34)	168 (3)	4.32 (.57)	224 (2)
Group Target Rate	4.47 (.44)	150 (6)	4.56 (.75)	213 (4)

† The N's refer to the number of workers and the number establishments (in parentheses).

‡ Computed from The Industry Wage Survey of the Wood Household Furniture industry in November 1974, Bureau of Labor Statistics (see U.S. Department of Labor, 1976*b*). The results pertain to production workers.

§ Computed from The Industry Wage Survey of the Nonferrous Foundries industry in May 1975, Bureau of Labor Statistics (see U.S. Department of Labor, 1977*d*). The results pertain to production workers.

Table 6
Effects on the Logarithm of the Hourly Wage Rate For Incentive Workers Paid an Individualistic (Piece or Target) or a Group (Piece or Target) Rate Production Workers in the Wood Household Furniture Industry (Standard Error of Estimate in Parentheses)

Constant	1.133 (.089)	1.316 (.074)	1.336 (.072)
Payment Scheme†			
Individual Target Rate	.027 (.009)	.000*(.009)	.007*(.009)
Group Piece Rate	–.093 (.014)	–.304 (.013)	–.311 (.013)
Group Target Rate	.109 (.008)	–.133 (.009)	–.135 (.009)
Sex (1=female)	–.121 (.006)	–.091 (.005)	–.073 (.005)
Union‡			
UBC	–.088 (.007)	–.199 (.008)	–.198 (.007)
UFW	.068 (.011)	.099 (.010)	.098 (.010)
IWA	–.169 (.018)	–.317 (.015)	–.332*(.015)
UIU	.043 (.009)	.058 (.010)	.064 (.009)
Other	–.134 (.010)	–.150 (.009)	–.156 (.009)
Size of Establishment§			
20–49 employees	.044*(.091)	–.090*(.076)	–.082*(.074)
50–99	.027*(.090)	–.021*(.075)	–.025*(.073)
100–249	.078*(.089)	.030*(.075)	.030*(.073)
250–499	.290 (.089)	.073*(.074)	.070*(.072)
500–999	.069*(.089)	.103*(.075)	.102*(.073)
1000+	.196 (.090)	.008*(.077)	–.001*(.074)
SMSA (1=in SMSA)	.053 (.005)	.081 (.006)	.241*(.023)
Area¶			
South	–.214 (.008)	–.018 (.008)	–.014*(.008)
North Central	–.007*(.008)	.186 (.008)	.185 (.008)
West	–.278 (.020)	–.462 (.017)	–.455 (.017)
Principal Product‖			
Living Room		–.252*(.015)	–.253 (.015)
Dining Room		–.213 (.016)	–.230 (.016)
Kitchen Wood		.321 (.014)	.326 (.014)
Bedroom Wood		–.166 (.015)	–.171 (.015)
Children's Wood		–.157 (.021)	–.172 (.021)
Outdoor Wood		–.102 (.043)	–.062*(.042)
Other		–.408 (.018)	–.256 (.007)
Secondary Product**			
Living Room		.108 (.012)	.119 (.011)
Dining Room		.130 (.010)	.121 (.010)
Bedroom Wood		–.094 (.013)	–.085 (.013)
Outdoor Wood		–.112 (.035)	–.106 (.034)
Other		–.258 (.008)	–.256 (.007)
Occupation††			
Assembler, Furniture			.013*(.011)
Subassembler, Furniture			–.071 (.008)
Assembler, Chairs			.016*(.017)
Cut-off-saw Operator			–.027 (.014)
Trimmer-machine Operator			–.016*(.017)

(Table 6 continued)

Gluers			−.008*(.015)
Maintainers			.042 (.013)
Molding-machine Operator			.095 (.022)
Mold.-mach. Op. (feed only)			−.032*(.028)
Off-bearers, machine			−.084 (.009)
Packers, Furniture			−.071 (.009)
Planer Operators			−.023*(.030)
Planer Op. (feed only)			−.025*(.040)
Plastic-top Installers			−.230 (.044)
Rip Saw Operator			.032 (.019)
Router Operator			.033 (.014)
Route Operator (feed only)			−.007*(.037)
Rubbers, Hand			−.082 (.012)
Rubbers, Machine			−.014*(.022)
Sanders, Hand			−.035 (.009)
Sanders, Machine Belt			−.000*(.010)
Sanders, Machine, Not Belt			.011*(.014)
Shaper Operators, Automatic			.051 (.024)
Shap. Op., Aut. (feed only)			−.083 (.042)
Shaper Operators, Hand			.009*(.027)
Shap. Op., Hand (feed only)			−.072*(.045)
Sprayer			.018 (.009)
Tenoner Operator			.060 (.016)
Tenoner Operator (feed only)			−.065*(.033)
Lathe Operators, Automatic			.099 (.028)
Lathe Op., Aut. (feed only)			.036*(.035)
Variety-Saw Operator			−.056 (.016)
R^2 (σ)‡‡	.435 (.215)	.618 (.177)	.642 (.172)

*Not significantly different from zero at the five percent level (two-tailed test).

NOTE.—Effects of Area, Size of Establishment, Main and Secondary Products, SMSA, Unionization, Sex, Occupation and Method of Pay on Hourly Wage Rate (the logarithm) for Non-Supervisory Production Workers. The Industry Wage Survey of the Wood Household Furniture industry in November 1974, Bureau of Labor Statistics (see U.S. Department of Labor, 1976*b*). N (workers) = 5573; N (establishments) = 77.

†Reference category: Individual piece rate.

‡Reference category: Not unionized.

Explanation of abreviations:

UBC=United Brotherhood of Carpenters and Joiners of America

UFW=United Furniture Workers of America

IWA=International Woodworkers of North America

UIU=Upholsterers' International Union of North America

Other=unionized but none of the major unions named above.

§Reference category: Establishments with 1-19 employees.

¶Reference category: Northeast.

‖Reference category: Radio, TV Wood Equipment.

**Reference category: No secondary product.

††Reference category: Assemblers of complete furniture.

‡‡Estimate of the residual standard error.

Table 7
Effects on the Logarithm of the Hourly Wage Rate For Incentive Workers Paid an Individualistic (Piece or Target) or a Group (Piece or Target) Rate
Production Workers in the Nonferrous Foundries Industry
(Standard Error of Estimate in Parentheses)

Constant	1.639 (.073)	1.718 (.067)	1.692 (.077)
Payment Scheme[a]			
Individual Target Rate	.007*(.010)	-.019*(.010)	-.035 (.010)
Group Piece Rate	-.260 (.024)	-.265 (.023)	-.245 (.023)
Group Target Rate	-.108 (.018)	-.090 (.020)	-.092 (.020)
Sex (1=female)	-.222 (.013)	-.163 (.013)	-.081 (.015)
Union[b]			
USW	.076 (.019)	.161 (.021)	.164 (.021)
UAW	.095 (.013)	.163 (.013)	.168 (.013)
IMA	.025*(.014)	-.046 (.016)	-.036 (.015)
Other	.024 (.011)	.028 (.011)	.032 (.011)
Size of Establishment[c]			
20–49 employees	-.082*(.073)	-.041 (.068)	-.049 (.067)
50–99	-.058 (.073)	.060 (.068)	.057 (.067)
100–249	-.045 (.071)	.022 (.067)	.013 (.067)
250–499	.044*(.072)	.149 (.067)	.164 (.067)
500–999	.170 (.075)	.415 (.070)	-.373 (.070)
1000 +	.099 (.074)	.235 (.073)	.219 (.073)
SMSA (1=in SMSA)	-.006 (.014)	.044 (.015)	.042 (.015)
Area[d]			
West	-.010*(.010)	-.946 (.010)	-.040 (.009)
South	-.164 (.017)	-.211 (.018)	-.192 (.018)
Primary Type of Metal Cast[e]			
Copper and copper base		-.093 (.020)	-.385*(.020)
Zinc and Zinc Base		-.118 (.013)	-.097 (.014)
Magnesium and Mag. Base		.318 (.049)	.360 (.048)
Other Metal		-.216 (.041)	-.197 (.043)
Primary Method of Casting[f]			
Permanent-mold, gravity		-.085 (.023)	-.070 (.026)
Permanent-mold, centrifug.		-.037 (.067)	.005 (.067)
Die Casting		-.193 (.067)	-.139 (.023)
Secondary Method of Casting[g]			
Sand Casting		-.249 (.045)	-.255 (.044)
Permanent-mold, gravity		-.066 (.019)	-.033*(.020)
Permanent-mold, centrifug.		.004 (.047)	-.027 (.046)
Die Casting		-.017 (.027)	-.011 (.027)
Other Methods		.030 (.037)	.046 (.037)
Jobbing Foundry (=1)[h]		-.094 (.013)	-.095 (.013)
Occupation[i]			
Grinders			-.086 (.040)
Chippers and Grinders			-.018 (.044)
Core Assemblers and Fin.			.035*(.048)
Coremakers, Hand			-.085*(.045)
Coremakers, Machine			.067 (.045)
Die-Casting-Machine Op. I			.012 (.042)
Die-Casting-Machine Op. II			-.017*(.041)
Die-Casting-Machine Set-Up			.021*(.056)
Filers, Light (Die Cast.)			-.007 (.052)
Filers, Heavy (Die Cast.)			-.146 (.058)

(Table 7 continued)

Furnace Tenders			.032 (.044)
Molders, Floor			.008*(.048)
Molders, Hand, Bench			.044 (.046)
Molders, Machine			.074 (.040)
Gravity Casting Operator			.042 (.041)
Polishers and Buffers			.010 (.043)
Pol. and Buff., mach. op.			−.102 (.043)
Pourers, Metal			.012 (.049)
Sand-or-shot-blast Operat.			-.076 (.063)
Sand Mixers, Hand and Mach.			.032 (.061)
Shakeout Men			−.124 (.047)
Shell-Mold Mach. Operator			−.060 (.060)
Sprue-Cutting Press Oper.			−.135 (.043)
Inspectors, Class C			−.176 (.052)
Electricians, Maintenance			.219 (.124)
Maint. Workers, general			−.193 (.081)
Mechanics, Maintenance			.051 (.123)
Tool and Die Makers			.220 (.105)
Laborers, General, Foundry			−.081 (.042)
Laborers, Material Handling			.096 (.079)
Packers, Shipping			−.150 (.053)
Shipping Clerks			−.165 (.123)
Ship. and Receiving clerks			−.044 (.103)
Truckers, Forklift			−.228 (.084)
R^2 $(\sigma)^j$	.338 (.189)	.447 (.172)	.500 (.165)

*Not significantly different from zero at the five percent level (two-tailed test).

NOTE.—Effects of Area, Size of Establishment, Main and Secondary Products, SMSA, Unionization, Sex, Occupation and Method of Pay on Hourly Wage Rate (the logarithm) for Non-Supervisory Production Workers. The Industry Wage Survey of the Nonferrous Foundries industry in May 1975, Bureau of Labor Statistics (see U.S. Department of Labor, 1977*d*). N (workers) = 2631; N (establishments) = 101.

[a]Reference category: Individual piece rate workers.

[b]Reference category: Not unionized.

Explanation of abreviations:

USW=United Steelworkers of America

UAW=United Automobile, Aerospace and Agricultural Implement Workers of America

IMA=International Molders and Allied Workers Union of North America

Other=unionized but none of the major unions named above.

[c]Reference category: Establishments with 1–19 employees.

[d] Reference category: Northeast and Midwest.

[e]Reference category: Aluminium.

[f]Reference category: Cast Based.

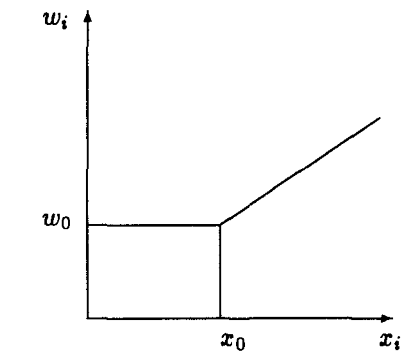
[g]Reference category: No Secondary Method.

[h]Reference category: Production Foundry.

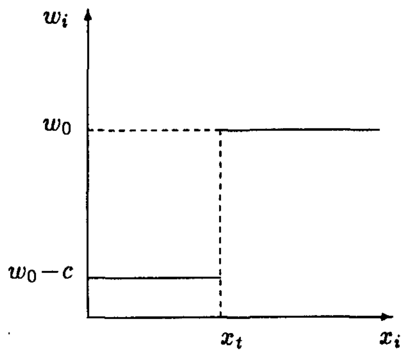
[i]Reference category: Chippers.

[j]Estimate of residual standard error.

(a) Linear piece-rate scheme with a guarantee



(b) Target-rate scheme



(b) Piece-rate scheme with a target

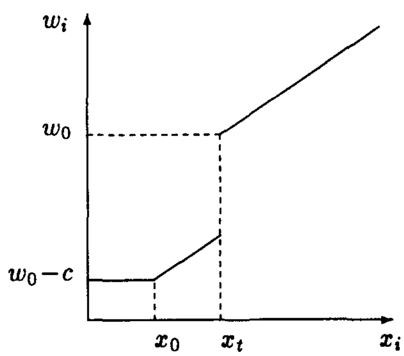


FIG. 1.—Graphic illustration of the material reward schemes in equations (3) and (8)

Legend:

The symbols in the figure denote the following: x_i is the output and w_i is the wage paid as function of output. x_t is the target under both a target-rate scheme and a piece-rate scheme with a target. x_0 is the amount of output that has to be produced before starting to earn a piece rate, under both the linear piece-rate scheme with a guarantee and under the piece-rate scheme with a target. w_0 is the baseline salary under a linear piece-rate scheme with a guarantee; it is the wage received under a target-rate scheme when the target is reached; it is the baseline salary recieved under piece-rate scheme with a target when the target is reached. $w_0 - c$ is the wage received under target-rate scheme when the target is not reached; it is the baseline salary received under a piece-rate scheme with a target when the target is no treached.