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SYMMETRY AND EFFICIENCY

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We consider teams where information asymmetry (adverse selection and moral hazard) is minimized by entry point screening designed to produce homogenous membership and work group arrangements and job rotation that render effort at worst imperfectly observable. We show that under membership symmetry, budget balance and strict rationality, a self-enforcing Pareto efficient (cooperative) and envy-free solution is attainable if and only if the production technology is of a unique concave family. Even in the absence of moral hazard and adverse selection, a self-enforcing Pareto efficiency remains impossible outside this family.

1. Introduction

Team theory is largely associated with moral hazard, this problem being the main source of its major failings (Alchian and Demsetz, 1972; Holmstrom, 1982; and Rasmusen, 1987). The research thrust since 1982 has been the search for mechanisms that force the Pareto efficient contribution of voluntary effort by individual members in a team characterized by budget balance, observable aggregate output, non-observability of effort and capacity and strict rationality. Holmstrom (1982) showed that the Pareto efficient solution is impossible for this type of team.

Holmstrom's (1982) own suggestion involved collective punishment specifying that whenever the observable output falls short of Pareto efficient, output is thrown away and everyone gets nothing. This violates budget balance at the same time that the credibility of the commitment is weak. Rasmusen's (1987) approach employed a fair and budget balancing lottery on who gets taxed in case of a shortfall. This requires risk aversion among members and could punish even the

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cooperative. A supergame approach to the team game often employed in Prisoner's Dilemma game can also force Pareto efficiency if the usual assumptions of the Folk Theorem hold (Macleod, 1985; and Radner, 1991). Job design is also employed to reduce moral hazard (Valsecchi, 1996).

Other design mechanisms work only when effort nonobservability is incomplete. Guttman and Schnytzer's (1987) "tit-for-tat" procedure works when the allocation is equal division and effort is fully observable. Sjöström (1996) and Ma (1988) employ a "forecasting mechanism" where member output forecast and actual output determine member returns but this works only when effort is fully observed by a monitor or if member effort is observed by immediate neighbors. Gradstein's (1996) "tax and subsidy" scheme to enforce cooperation in oligopoly works only when efforts is fully observed. When effort is fully and costlessly observable, Sen (1965) employed an "egalitarian bias" and "membership symmetry" to guarantee Pareto efficiency. The first question suggests itself: are mechanisms that play down the problem of moral hazard of any value?

Moral hazard is only one bar to Pareto efficiency. Even were effort fully and costlessly observable as in small teams, "member capacity" may be private information and therefore, the team may be unable to conclude whether a member is "shirking" his/her responsibility or is really doing his/her level best under an inferior set of conditions. There is a "hidden information" or "adverse selection" problem. Moral hazard and "adverse selection" constitute the asymmetric information problem of the team. In this paper, we consider organizations that deal with the problem of asymmetric information before they arise and, thus, face a more tractable problem.

The issue of homogeneity is of more interest in certain societies than in others. This seems, for example, true of the Japanese society, often casually described by the adage "The nail that sticks out...". This is even more pronounced in the Japanese firm where aspirants are carefully screened for fitness with the company mold. There are also countless anecdotes pointing to the "vent for homogeneity" in Japanese companies from group recreation to group night-outs. This is further reinforced in the workplace where team members are rotated to various tasks so that everyone becomes skillful in every facet of the shop floor and members become, so to say, interchangeable (Aoki, 1988). An bsent member can be substituted for without apparent effect on output. This also serves, advertently or otherwise, the purpose of making effort more observable since everyone has an idea of what is required of every task. This feature strikes one as the real world counterpart of the concept of symmetry (Nash, 1950; Fabella, 1990; and Osborne and Rubinstein, 1994) where the social choice function or the bargaining solution is invariant with respect to permutation of members. Suppose we seriously consider " membership symmetry" for the moment.

One implication of the "membership symmetry" assumption is ex ante to vanish the "adverse selection" problem. If everyone is like everyone else, there is really no private information. A second implication of symmetry is to imbue the outcome with a tinge of "fairness". Symmetry and its more advanced ordinal cousin "envy freeness" are well-known neo-classical economics' entries into the theory of justice (Thomson and Varian, 1985). The interest in the fairness implication is because Japanese firms also exhibit a relatively more equitable distribution of income. Some would, no doubt, claim that such an outcome is "fairer" and accounts for the remarkable workplace harmony in Japan.

The type of organization we have in mind has the following stylized features: (i) it carefully chooses its membership to achieve a high degree of homogeneity in attitude and temperament. This can also come about by self-selection as in the Israeli kibbutz; (ii) it employs practices such as a system of job rotation designed to achieve a high degree of substitutability among its members in production. In addition, (iii) it persists through a self-enforcing equilibrium despite (iv) self-interested (if homogeneous) members whose individual utilities rise with individual shares which, in turn, is determined partly or wholly by individual effort rendered observable by purposive work group arrangements. Finally, (v) the sum of member shares exhausts the total pie (implying no residual claimant which, in turn, requires that the equilibrium be self-enforcing).

This is none other than the Holmstrom team wrought very small, that is, without asymmetric information. Instead of tackling the problem of efficiency in the full-blown team by designing some mechanism (a lottery as in Rasmusen (1987) or a tax as in Gradstein (1996)) of varying degrees of realism, we entertain an environment where rigorous entry point screening including self-selection preempts adverse selection (or diversity in taste), and judicious small group work arrangements, job rotation, and skill diversity design (e.g., subcontracting) preempt moral hazard. This is probably the strategy against opportunistic behavior most employed by actual organizations apart from actual monitoring and firing.

With asymmetric information taken care of, one would think that cooperation and Pareto efficiency in teams becomes a non-issue. The point we will try to make in this paper is that information symmetry does not solve all the efficiency problems of team organization; that, therefore, mechanisms that implement Pareto efficiency while assuming observability have a role to play. Although moral hazard and adverse selection do pose a problem for team efficiency, they are not unique.

The next question is whether this type of organization resembles anything in the real world. We have already alluded to the Japanese firm as having relatively more homogeneous workforce (Odagiri, 1992) and which exhibits as much or more team-like features than principal-agent ones and certainly more than firms elsewhere (e.g., workers rather than capitalists as owners, firm-specific human capital accumulation, lifetime employment, subcontracting, seniority, bonus system and, of course, job rotation (Dore, 1973; Aoki, 1988; Odagiri, 1992; Nagatomi, 1996)). The Japanese firm is also proven to be very efficient and the structure durable despite the battering it received in the recession of the last few years (Wolf, 1996). Finally, as a result of greater homogeneity, it exhibits a more equitable income distribution, and the remarkable internal harmony of Japanese firms contrasts starkly with the internal turmoil of the S. Korean chaebols in the last ten years. Thus, the feasibility of our stylized organization suggests something of the feasibility of the Japanese type firm.

In Section II, we reformulate the Holmstrom team by introducing the Sen sharing, a convex combination of "proportional" and "equal division" allocation, thus, allowing for some effort observability. Assuming Nash conjectures, we generate the Nash equilibrium conditions and define the cooperative Nash equilibrium (CNE) solution. We then impose "membership symmetry" on CNE and analyze the implications. We show that "membership symmetry" is a property of a family of functions unique up to a factor of proportionality and a degree of homogeneity. We discuss the results in the last section.

2. The Model

Consider a team of $n \geq 2$ members indexed by i = 1, 2, ..., n. Each member i voluntarily supplies effort L_i to a production process represented by quasi-concave, increasing and twice differentiable production function G defined over $L = \{L_i\}$, $i = 1, 2, \ldots, n$. In return, i gets s_i of F (which G less fixed cost) where s_i is a convex combination of "equal division" (n^{-1}) and "proportional" ($L_i/\Sigma L_j$) allocations, i.e., $s_i = [(1-\alpha)(L_i/\Sigma L_j) + (\alpha/n)]$, $0 \leq \alpha \leq 1$ also known as "Sen sharing" (Sen, 1965). If $\alpha = 0$, then effort is completely observable and sharing is "proportional." If $\alpha = 1$, effort is completely unobservable and sharing is "equal division". Otherwise, effort is imperfectly observable. Member i's utility function is

$$(1) \quad U_i = s_i F - V_i(L_i) \qquad i = 1, 2, \ldots, n,$$

where $V_i(.)$ is the disutility of effort function assumed convex, strictly increasing and twice differentiable. Note that i is risk-neutral with respect to own share (Holmstrom, 1982; Fabella, 1989).

Definition 1: The teams' welfare function is $W = \Sigma U_i = F - \overset{n}{\Sigma} V_i(L_i)$. The first best cooperative solution when all information is public is attained if and only if $F^i = V_i'$, $\forall i = 1, 2, \ldots, n$.

Assuming identical Nash conjectures by all members, the first order condition for a maximum is:

$$(2) \quad [(1-\alpha)(L_i/\Sigma L_j) + (\alpha/n) + (F/F^i)\,(1-\alpha)\Big(\sum_{j\neq 1}^{n} L_j/\Sigma L_j\Big)^2]\, F^i = V_i',\ i = 1, 2, \ldots, n.$$

These n equations constitute the Nash equilibrium conditions. The set $\{L_i^*\}$, $i = 1, 2, \ldots, n$ which solves (2) is the Nash equilibrium (NE) solution. Let

$$A_i = (1-\alpha)\,(L_i^* / \Sigma L_i^* + (\alpha/n) + (F/\,F^i \Sigma L_j^*)(1-\alpha)\,(\sum_{j\neq i} L_j^* / \Sigma L_j^*)$$

$$R_i = [C - (L_i^* / \Sigma L_j^*)]\,[1 - (L_i^* / \Sigma L_j^*)]^{-1}$$

$$C = (n-\alpha)\,[n\,(1-\alpha)]^{-1}.$$

Then we immediately have, from (2):

Definition 2: The Nash equilibrium $\{L_i^*\}$ is cooperative if and only if $A_i = 1$, $i = 1, 2, \ldots, n$, i.e., (2) reduces to $F^i = V_i'$, $\forall$i.

Lemma 1: The Nash equilibrium is cooperative if and only if:

$$(3) \quad F = F^i R_i \Sigma L_j^*, \qquad i = 1, 2, \ldots, n.$$

Proof: If $A_i = 1$ or (3), (2) reduces to $F^i = V_i'$ $\forall i$. If NE is cooperative, then from (2), $F^i = V_i'$ and $A_i = 1$, or (3). Q.E.D.

Whenever (3) is true, the Nash equilibrium is also the cooperative equilibrium. A cooperative Nash equilibrium, for which we will employ the shorthand, CNE, is self-enforcing. Now we introduce "membership symmetry:"

Definition 3: CNE satisfies membership symmetry (*MS*) if $L_i^* = L_k^*$, $\forall$i, $k = 1, 2, \ldots, n$, i.e., the solution $\{L_i^*\}$ of (2) is invariant with respect to any permutation of the members.

From (3), the following is immediate:

Lemma 2: CNE satisfies *MS* if and only if $F^i = F^k = F'$, $\forall\, i, k$ and $V_j'(L_k^*) = V_k'(L_k^*)$, $\forall i, k$.

Proof: (i) (only if) Suppose CNE satisfies *MS*. Then $R_i = R_j = R$, $\forall_i, j$. From (3), we have $F^i R \Sigma L_j^* = F^j R \Sigma L_j^* \Rightarrow F^i = F^k = F$, $\forall\, i, j$. (if) Suppose $F^i = F^k$, $\forall\, i, k$, then from (3), $F R_i \Sigma L_j^* = F R_j \Sigma L_j^* \Rightarrow R_i = \mathrm{R}_j = R$, $\forall\, i, j$. This implies that $L_i^* = L_j^* = L^*$, $\forall\, i, j$. (ii) Suppose $V_j'(L_j^*) \neq V_k'(L_k^*)$, some i, k. Then $F^i \neq F^k$, some i, k and the *CNE* equilibrium does not satisfy *MS* and vice-versa. Q.E.D.

Thus, *MS* at *CNE* is equivalent to the combination of taste symmetry ($V_i'(x) = V_j'(x)$) and productivity symmetry ($F^i \neq F^k$, $\forall\, i, k$). Furthermore:

Lemma 3: F supports *CNE* satisfying *MS* if and only if F is homogeneous of degree $R^{-1} = (1-\alpha)$.

Proof: (if) From Lemma 2, we have $F^i = F^j = F'$, $\forall i, j$. The CNE condition (3), $(F^i \Sigma L_j^*) = FR_i^{-1}$, can be rewritten as $\Sigma L_j^* F^j = FR_i^{-1}$. Now we rewrite R_i as

(4) $[(1-\alpha)\, n\, (\Sigma\, L_j^* - L_i^*)]\,[\, n\, (\Sigma\, L_j^* - L_i^* + \alpha\, (\Sigma\, L_j^* - nL_i^*)]^{-1}$.

If MS holds at CNE, then $\alpha\, (\Sigma\, L_j^* - \mathrm{n}L_i^*) = \alpha(nL^* - nL^*) = 0$ and R_i reduces to $(1-\alpha)$. Furthermore, $R_i = R_j = R$ due to *MS*. Thus, we have $\Sigma L_j^* F^j = F(1-\alpha)$ which defines a function F homogeneous of degree $(1-\alpha)$. (only if) Suppose F is not homogeneous of degree $(1-\alpha)$. Then $(1-\alpha)F \neq \Sigma L_j^*\, F^j$ ΣL_j^* by *MS*. So, $F \neq F^i\, \Sigma L_j^* / (1-\alpha) = F^i\, R_i\, \Sigma L_j^*$. A contradiction by Lemma 2. Q.E.D.

We know that *MS* at *CNE* forces $F^i = F^k$, $\forall\, i, k$. Let us analyze this property further.

Definition 4: F is "factor symmetric" (*FS*) if $F^i = F^j = F'$, $\forall\, i, j = 1, 2, \ldots, \mathrm{n}$.

We now show that the family of factor symmetric functions that can support CNE is unique up to a constant of proportionality and the degree of homogeneity.

Theorem 1: F is *FS* and supports *CNE* if and only if $F(.) = A(\Sigma L_j)^{(1-\alpha)}$.

Proof: (only if) If F is FS and supports CNE, then, by Lemma 3, F is homogeneous of degree $(1-\alpha)$. As support to CNE it must satisfy the CNE conditions (3) which can now be written, using Lemma 3, as:

$$(F^i / F) = (1-\alpha) / \mathrm{E}L_j,\ \forall\, \mathrm{i} = 1, 2, \ldots, n.$$

Integrating with respect to L_i gives

$$\log F = \log\, (\Sigma L_j)^{1-\alpha} + \log \mathrm{A}$$

where A is the constant of integration. Taking the anti-log gives:

$$F = A(\Sigma L_j)^{1-\alpha}.$$

(if). We show that F satisfies FS and the CNE conditions (3). We have $F^i = (\Sigma L_j)^{-\alpha} = F^k = (\Sigma L_j)^{-\alpha}$ and F satisfies FS. The right hand side of the CNE condition (3) is $F^i R \Sigma L_j = F^i \Sigma L_j / (1-\alpha)$ (by Lemma 3). Substituting $A(1-\alpha)(\Sigma L_j)^{-\alpha}$ for F_i gives:

$$A(1-\alpha)(\Sigma L_j)^{-\alpha}\Sigma L_j \,/\, (1-\alpha) = A(\Sigma L_j)^{1-\alpha} = F.$$

Likewise, substituting for F^k in $F^k \Sigma L_j/(1-\alpha)$ gives F. Thus, this is true for all $i, k = 1, 2, \ldots, n$. Thus, F supports CNE. Q.E.D.

Thus, $F(.)$ is unique up to a factor of proportionality and degree of homogeneity. There are factor symmetric functions that cannot support CNE. An example is $F(.) = A(\Sigma L_j)^{\Omega}$, $\Omega > 1$. Another is $F(.)A(\Sigma L_j)^{\Omega} + \beta$, $0 < \Omega < 1$, $\beta > 0$.

In regard the remarkable internal social harmony of Japanese firms, we first have:

Definition 5: An allocation is "envy-free" if i does not strictly prefer k's share in total output to his own, $\forall\ i, k = 1, 2, \ldots, n$.

The following is immediate:

Corollary: The allocation at CNE satisfying MS is "envy-free."

Proof: By MS, $L_i^* = L_k^*$, $\forall\ i, k$. Thus, $s_i = s_k$ and $s_i F = s_k F$, $\forall\ i, k$. Thus, allocation is equal division and so envy free. Q.E.D.

It is this envy-free feature that supports social harmony.

Whether we want symmetry because it reflects some relevant economic environment (such as that of a homogeneous society or where membership is limited to kindred spirits such as the Kibbutz) or because we want it to normatively reflect our sense of fairness, it has the effect of allowing a self-enforcing efficient solution. It does this by vanishing information asymmetry. Although efficient cooperation is possible, the choice of allowable production technology is limited to exactly one family. This shouldn't be too surprising because the symmetry assumption in Nash bargaining, for example, conspires with others to generate a unique Nash bargaining solution. If production technology is not as in the Theorem 1, then there is room for mechanisms that implement Pareto efficiency while requiring some effort observability!

Our interpretation of the notion of the homogeneous Japanese work force relates to "taste" or "temperament" especially with respect to effort or work. This is secured by entry point screening. The proper "temperament" is, however, not sufficient. One must also have the all-around skills that makes one interchangeable in the production process. This is secured partly by job rotation which also improves observability. Work group and skill diversity design also improve observability. The "temperament" plus the "production interchangeability" makes the prototypical "Sony Man" or "Toyota Man". These correspond to "membership symmetry" which is coextensive with "taste" and "factor symmetry". These allow the genesis of an efficient self-enforcing and envy-free cooperative solution in a team. This is the economic logic behind the combination of the "vent for homogeneity" and "job rotation" in Japanese industrial organization. Its consequence is efficiency with social harmony. Finally, we have as a complement to the Holmstrom result, the flip side of Theorem 1:

Theorem 2: For a team, with symmetric and strictly rational membership whose effort is observable either fully or partly, that implements Sen sharing satisfying budget balance, a Pareto efficient Nash equilibrium is impossible if $F(.) \neq A(\Sigma L_j)^{\Omega}$, $0 \leq \Omega \leq 1$.

What this says is that even if moral hazard and adverse selection are non-existent, Pareto efficiency remains unattainable for such a team. Thus, there is, indeed, room for mechanisms that require effort observability to force Pareto efficiency!

3. Conclusion

In economic environments where information asymmetry is dealt with by entry point screening and/or self-selection (contra "adverse selection") and job rotation and physical and skill diversity design of the workplace (contra "moral hazard"), cooperation and Pareto efficiency in teams is, indeed, attainable. Holmstrom's moral hazard result was, therefore, of interest. But the opening is narrower than one would have expected. In this paper, we showed that: (i) "membership symmetry" (nee "taste symmetry" and "factor symmetry") allows teams to attain the cooperative Nash equilibrium; (ii) that factor symmetry that is compatible with cooperative Nash equilibrium is exhibited by and only by a family of functions unique up to a constant of proportionality and a degree of homogeneity, viz., $F(.) = A(\Sigma L_j)^{\Omega}$, $0 < \Omega \leq 1$. Thus, Pareto efficiency is attainable, as most observers expect, but the opening is much narrower than expected. There is, indeed, room for implementing mechanisms that require observability; (iii) if the observability of effort is imperfect and given as a degree "α" where $0 \leq \alpha \leq 1$ (where $\alpha = 0$ means effort is wholly observable and $\alpha = 1$ means effort is completely unobservable), then team Pareto efficiency is attained if and only if $\Omega = (1-\alpha)$.

The relative homogeneity of the work force in Japanese firms is achieved in two stages: entry point screening which looks for certain attitudes or temperament that fits the company philosophy (which we formally model as "taste symmetry") and "job rotation" which makes for workers being substitutable for each other (which in the model we termed "factor symmetry"). Both these practices serve to reduce the latitude for opportunistic behavior occasioned by asymmetric information. Taste and factor symmetry preempt "adverse selection" and factor substitutability raises effort observability and reduce "moral hazard." Together, they conspire to force a cooperative and efficient equilibrium that is self-enforcing (Nash) in a team environment where the role of the capitalist is minimal. The implied allocation is envy-free, thus, explains the remarkable social harmony in Japanese firms.

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