Production when Workers Value Output

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Abstract

Consider a worker who values the output produced beyond the wage he earns. Suppose output increases with the worker's effort, increases with the capital the employer provides, and that these levels are not verifiable. Under plausible conditions an increase of one input induces an increase in the other. Output will then be higher if the employer can commit to a level of capital than if it cannot. If the employer cannot commit, then output may decline as the worker values the output more. When the employer pays the worker for increased output, output may be lower when the worker values it than when he does not. Lastly, efficiency may be enhanced when a firm is paid more for a unit of output than its marginal social value.

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Workers commonly care about the wages they earn, but not about what the firm produces—a person will prefer working in a widget factory over working in a car factory only if he earns a higher wage or enjoys better working conditions.

Yet some workers take pride in their work, caring deeply about what is produced. The brave performance of New York City firemen and policemen after the September 11 attacks is consistent with the view that these people cared deeply about what they accomplished. University professors often take such pride in their research that they devote effort that exceeds what could be explained by income maximization. Heckman, Smith and Taber (1996) provide statistical evidence that some governmental workers care about outcomes. They investigate training centers under the Job Training Partnership Act, which received monetary rewards based on the employment levels and wage rates attained by the program's graduates. This creates an incentive for the manager to 'cream-skim' the most employable of the applicants into the program. But the authors find that people with lower expected earnings levels are more likely to be accepted into the program, contradicting the cream-skimming prediction. Instead, it appears that for these bureaucrats preferences for helping the disadvantaged overrode monetary incentives.

Such behavior is consistent with the results of survey responses. In a 1977 survey in the United States, half of the respondents agreed that "what I do at work is more important to me than the money I earn." Over ninety percent stated that they put in more effort into their job than required (Quinn and Staines (1979)).

In theoretical work, Dixit (2000) notes that organizations serving an idealistic or ethical purpose may attract workers who share these goals. Delfgaauw and Dur (2002) model workers who like to exert effort at the workplace, examining optimal monetary incentive schemes, a worker's effort in equilibrium, and a job seeker's incentives to reveal his motivation.

A good which benefits people besides the direct consumers is often a public good, and since I assume that increased output benefits both the employer and the worker, the output may be considered a public good. Note, however, that for my purposes the good may in other ways be a private good (for example, as with health care, use by final consumers is rivalrous).

I shall say that the utility a worker enjoys from increased production of a good, beyond the pay he receives, arises from "devotion" to his job. Some examples of devoted workers appear in jobs related to public safety, such as soldiers, policemen, and firefighters. But the concept is more general. A nurse who cares about the health of patients or a university professor who takes pride in writing a great book may also value the output they produce.

The issue addressed here is how an employer will respond to workers who value output—under what conditions will he exploit it by spending less on other factors of production, under what conditions will increased devotion increase output, and under what conditions will it reduce output.

1 Literature

My assumption that a worker cares about the output, and that he can increase its provision, relates to the private provision of public goods. And my focus on how increased effort by a worker can cause the employer to reduce the resources it allocates to production relates to crowding out in the private provision of public goods. A large literature finds that, in theory, crowding out can be large, or even complete. Relatedly, analyses of the Good Samaritan Paradox (see Bruce and Waldman (1990) and Lindbeck and Weibull (1988)) show that recipients of altruistic benefits who anticipate the gifts may act in ways which lower the welfare of the altruists, and negate the benefits of their gifts.

Several papers on the private provision of public goods consider, as I do, production. Steinberg (1989, p. 146) suggests that complementarity of private donations and governmental contributions may lead to incomplete crowding out. Andreoni (1998) considers increasing returns at low levels of the public good, so that a small contribution can elicit increased contributions.

In comparing Stackelberg to Nash solutions, I build on Varian (1994) who shows that if both parties care only about total output and if one party can commit first, total contributions will be smaller than in the simultaneous move game. Romano and Yildirim (2001) show that with more general utility functions (which allow, for example, for warm-glow or snob appeal) a charity may increase total contributions by announcing them sequentially.

Holmstrom (1982) studies a firm in which output increases with the joint effort of the workers. Though he does not refer to the workers as privately providing a public good, he does emphasize the free riding problem, and describes a contract which can achieve efficiency. A similar problem is considered by Congleton (1991), where the complementarity between different inputs means that the Nash equilibrium can be inefficient. Since Holmstrom and Congleton assume workers care only about income, not output, they do not address the effects I consider. Lastly, Congleton (2002) considers a government which purposely gives discretion to officials, because it knows that some officials care about the policies they implement, and that by giving them greater discretion it can attract more talented people.

2 Assumptions

A good is produced using an input provided by the employer, and an input provided by the worker. For simplicity, I call the employer's input capital, indicated by K. But the input can be far more general, including, for example, the amount of labor the employer hires in addition to the worker under consideration.

A worker's input consists of two parts. First, an employer can ensure that the worker provides at least the level F. Second, the worker can provide effort, x, which the employer cannot directly observe or verify.[1] I call this unverified effort. For the moment, suppose the worker is not paid for unverified effort, though this assumption is relaxed in Section 3.3. The cost to a worker of unverified effort x is $C(x)$.

The employer (which can be government, a non-profit organization, or a private firm) values each unit of output at p. The valuation can reflect the price at which the employer sells a unit of output, the marginal benefit to a manager of a subsidiary from increasing output, the preferences of government when it is the producer, and so on. A devoted worker values each unit of output at $V > 0$, which can be less than or more than p.

The firm hires one worker. I begin by assuming an exogenous wage, w, and later consider a wage which varies with output. When the wage is fixed, it can be ignored in the maximization problems discussed below.

We can also view the wage not as exogenous, but as set before the firm

[1] Since the employer is paid for output, I implicitly assume that output is verifiable. For effort to remain unverified, I must therefore also assume that capital cannot be verified. Intuitively, the firm may claim that high output results from its provision of much capital, while the worker may claim that it results from his high effort. An outside court or arbitrator cannot tell which is true.

chooses capital or the worker chooses effort, but with each actor having rational expectations of the choices the other actor will make. For example, the equilibrium wage may be higher when potential workers anticipate that the firm will provide little capital. But the firm sets capital after the wage is set, and so views the wage as a parameter when deciding on capital.

Each unit of capital costs r. The amount of capital is K, and output is $Q = F(K, x)$. The employer maximizes $pQ - rK = pF(K, x) - rK$; its choice variable is K. The worker maximizes $VF(K, x) - C(x)$; his choice variable is x.

3 Results

Critical to the analysis is consideration of how a worker's choice of x varies with K, and of how an employer's choice of K varies with x. The first-order condition for the firm is $pF_K(K, x) = r$, yielding $F_{KK}(dK/dx) + F_{Kx} = 0$, so that $dK/dx = -F_{Kx}/F_{KK}$. Diminishing marginal product would make F_{KK} negative. But the sign of F_{Kx} is ambiguous. If the two inputs are substitutes, then $F_{Kx} < 0$. But if the inputs are complements the sign will be positive. Therefore dK/dx can be either positive or negative, and the firm's reaction curve can slope upwards or downwards. Similarly, the worker's reaction curve is derived from his first-order condition that $VF_x(K, x) = C'(x)$, yielding $dx/dK = VF_{xK}/(C" - VF_{xx}$. This too can be positive or negative.

3.1 Upward sloping reaction functions

The simpler case to analyze has both reaction curves upward sloping. The Nash equilibrium must satisfy the first-order conditions for the worker and for the employer, namely x and K must simultaneously satisfy $pF_K(K, x) = r$ and $VF_x(K, x) = C'(x)$. The equilibrium is stable if the worker's reaction function is steeper than the employer's reaction function. This is shown in Figure 1.[2]

[2]Such a stable solution is consistent with even simple production and cost functions. For example, let $Q = (\gamma + K)^\alpha(F + x)^\beta$, where γ, F, α, and β are parameters. Let a worker's cost of effort x be cx. Then the Nash equilibrium is stable for a wide range of parameter values, including $V = 2, p = 1, r = c = 1$, and $\alpha = \beta = 0.4$.

If the worker places no value on output, $x = 0$, and the Nash equilibrium lies at the point where the employer's reaction function, EE, intersects the vertical axis. When the worker does value output, the Nash equilibrium is at N, where the employer's reaction function intersects the worker's reaction function. And since the employer's reaction function (EE) slopes upward, point N shows greater use of both inputs, and greater output, than the Nash equilibrium when the worker does not value output.

Consider next the Stackelberg solution. That is, the firm chooses K to maximize $pF(K,x) - rK$ subject to the worker maximizing his utility, or subject to x satisfying $VF_x(K,x) = C'(x)$. To determine that solution, it is useful to depict the employer's iso-utility (or for a firm, iso-profit) curves. An iso-utility curve is shown as curve PP. To see the shape, consider a given level of x, say $\overline{x}$. Then the employer may enjoy the same utility for both a high level of K and a low level of K. Starting at a low K, an increase in K may be highly productive, and so utility is kept constant only if an increase in K is associated with a decrease in x; this is the negatively sloped part of the curve. But at high K, the marginal product of K will be low, so that an increase in K increases costs but little increases output, thereby reducing utility. To keep utility constant, x must increase; this is represented by the positively sloped section of the iso-utility curve. Note also that movements to the right increase the employer's utility—for a constant K, an increase in x increases output. And note that the employer's reaction curve can be derived by the points on each iso-utility curve where the tangent is vertical: at such a point, the employer maximizes utility for a given x.

The employer maximizes profits or utility by choosing the point on the worker's reaction function (WW) which is tangent to one of the employer's iso-utility curves, as at point S. Since at point N the tangent to the employer's iso-utility curve is vertical, point S must lie to the right of N. And since WW slopes upward, at S both x and K are greater than at N. The Stackelberg solution thus has greater output than the Nash solution.

A Stackelberg solution can arise if the employer commits to a fixed level of K, or if it lacks the flexibility to adjust K in response to the worker's unverified effort. As one application, if government wishes to provide the good, and governmental agencies are less flexible than private firms, then production by the agency can lead to a Stackelberg solution, while provision by a private firm which is paid by government would not. Government would therefore prefer to produce the good directly. Moreover, devoted workers may prefer to work for an employer that will produce more, and so will prefer a governmental job.

3.2 Downward sloping reaction functions

More interesting results appear when the reaction functions slope down: an increase in the worker's effort reduces the employer's allocation of capital, and an increase in capital reduces the worker's effort.[3]

The result that increased labor induces the firm to reduce capital relates to standard results of crowding out. The novel aspects lie in seeing that when workers care about output we have a problem that relates to the private provision of public goods, in examining how output varies with the worker's effort, and in comparing results when the employer can and cannot commit.

The geometric solution is shown in Figure 2. The employer's reaction function is EE; the worker's reaction function is WW. Figure 2 also supposes that the worker's reaction curve is steeper than the employer's reaction curve, ensuring that the Nash equilibrium is stable. The Nash equilibrium is at point N, where the two reaction curves intersect.

3.2.1 Stackelberg solution

Now suppose that the employer can commit, making for a Stackelberg game. The Stackelberg leader should not be interpreted solely as the first mover. Rather, an employer plays a Stackelberg game if it cannot adjust capital after observing labor effort. The employer maximizes its utility by choosing that level of K which makes his iso-utility curve tangent to the reaction curve of the worker. This is shown as point S. If the worker's reaction curve has a negative slope, this tangency necessarily lies to the right of point N, which represents the Nash equilibrium. When the employer can commit to K it will choose a smaller K than at a Nash equilibrium.

The employer who can commit to keep K unchanged benefits (utility is higher at S than at N) because given a low level of K, a worker has more incentive to increase effort when K is fixed than when K declines as the worker increases x.

[3] A simple production function which generates such reaction functions is $Q = (K+x)^{\alpha}$, with $0 < \alpha < 1$.

Still to be determined is whether output is higher at N than at S. To determine that, I introduce isoquants, showing values of K and x at which output is constant. Consider isoquant II which goes through point N, the Nash equilibrium solution. As K declines, the worker increases x; but if the worker's marginal cost of effort increases with x, his increased effort will not suffice to keep output constant; instead output will decline. Therefore, to the right of point N, the isoquant lies above the worker's reaction function, or to the right of N curve II lies above curve WW. Point S, the Stackelberg solution, therefore necessarily shows lower output than does the Nash equilibrium. One interpretation is that an employer who can commit to a level of capital will exploit the worker's devotion by choosing a low level of capital that induces the worker to increase effort, but that reduces total output.

3.2.2 How output varies with the worker's devotion

I compare next the Nash and Stackelberg solutions with a worker who values output and a worker who does not. Thus, suppose x is zero. Then the employer sets capital at K_0, where its reaction function intersects the vertical axis. How does output at N compare to output at K_0? Notice that points K_0 and N lie on the reaction function EE. Consider the isoquant that goes through point K_0. When the employer's marginal cost of capital is a constant, and x and K are perfect substitutes, the isoquant coincides with the employer's reaction curve: the employer would fully compensate for an increase in effort by reducing capital to maintain the same output. Under these conditions, points N and K_0 show the same output, and point S shows lower output than point N. Output may thus be lower when the worker values it.

Suppose in contrast that the employer faces an increasing marginal cost of K. Then the isoquant through point K_0, curve K_0J, lies below curve EE: the employer responds to an increase in the worker's effort by reducing capital, but the reduction is sufficiently limited so that total output increased. Point N would then lie on a higher isoquant than point K_0, and point S could lie on a higher isoquant than point K_0. Output would then be higher when the worker values it.

3.3 Pay that varies with output

I assumed so far that the worker's pay is fixed, invariant with his effort or with output. One might object that if output is observable, then the employer can deduce the worker's effort. So why not pay him a bonus when output is high? Surely, for example, if the firm pays anything less than p for a marginal increase in output beyond the level that the worker would choose absent incentive pay, the firm would increase its profits.

Note first that if the levels of x and of K are unverifiable, the employer may effectively renege on paying the worker for increased effort: the employer may claim that the high output arose not from the worker's efforts, but from its high spending on K. Some contractual provisions cannot be enforced.

Note also that incentive pay would change the worker's reaction function, the employer's reaction function, and the employer's iso-utility curves. But if the reaction functions continue to be negatively sloped, the qualitative results described above hold.

To consider further how devotion affects output when the worker is given incentive pay, I shall continue to suppose that effort is not verifiable, but that output is, so that the worker's pay increases with output.

In Figure 3, let the worker's reaction curve when he does not value output be WW; let the employer's reaction curve be EE. The Nash equilibrium is at N. For an illuminating case, let K and x be perfect substitutes, let production exhibit diminishing marginal product, and let the unit cost of K be constant. Then the isoquant through N is necessarily flatter than EE. The reason is that an employer who gave no incentive pay would have its reaction function coincide with the isoquant: the employer would respond to an increase in x by reducing K to keep output constant. But if the worker's pay increases with output, the employer would not want to keep output constant: by reducing output it would reduce its costs. Thus, EE lies below the isoquant II to the right of N.

Now suppose that the worker values output. His reaction function shifts up, from WW to $W'W'$. The new Nash equilibrium is at N'. If EE slopes downward, then N' necessarily lies to the right of N, and therefore represents lower output than N. That is, for a given pay system, output may be lower when the worker values it.

Of course, an employer with devoted workers will change its pay system, so that the reaction function is no longer EE. But we saw that without wage incentives, output may be lower when workers value it. So the combination of wage incentives and devotion can reduce output.

4 Contracts to overcome commitment problem

When workers care about output, two market imperfections arise. First is a standard externality—an increase in capital increases the utility of a devoted worker. The effects of this externality are conventional, and so to highlight other effects I ignore it. Second, when the worker values output, the Nash equilibrium is inefficient as measured by $pQ - rK$. (That is, suppose again that the welfare of workers does not enter into social welfare). If the employer could commit to its level of capital, welfare could be made higher.

The inefficiency could be resolved in several ways. First, depending on whether government or private firms can better commit, production should be assigned to one or the other.

Second, workers might negotiate with the employer for a higher level of capital, in return for a lower wage. But this may not be verifiable.

Third, following Holmstrom (1982) an organization (say government) could subcontract, offering to pay the producer only if output is at the level the organization views as optimal. Multiple equilibria can appear, but one of them is the Stackelberg outcome described above.

Fourth, the organization could subsidize or restrict the capital used by the producer. Both policies have been used by government. The federal government has subsidized hospital construction. But with the Certificate of Need program adopted by the United States in the late 1970s and the early 1980s, it has also limited hospital capacity.

Fifth, an organization could offer a subcontractor a price for the output which differs from the organization's marginal valuation of the good. If the organization (say government) pays more than p per unit of output, then the employer's reaction curve shifts up; the Nash equilibrium between the firm and the worker will have more capital. An employer paid less than p could be induced to provide less capital than in the Nash equilibrium. Thus, government can induce the solution that it would choose were it the employer and behaved as a Stackelberg leader. Coupled with a lump sum payment to or from the firm which ensures zero profits, government can thus induce the outcome that it would choose were it the employer and behaved as a Stackelberg leader.

These considerations may explain why government pays firms to produce goods which are not public goods. When workers, such as medical personnel in hospitals, or university professors in research labs, care about output, indirect provision can yield better outcomes than unmediated provision.

5 Notation

$C(x)$ A worker's cost of unverified effort x

F Monitored effort of worker

p Valuation of unit of output by employer

V Valuation of unit of output by worker

x unverified effort of a worker

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