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Market power and the form of enterprise: capitalist firms, worker-owned firms and consumer cooperatives

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Abstract

This paper examines the effect of market power on forms of enterprise. An efficiency comparison is made among three types of firms capitalist firms, worker-owned firms, and consumer cooperatives where each type of firm has monopoly and monopsony power in the market. Our result, that form depends on which variable is least sensitive to external change, can be understood by the standard theory of monopoly and monopsony and by some insight into implications of firm ownership on the structure of transactions among individuals.

JEL classification: D23; L22; P13

Keywords: Market power; Ownership of the firm; Form of enterprise; Capitalist firm; Worker-owned firm; Consumer cooperative

1. Introduction

This paper examines the effect of market power on an efficient form of enterprise. One way to classify organizational forms of firms is to categorize them according to their ownership structure, which is characterized by the rights of decision making and of claim to the firm's residual earnings (Dow, 1986; Hansmann, 1996). Based on this idea, we will consider three types of firms: firms owned by the suppliers of physical capital (referred to as capitalist firms), those owned by the workers (worker-owned firms), and those owned by their customers (consumer cooperatives). We will then make an efficiency comparison among them, given that each type of firm has monopoly and monopsony power in the market.

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The motivation for this research derives to a large extent from the numerous empirical observations and explorations made in Hansmann (1996). For example, farm marketing cooperatives, such as the grain elevator cooperatives in the late nineteenth century throughout the United States, or the fruit and vegetable canning cooperatives in the mid twentieth century in California, were formed when the middlemen who purchase farm products had a potential monopsony power in the market (Hansmann, 1996, p. 120–125). Many farm supply cooperatives, furnishing the member farmers with farm inputs, such as fertilizer, petroleum, farm chemicals, feed, and seeds, were established in the period when investor-owned firms had a substantial monopoly power over farmers in the supply of those farm inputs (Hansmann, 1996, p. 149–151). In these cases, market power seems to be the primary reason for the establishment of firms that are owned by individuals who are not the investors to the firm.

The theoretical literature on the relation between market power and enterprise form has been developed along two different lines. One is a performance comparison between different types of firms. Ireland and Law (1982) compared the efficiency of capitalist and worker-owned firms when these firms have monopoly power in the output market. Alternatively, Stewart (1984) compared the efficiency of these two types of firms when such firms have monopsony power in the labor market. The other is an efficiency evaluation of markets, in which different types of firms coexist. Assuming an output market with a capitalist firm monopolist, Sexton and Sexton (1987) considered the possibility that customers of the product form a cooperative and enter the market as the second supplier of the product. Cremer and Crémer (1992, 1994) analyzed a mixed duopoly by a capitalist firm and a worker-owned firm and examined the outcomes of Bertrand and Cournot competition. Ireland and Stewart (1995) compared the consequences of three kinds of duopoly: by two capitalist firms, by a capitalist firm and a worker-owned firm, and by two worker-owned firms.

This paper falls under the former strand of literature, but is also related to the latter. Two points, however, distinguish this study from the prior contributions listed earlier. First, whereas most of the existing literature deals only with capitalist and worker-owned firms, we will deal with consumer cooperatives in addition to capitalist and worker-owned firms. Second, these three types of firms are distinguished not by their objective functions, but by the allocation of ownership rights to the firm. In this sense, the three types of firms will be treated in a totally symmetric manner. In order to illustrate the characteristics of this paper, we will briefly discuss its similarities and dissimilarities to Stewart (1984) and Sexton and Sexton (1987).

In the existing theoretical literature, the setting of the present paper is probably closest to that of Stewart. He compared a capitalist firm with a worker-owned firm of the Ward (1958) type that is assumed to maximize net income per worker. While a capitalist firm, were it formed, would have a monopsony power in the labor market, a worker-owned firm would face a kind of participation constraint so that the net income per worker must be greater than the wage that would be paid by a counterpart capitalist firm hiring the same amount of labor. This asymmetry between a capitalist firm and a worker-owned firm in its way of exerting market power is the major source of different consequences. In the present paper, a worker-owned firm of the Dow (1993) type is assumed, in which workers have the rights of decision making and of claim to the firm's residual earnings. This allows us to treat the market power exercised by capitalist and worker-owned firms in a symmetric manner. That

is, just as a capitalist firm exercises a monopsony power in hiring labor, a worker-owned firm exercises a monopsony power in hiring physical capital.

Concerning policy implications, our study seems to be an alternative to what Sexton and Sexton suggest. They considered that, in a monopolistic market with a single capitalist firm, a consumer cooperative may be established and enter the market to compete with the incumbent monopolist. Entry of a consumer cooperative into a monopoly market is desirable from a social point of view, since such action is expected to reduce the efficiency loss under monopoly. We tackle the problem of monopoly from another point of view. That is, if monopoly by a capitalist firm is causing inefficiency, then why not consider taking the ownership rights to the firm away from the owners of physical capital and giving them to another group of individuals. For example, if consumers' monopsony power in hiring physical capital were weaker than capital owners' monopoly power in selling the product, then the efficiency loss would be made smaller under a consumer cooperative rather than a capitalist firm.

Before describing the main results obtained in this paper and their interpretations, we remark upon two premises in analyzing the model.

First, as was pointed out earlier, the three enterprise types are modeled in a symmetric manner in this study. That is, in a capitalist firm, the owners of physical capital have the ownership rights to the firm, use their own physical capital, hire workers, and sell the product to the consumers. In a worker-owned firm, workers have the ownership rights to the firm, rent the physical capital from its owners, use their own labor, and sell the product to the consumers. In a consumer cooperative, consumers have the ownership rights to the firm, rent the physical capital from its owners, hire workers, and consume the product by themselves. It should be noted that it is physical capital, not financial capital, that is meant by capital in the present context. Therefore, the market for capital means the rental market for physical capital, or in other words, the market for physical capital services, not the stock market.[1] An implicit idea behind this is that the physical capital that is used for production is specific to the firm in the sense of Williamson (1979), and then is of no use outside the subeconomy in question. We will come back to this point in Section 2.

Second, there are two possible mechanisms through which the proceeds of a firm are allocated among individuals. One is the market mechanism that allocates proceeds through trades in the market (Ireland and Law, 1982; Stewart, 1984; Dow, 1993, Section 2, the first-half of Section 4). The other is a bargaining process that allocates proceeds according to the relative bargaining power of individuals (Dow, 1993, Section 3, the second-half of Section 4; Schotter, 1994, Chapter 19, Section 7). This paper adopts the market mechanism rather than a bargaining process for the following reasons. First, individuals with ownership rights will necessarily coordinate themselves in order to pursue managerial tasks and to settle the division of the firm's residual earnings. Real world examples include a general meeting of shareholders for stock companies and a poll from all members for cooperatives. In contrast, such coordination for managerial and distributive purposes is not necessary for individuals

[1] Dow (1986) suggests that the services extracted from physical capital, not the physical capital itself, are used as a factor of production in the firm. In this interpretation, the capital services are traded in the market for physical capital services under a worker-owned firm, just as labor is traded in the labor market under a capitalist firm. See Dow (1986), Section 3.

without ownership rights. Second, in the real world, we do not see many organizations of non-owner individuals. We do not very often observe formal organizations of capital suppliers to a specific firm outside the class of capitalist firm.[2] Although labor union is a very common phenomenon in a capitalist economy, the participation rate of workers in labor unions is actually not very high. In Japan, for example, the participation rate is 23.2 percent, implying that three out of four workers are unorganized (Labor Minister's Secretariat Department of Policy Investigation, 1997). Organizations of consumers for a specific firm are also seldom seen outside the class of consumer cooperative.[3] Third, as was stated at the outset of the paper, our aim is to examine implications of *market* power on an efficient form of enterprise. If a bargaining process is presumed, a bilateral monopoly will arise and the market will collapse; the relationship between the market power and the enterprise form thus cannot be analyzed.[4]

The main result obtained from these settings of the model is as follows. A capitalist firm (worker-owned firm, or consumer cooperative, respectively) will be formed when the supply of the physical capital services (supply of labor, or demand for the product, respectively) is least sensitive to variations in the rental rate (wage, or product price, respectively). This result can be understood by means of the standard theory of monopoly and monopsony and grants some insight into implications of ownership of the firm to the structure of transactions among individuals.

Let us consider a monopoly in a product market. There are two factors that affect the degree of price distortion in equilibrium: demand responsiveness to price, and the monopolist's incentive to raise the price. When the demand is highly responsive to the price, variations in price have a large impact on the quantity purchased by the consumers. The monopolist then has only a little incentive to raise the price above the marginal cost, because at every step of raising the price he would lose a substantial quantity that he can sell to the consumers. (The monopolist is able to charge a higher price if he wishes, but that does not meet his interest.) Consequently, the monopolist will set the price close to the marginal cost. On the other hand, when the demand is not very responsive to the price, variations in price have small impact on the quantity purchased by the consumers. The monopolist then has a good deal of incentive to raise the price far above the marginal cost because he can raise the price without losing a substantial quantity of sales. Thus, the less sensitive the demand is for the product, the greater the monopolist's incentive to raise the price will be, and as a result the larger the

[2] An exception is a creditors' gathering in case of bankruptcy of the firm. However, this is an event on a special occasion.

[3] An exception is a patients' organization that is formed to sue collectively a drug company for selling a medicine that caused serious side effects on the patients. Of course, this is also an event on a special occasion.

[4] In fact, costs of establishing and operating the organization will influence the decision of non-owner individuals whether organizing or not organizing themselves. For these costs, refer to Meade (1975), Ben-Ner (1988), and Hansmann (1996). In any case, when these costs of organization are relatively large, the non-owner individuals will choose to stay unorganized, and a market solution will prevail. When these costs are relatively small, they may choose to organize themselves, and the market will collapse. Although it seems quite reasonable to assume market solution in the present context by the reasons stated in the text, or at least for the first step of the analysis, it might be an interesting extension to introduce some asymmetries to the model, such as a capitalist firm with organized workers and unorganized consumers being compared with a consumer cooperative with unorganized capital suppliers and organized workers, and so on.

distortion in the product market will be. (In other words, monopolist's rent-shifting power works strongly when demand is not easily affected by variations in price.)[5]

This inefficiency in the product market might be avoided if we can somehow arrange transactions so that the product market is not used. Theoretically, this can be accomplished by giving firm ownership to the consumers, thus establishing a consumer cooperative. Under a consumer cooperative, the product is no longer sold and bought, and therefore monopoly power is by no means exercised in the product market. Hence, if the demand for the product is insensitive to the price, thus giving rise to strong monopoly power in the product market, then there is a comparative efficiency for a consumer cooperative.

Similarly, when the supply of labor is insensitive to the wage, the employer of labor will exercise strong monopsony power over the workers, giving rise to a large efficiency loss. This inefficiency can be avoided by giving firm ownership to the workers and establishing a worker-owned firm since, under a worker-owned firm, labor is no longer sold and bought, and monopsony power is by no means exercised in the labor market. Thus, when the supply of labor is insensitive to the wage, there is a comparative efficiency for a worker-owned firm. By similar reasoning, when the supply of physical capital services is insensitive to the rental rate, there is a comparative efficiency for a capitalist firm.

An essential feature of the model in establishing this conclusion is that ownership of the firm implies choice of the market that is *not* used for transactions. That is, for a capitalist firm, the physical capital is not rented, or in other words, the rental market for the physical capital is not used, whereas the labor market and the product market are used. In a worker-owned firm, labor is not hired, or in other words, the labor market is not used, whereas the rental market for the physical capital and the product market are used. In a consumer cooperative, the product is not sold and bought, or in other words, the product market is not used, whereas the rental market for the physical capital and the labor market are used. A relative social efficiency can therefore be attained by dispensing with the market where the largest efficiency loss would be caused by the market power. This perspective of ownership rights as a selection of markets plays an important role in explaining the result obtained in this paper.

The next section frames an economic model of capitalist firm, worker-owned firm, and consumer cooperative. Section 3 examines an efficient enterprise form in relation with potential market power in each market. Section 4 observes worker-owned firms and consumer cooperatives in reality from the viewpoint of market power. Section 5 concludes the paper.

[5] This property can be illustrated by using an example. Assume that the utility function is of quasi-linear form $u(x, m) = x^{\alpha} + m$, where x is the quantity of the commodity and $0 < \alpha < 1$. Maximizing the utility subject to the budget constraint $px + m = M$, where p is the price of the commodity and M the income, yields the inverse demand function $p(x)$, and in turn the demand function $x(p)$. The monopolist then maximizes its profit $(p(x) - c)x$, where c is the unit cost. This yields the monopoly price p^{m} with $(p^{\mathrm{m}} - c)/p^{\mathrm{m}} = 1/\epsilon$ where $\epsilon = -x'(p)p/x = 1/(1-\alpha)$ is the constant price elasticity of demand. This condition says that the smaller the elasticity is, the greater the price distortion will be. Putting the demand function back to the original utility function, together with the budget constraint, yields the indirect utility function $v\,(p^{\mathrm{m}}(\epsilon), M)$, where $p^{\mathrm{m}}(\epsilon) = c\epsilon/(\epsilon - 1)$. Differentiating v with respect to ϵ yields $\partial v/\partial\epsilon = (\partial v/\partial p^{\mathrm{m}})(\mathrm{d}p^{\mathrm{m}}/\mathrm{d}\epsilon)$. Notice that $\partial v/\partial p^{\mathrm{m}} = -(\partial v/\partial\epsilon)x < 0$ by Roy's identity, and $\mathrm{d}p^{\mathrm{m}}/\mathrm{d}\epsilon = -c/(\epsilon - 1)^2 < 0$. That is, the smaller the elasticity is, the higher the monopoly price will be, which results in a lower utility level.

2. The model

In this section we develop a model that provides the minimum necessary to analyze the relationship between imperfect competition in the market and the efficient enterprise form. Let us consider a subeconomy with a set N_1 of owners of physical capital, a set N_2 of workers, and a set N_3 of consumers. It is assumed that $N_i \cap N_j = \emptyset$ for $i, j \in \{1, 2, 3\}$ with $i \neq j$, and that individuals in the same group are identical in initial endowment and preference.[6] Let numbers 1, 2, and 3 indicate a representative owner of the physical capital, worker, and consumer, respectively. Let $k^0 \in (0, \infty)$ be 1′s initial endowment of physical capital, and $k \in [0, k^0]$ be the amount of physical capital 1 provides for production. Let $l^0 \in (0, \infty)$ be 2′s initial endowment of labor, and $l \in [0, l^0]$ be the amount of labor 2 provides for production. Let $x \in [0, \infty)$ be the amount of the product 3 consumes. The circumstance we assume is that there is a demand for a differentiated product, and correspondingly there are physical capital and labor that are specific for production of the differentiated product.[7]

Let $K = n_1 k$, $L = n_2 l$, and $X = n_3 x$, where $n_i = \#N_i$ for $i \in \{1, 2, 3\}$.[8] For a function $v_1 \colon R_+ \to R$, let $v_1(k^0 - k)$ be 1′s utility (measured in monetary term) from the physical capital reserved for himself.[9] For a function $v_2 \colon R_+ \to R$, let $v_2(l^0 - l)$ be 2′s utility from leisure. For a function $v_3 \colon R_+ \to R$, let $v_3(x)$ be 3′s utility from consumption of the product.

Production technology is assumed to be of constant coefficient type, that is, $X = \min\{aK, bL\}$ for some positive numbers a and b. Without loss of generality, quantity of physical capital and labor is measured so that $a = b = 1$. It then follows that the technological constraint and production efficiency require that $K = L = X$, or equivalently that

$$k = \left(\frac{n_3}{n_1}\right) x \tag{1}$$

[6] The assumption that $N_i \cap N_j = \emptyset$, $i, j \in \{1, 2, 3\}$, $i \neq j$, is a functional division of input and output that is frequently used for analytical convenience in the literature. See, for instance, Dow (1993). Of course, this convention does not exclude the possibility that the owners of physical capital work for or purchase goods from another firm, that the workers own and rent physical capital to or purchase goods from another firm, or that the consumers own and rent physical capital to or work for another firm.

[7] As an example for such a circumstance, consider travel to a country that has just opened its border to foreigners. Some people are interested in making journeys around the unknown country (as the products). For that demand, there is a limited number of condominiums and apartment houses that can be used for the travelers' accommodation (as the physical capital) and a limited number of local residents who speak major as well as local languages and can serve as interpreters (as the labor).

[8] The symbol # indicates cardinality of the set.

[9] There are some interpretations for v_1: (1) v_1 is 1′s utility from self-consuming the physical capital. For example, if a person owns a room in a condominium, he can rent it to a firm for an office use, or he can use it as his second residence; (2) v_1 reflects maintenance cost for the physical capital that is provided for and used in the firm. For instance, let $c_1 : [-k^0, 0] \to R$ be a function defined as $c_1(k - k^0) := -v_1(k^0 - k)$ with $c_1(k - k^0)|_{k=0} = c_1(-k^0) = 0$ (no maintenance cost is needed if all the physical capital is reserved) and $c_1(k - k^0)|_{k>0} > 0$ (some maintenance cost is needed if a positive amount of the physical capital is provided for and used in the firm). In this case, the assumptions $v_1' > 0$ and $v_1'' < 0$ are translated in terms of c_1 as $c_1' > 0$ (the marginal maintenance cost of the physical capital used in the firm is positive) and $c_1'' > 0$ (the marginal maintenance cost of the physical capital used in the firm is increasing in its quantity), respectively.

and

$$l = \left(\frac{n_3}{n_2}\right) x. \tag{2}$$

We now impose the following assumptions.

Assumption. For $i \in \{1, 2, 3\}$, v_i is twice continuously differentiable and the third derivative exists with

$$v_i' > 0, v_i'' < 0, \text{ and } v_1''' \geq 0, v_2''' \geq 0, \text{ and } v_3''' \leq 0, \tag{A.1}$$

$$v_3'(0) > v_1'(k^0) + v_2'(l^0), \tag{A.2}$$

and

$$v_3'(\hat{x}) < v_1'\left(k^0 - \left(\frac{n_3}{n_1}\right)\hat{x}\right) + v_2'\left(l^0 - \left(\frac{n_3}{n_2}\right)\hat{x}\right) \quad \text{for some} \quad \hat{x} > 0. \tag{A.3}$$

(A.1) ensures that the firms' objective functions are strictly concave, and that the second order conditions for maximization problems are satisfied. (See footnotes 16, 19, and 21.) (A.2) and (A.3) together imply that producing some positive amount of the product is desirable from a social point of view. (See footnote 14.)

Ownership of the firm is characterized by the rights to make production decisions and to claim residual earnings of the firm (Milgrom and Roberts, 1992, Chapter 9). The type of a firm is then defined according to the distribution of the ownership rights to the firm among individuals (Dow, 1986, 1993; Hansmann, 1996). Basically, we follow this characterization for firm types. That is, in a capitalist firm, the owners of the physical capital use their own physical capital, hire labor in the labor market, and sell the product to the consumers in the product market, and then claim the (residual) profit of the firm. In a worker-owned firm, workers rent the physical capital in the rental market for the physical capital, use their own labor, and sell the product to the consumers in the product market, then claiming the surplus of the firm (which corresponds to the profit of the capitalist firm). We extend such formulation to the consumer cooperative. That is, in a consumer cooperative, consumers rent the physical capital in the rental market for the physical capital, hire labor in the labor market, and supply the product to themselves, where they receive the surplus of the firm (which in this model coincides with the consumer surplus; refer to Eq. (11)). Therefore, in the present setting of the model, the group of owners of the physical capital is the monopsony employer of labor and the monopoly seller of the product under a capitalist firm; the group of workers is the monopsony renter of the physical capital and the monopoly seller of the product under a worker-owned firm; and the group of the consumers is the monopsony renter of the physical capital as well as the monopsony employer of the labor under a consumer cooperative.

For simplicity, it is assumed that the firm's residual earnings are divided equally among individuals in the group with ownership rights to the firm. Under a capitalist firm, payoffs to an owner of the physical capital, a worker, and a consumer are thus given by

$$u_1 = \frac{pX - wL}{n_1} + v_1(k^0 - k) \tag{3}$$

$$u_2 = wl + v_2(l^0 - l) \tag{4}$$

$$u_3 = -px + v_3(x) \tag{5}$$

respectively, where w and p are the wage and the product price, respectively. Under a worker-owned firm, payoffs to an owner of the physical capital, a worker, and a consumer are given by

$$u_1 = rk + v_1(k^0 - k) \tag{6}$$

$$u_2 = \frac{pX - rK}{n_2} + v_2(l^0 - l) \tag{7}$$

$$u_3 = -px + v_3(x) \tag{8}$$

respectively, where r is the rental fee. Under a consumer cooperative, payoffs to an owner of the physical capital, a worker, and a consumer are given by

$$u_1 = rk + v_1(k^0 - k) \tag{9}$$

$$u_2 = wl + v_2(l^0 - l) \tag{10}$$

$$u_3 = -\frac{rK + wL}{n_3} + v_3(x) \tag{11}$$

respectively.[10]

In what follows, we consider an efficient ownership structure of the firm in a two-stage model. In the first stage, individuals decide upon allocation of ownership rights to the firm. At this stage, the ownership structure upon which individuals agree is contractible, and some side payments can be made. Alternatively, quantity of the physical capital services, labor, and the product that are traded in the future are all noncontractible.[11] In the second

[10] The product is not sold and bought at the product market under a pure form of consumer cooperative as described in the present model. Then, in our symmetric models of firms, the surplus of the consumer cooperative represented by (11) is one that corresponds to the profit of the capitalist firm. In fact, it coincides with consumer surplus discussed in welfare economics.

[11] For instance, in case K and L show the intensity of use of physical capital and labor as input, respectively, it is difficult to write a contract upon these variables. (For instance, Dow (1993) adopts this interpretation.) Also, if X shows the quality of product, then it is hard to write a contract upon it. (See, for instance, Tirole (1988), Chapter 2, Section 3, and Varian (1993), Chapter 34.)

Indeed, if these variables are directly contractible, then the first best input–output bundle can always be chosen regardless of the organizational structure of the firm. Essentially, the organizational form selection problem as discussed in this paper arises from the setting that input–output bundles are not directly contractible, and therefore, that efficiency must be sought through a proper allocation of ownership rights among individuals. By the same reason, direct contractibility on the key variables is excluded in Grossman and Hart (1986) and Hart and Moore (1988, 1990).

Also it is implicitly assumed here that, at stage 1, individuals cannot commit themselves not to exercise monopoly and monopsony power at stage 2. Such a promise might be possible under some circumstances, for example when a strong anti-trust agency is present. However, a strict enforcement of anti-trust policy is often impossible due to informational deficiencies or a high cost of proving manipulation of prices. From an analytical viewpoint, if such a promise is possible, and therefore market power is by no means exercised at stage 2, the question of the present paper, that how market power affects enterprise form, thoroughly degenerates.

stage, the individuals trade the physical capital services, labor, and the product in the spot market. In this process, the most efficient ownership structure of the firm will be chosen by the individuals.[12]

Independent of the organizational form of the firm, the social value of the firm is given by

$$V = \sum_{i=1}^{3} n_i u_i = n_1 v_1(k^0 - k) + n_2 v_2(l^0 - l) + n_3 v_3(x). \tag{12}$$

3. The efficient form of enterprise

By using (1) and (2), the social value of the firm (12) is represented as a function of the output level x, as $V(x)$. The socially optimal output level is characterized by

$$V'(x) = n_3[v_3'(x) - v_1'(k^0 - k) - v_2'(l^0 - l)] = 0 \tag{13}$$

with k and l being given by (1) and (2), respectively.[13] Let x^* be the output level that satisfies (13).[14]

Under a capitalist firm, from (4), each worker provides labor to the firm according to

$$w = v_2'(l^0 - l). \tag{14}$$

This equation serves for the inverse labor supply function, $w = w(l)$ with $w' > 0$, from which we obtain the labor supply function, $l = l(w)$.[15] From (5), each consumer purchases the product from the firm according to

$$p = v_3'(x). \tag{15}$$

This equation serves for the inverse demand function for the product, $p = p(x)$ with $p' < 0$, from which we obtain the demand function for the product, $x = x(p)$. The owners of the physical capital choose an output level that maximizes (3), subject to (14), (15), and the technological constraints, (1) and (2). And u_1 then becomes a function of x, and let $U_1(x) = n_1 u_1(x)$. The output level chosen by the owners of the physical capital is characterized by

$$U_1'(x) = n_3[(p + p'(x)x) - v_1'(k^0 - k) - (w + w'(l)l)] = 0 \tag{16}$$

[12] In this paper, negotiation at the first stage is assumed to be made at no costs, and the payoff functions of individuals satisfy the no-wealth-effects condition. Hence, owing to the Coase Theorem (Coase (1960)), an efficient ownership structure of the firm will be chosen at stage 1. This analytical methodology is widely used in the literature with incomplete contracts, which includes Hart and Moore (1990). For the details of the discussion on the relative efficiency principle, see Milgrom and Roberts (1992), Chapters 2, 4 and 9.

[13] The second derivative of V is given by

$$V''(x) = n_3[v_3''(x) + v_1''(k^0 - k) + v_2''(l^0 - l)]$$

which is negative by (A.1). The second order condition is therefore satisfied.

[14] Existence and uniqueness of x^* is shown in the proof of Lemma in Appendix A.

[15] Since $v_2'' \neq 0$ by (A.1), the inverse function of v_2' exists.

with k and l being given by (1) and (2), respectively.[16] Let x_1 be the output level that satisfies (16).[17]

Under a worker-owned firm, from (6), each owner of the physical capital provides the physical capital to the firm according to

$$r = v_1'(k^0 - k). \tag{17}$$

(17) serves as the inverse supply function for the physical capital services, $r = r(k)$ with $r' > 0$, from which we obtain the supply function for the physical capital services, $k = k(r)$. The workers choose an output level that maximizes (7), subject to (15), (17), and the technological constraints, (1) and (2).[18] And u_2 then becomes a function of x, and let $U_2(x) = n_2 u_2(x)$. The output level chosen by the workers is characterized by

$$U_2'(x) = n_3[(p + p'(x)x) - (r + r'(k)k) - v_2'(l^0 - l)] = 0 \tag{18}$$

with k and l being given by (1) and (2), respectively.[19] Let x_2 be the output level that satisfies (18).

Under a consumer cooperative, the consumers choose an output level that maximizes (11), subject to (14), (17), and the technological constraints, (1) and (2).[20] And u_3 then becomes a function of x, and let $U_3(x) = n_3 u_3(x)$. The output level chosen by the consumers is characterized by

$$U_3'(x) = n_3[v_3'(x) - (r + r'(k)k) - (w + w'(l)l)] = 0 \tag{19}$$

with k and l being given by (1) and (2), respectively.[21] Let x_3 be the output level that satisfies (19).

For $i \in \{1, 2, 3\}$, let $k_i = (n_3/n_1)x_i$, $l_i = (n_3/n_2)x_i$, $r_i = r(k_i)$, $w_i = w(l_i)$, and $p_i = p(x_i)$. Further, let $\dot{k}(r) = k'(r)/k(r)$, $\dot{l}(w) = l'(w)/l(w)$, and $\dot{x}(p) = x'(p)/x(p)$. For example, k_1 is the supply of the physical capital services in equilibrium under a capitalist firm, r_2 is the rental rate for the physical capital in equilibrium under a worker-owned

[16] The second derivative of U_1 is given by

$$U_1''(x) = n_3[v_3'''(x)x + 2v_3''(x) - v_2'''(l^0 - l)l + 2v_2''(l^0 - l) + v_1''(k^0 - k)]$$

which is negative under (A.1). The second order condition is therefore satisfied.

[17] Existence and uniqueness of x_1 is shown in the proof of Lemma in Appendix A.

[18] The demand function for the product under a worker-owned firm is the same as that under a capitalist firm, (15).

[19] The second derivative of U_2 is given by

$$U_2''(x) = n_3[v_3'''(x)x + 2v_3''(x) - v_1'''(k^0 - k)k + 2v_1''(k^0 - k) + v_2''(l^0 - l)]$$

which is negative under (A.1). The second order condition is therefore satisfied.

[20] The supply functions for the physical capital services and labor under a consumer cooperative are the same as those under a worker-owned firm and a capitalist firm, (17) and (14), respectively.

[21] The second derivative of U_3 is given by

$$U_3''(x) = n_3[-v_1'''(k^0 - k)k + 2v_1''(k^0 - k) - v_2'''(l^0 - l)l + 2v_2''(l^0 - l) + v_3''(x)]$$

which is negative under (A.1). The second order condition is therefore satisfied.

firm, $\dot{k}(r_3)$ is the rate of change in the supply of the physical capital services at the equilibrium under a consumer cooperative, and so on. We now obtain the following result.

Proposition. *A capitalist firm will be formed if* (P.1) $\dot{k}(r_1) < \min\{\dot{l}(w_1), -\dot{x}(p_1)\}$, *a worker-owned firm will be formed if* (P.2) $\dot{l}(w_2) < \min\{\dot{k}(r_2), -\dot{x}(p_2)\}$, *and a consumer cooperative will be formed if* (P.3) $-\dot{x}(p_3) < \min\{\dot{k}(r_3), \dot{l}(w_3)\}$.[22]

Proof. See Appendix A. □

The following remark assures that this proposition is well defined.

Remark. (P.1) through (P.3) in Proposition are mutually exclusive and exhaustive. That is, out of (P.1) through (P.3), no two cases take place simultaneously, and except for boundary situations one case must always occur.

Proof. See Appendix B. □

The earlier proposition can be interpreted as follows. Let us first consider the case of monopoly. When the demand for the product is insensitive to the product price, the seller of the product will exercise a strong monopoly power over the consumers in the product market. The efficiency loss caused by the monopoly power in the product market can be prevented by forming a consumer cooperative, since the product market is not used under a consumer cooperative. (Indeed, the product is not *sold* and *bought* under a consumer cooperative. Notice that the product price p does not appear in payoffs, (9) through (11), under a consumer cooperative.) A similar reasoning holds for the case of monopsony. When the supply of labor is insensitive to the wage, the employer of labor will exercise a strong monopsony power over the workers in the labor market. The efficiency loss caused by the monopsony power in the labor market can be prevented by forming a worker-owned firm since the labor market is not used under a worker-owned firm. (Indeed, the labor is not hired under a worker-owned firm. Notice that the wage w does not appear in payoffs, (6) through (8), under a worker-owned firm.) Also, when the supply of physical capital services is insensitive to the rental rate, the renter of physical capital will exercise a strong monopsony power over the owners of physical capital in the rental market for physical capital. The efficiency loss caused by the monopsony power in the rental market for physical capital can be prevented by forming a capitalist firm since the rental market for physical capital is not used under a capitalist firm. (Indeed, physical capital is not rented under a capitalist firm. Notice that the rental rate r does not appear in payoffs (3) through (5) under a capitalist firm.) In sum, the best way of coordinating transactions is to eliminate the market with the strongest market power, and leave the markets with only weaker market power.

[22] If it happens that $\dot{k}(r_1) = \dot{l}(w_1) < -\dot{x}(p_1)$ in case (P.1), for instance, then capitalist and worker-owned firms are equally desirable, so individuals are indifferent to the choice between the two enterprise forms.

4. Empirical observations

Various economic factors are thought to influence the actual organizational form of enterprise. Market power, as discussed in this paper, is just one possible determinant, and it can explain at most one aspect of the reality. In this section, based on the theoretical result obtained in the previous sections, we briefly discuss possible involvement of market power in an establishment of worker-owned firms and consumer cooperatives.

4.1. Worker-owned firms

Overall, the labor market today appears fairly competitive in developed countries. Monopsony power hence may not be an extensive cause for an establishment of worker-owned firms there. At an earlier stage of the market economy, however, the labor market was not as competitive as today, and some historical cases are observed in which worker-owned firms were established to cope with the exploitation of labor by the capitalist firm. Even today, when mobility of labor is imperfect, monopsony power can still exist in local labor markets where worker-owned firms are established in response.

Worker-owned firms can be observed from the very beginning of the history of market economy. In the late 18th century England, where private mill owners dominated the market for flour, workers struggled with unfavorable working conditions. They tried to cope with the situation by starting similar ventures by themselves. Workers built mills and bakeries in such places as Woolwich, Chatham, and Hull, and ran them cooperatively (Thornley, 1981, p. 12–13). In the 19th century, English workers were still suffering from poor working conditions in a market dominated by capitalist firms: wages were low, jobs were hard, repetitive and long lasting, and workplaces were unsafe and unhealthy. In this background, the Rochdale Society emerged in Rochdale. The members of the society were skilled workers, including a weaver, wool sorter, clogger, cabinet maker, tailor, joiner, hatter, and shoe maker. In 1854, they established a cotton factory by leasing a workroom. The factory was run in a cooperative manner with workers all being shareholders. Many workers' cooperatives of a similar nature were established throughout the 1840s in various places of England (Oakeshott, 1978, Chapter 5; Thornley, 1981, p. 18–20). These workers' cooperatives established in the Industrial Revolution period seem to be a pertinent example of the worker-owned firms that were created to cope with the capitalist firm's exploitation of workers in monopsonistic market conditions.

A similar case can be found in the United States. In the wave of recession of the early 20th century, shingle industry workers in Washington were suffering from unfavorable working conditions. The shingle weavers had little or no job security and had few alternatives for employment in towns controlled by large timber companies. With low capitalization requirements for entry into the industry, the shingle weavers sought a solution by establishing workers' cooperatives (Aldrich and Stern, 1983, p. 381–384). With few alternative job opportunities, weavers' supply of labor was thought fairly insensitive to the wage, putting the timber companies in an easy position to exploit the

weavers. It seems quite reasonable that the weavers established worker-owned firms in this environment.[23]

It is argued that when a worker chooses his job, personal reasons, such as a personal connection to, or an intimacy with, a certain geographical area play an important role, sometimes more important a role than wages (Addison and Siebert, 1979, Chapter 5, Section 4). Workers are therefore often imperfectly mobile between regions, thus allowing a local labor market to have a monopsonistic structure. For example, empirical research found monopsony power in the local market for school teachers, printing employees, construction workers, and hospital nurses (Addison and Siebert, 1979, Chapter 5, Section 2). Addison and Siebert (1979, p. 166) argue that 'the fact that many nurses are often secondary workers also tends to limit geographical mobility and reduce their elasticity of supply in an area'. If monopsony power exists in a local labor market, there may well be a good reason to establish worker-owned firms in town to avoid the exploitation of workers. For example, some of the major characteristics of the plywood industry in the United States are its geographical concentration close to raw materials in an area distant from major markets and a market dominated by the construction industry (Berman (1967, Chapter 3)). It is understandable that worker-owned plywood cooperatives were born and grew in such market circumstances. In fact, Ben-Ner (1987, p. 437–438, 444) explained the prevalence of plywood manufacturing cooperatives in the Pacific Northwest due to monopsony power in the local labor market. If Addison and Siebert's argument can be applied to other occupations in town, such as construction workers, printing employees, or transportation workers who are also secondary, then local monopsony power may account for the worker-owned firms in construction industry in Italy, printing industry in France, or transportation industry in Sweden and Israel.[24] As well, we see food processing workers' collectives in farm areas of Japan that produce foods, such as jam and syrup from the raw agricultural products produced in that area. Rationality for these worker-owned firms may also lie in monopsonistic labor markets in remote farm areas (Tomizawa and Kawaguchi, 1997, Chapter 7).

4.2. Consumer cooperatives

In the present context, a consumer cooperative is not restricted to the firm that is owned by households, such as consumer-owned grocery cooperatives. It also includes firms that are owned by producers, such as farmer-owned farm supply cooperatives or retailer-owned wholesale cooperatives.

Cooperatives of farm supplies, such as fertilizer, petroleum, farm chemicals, livestock feeds, or seeds, seem a typical example of the consumer cooperative that is established to avoid market power. Historically, farm supply cooperatives grew most rapidly during the two decades after World War 1, when investor-owned firms dominated the market for farm supplies (Hansmann, 1996, p. 149–151). The farm supplies listed earlier are all necessities for farmers, so the demand for those goods cannot be very sensitive to the price. It then

[23] We can see various examples for worker-owned firms that are similar to the shingle industry in the modern history of the United States. For a brief summary on this issue, see Berman (1967), Chapter 2.

[24] For worker-owned firms in these countries, refer to Oakeshott (1978), Chapters 8 and 9; Thornley (1981), Chapters 8 and 9; Bonin et al. (1993); and Hansmann (1996), Chapter 5.

follows that a proprietary high price would prevail under monopoly by a capitalist firm. Such exploitation can be avoided by organizing the firm as a farmer cooperative, as was discussed in the previous sections.

Retailer-owned wholesale cooperatives provide yet another example that matches our argument. Wholesale firms that supply hardware to hardware retailers, groceries to grocery stores, drugs to drug stores, and baking supplies to bakeries, are often owned by the retailers (Hansmann, 1996, pp. 157–158). As farm supplies are to farmers, these types of merchandise are essential for the retailers to do their business, thus making the demand for these goods insensitive to the price. If an economic condition, such as economies of scale allows only a limited number of wholesalers to operate in the distribution system, then they would exploit the retailers were they organized as an investor-owned firm. Retailer-owned wholesale cooperatives can be a solution to avoid such exploitation of retailers and improve overall efficiency of transactions.

Consumer-owned retail cooperatives appear less common than retailer-owned wholesale cooperatives in the United States. One exception is retail of books, in which student-owned university bookstores contribute to a relatively large market share of consumer cooperatives (Hansmann, 1996, p. 161–163). Although books in general may not be categorized as necessary goods, textbooks are necessities for university students. Demand for textbooks is hence thought relatively insensitive to the price. Since usually only one major bookstore resides on a campus, it would exploit students were it organized as an investor-owned firm. Strong incentives thus arise for replacing investor ownership with student ownership for campus bookstores.

Customer-owned electricity cooperatives are common in rural areas of the United States. It is reported that about 50 percent of all electric power consumed in rural areas is supplied by electricity cooperatives (Berman, 1967, p. 9; Hansmann, 1988, p. 297–298; Hansmann, 1996, chptr 9). Since electricity is a fundamental resource for households, its demand cannot be very sensitive to the electricity price, and since the market for electricity becomes monopolistic by a technological reason (i.e. a decreasing average cost), customers are exposed to a proprietary high price for electricity. Price regulation by the government is one common means for dealing with this problem, which is inclusively applied to the electric power companies in urban areas. Customer ownership can be an alternative solution. That is, by organizing the firm as a customer-owned electricity cooperative, the market for electricity, which is subject to natural monopoly, can be dispensed with, and then overall efficiency of transactions is improved.

5. Conclusion

In this paper, we studied how market power affects the form of enterprise. The main result, the proposition in Section 3, states that enterprise forms are determined by the intensity of market power in each market, which in turn depends upon how sensitive the input supply and output demand are to their prices.

In interpreting the result, we introduced a perspective of ownership of the firm as a selection of markets used for transactions among individuals. In principle, this viewpoint can be applied not only to the issue of market power as discussed in this paper, but also to

other sorts of market failure, such as asymmetric information or externalities. Whatever the cause of market failure, individuals can be better off by choosing an enterprise form that dispenses with the market with the greatest distortion. In this sense, firm ownership can be an effective means to deal with the market failure.

We conclude the paper with a brief discussion on the comparison of the present results with the conclusions presented in Ireland and Law (1982) and Stewart (1984) that made a comparative analysis between a capitalist firm and an Illyrian worker-owned firm in the context of market power.

Ireland and Law compared the equilibrium output levels of a capitalist firm and a worker-owned firm when both have monopoly power in the output market. They showed that a worker-owned firm will produce a lower amount of output than a capitalist firm. The reason for this is that an Illyrian worker-owned firm will restrict the number of workers who participate in production in order to realize a high net income per worker. In the present paper, on the other hand, other things (in particular, the degree of monopsony power over input) being equal, the presence of market power in the output market makes no difference regarding the equilibrium output level between capitalist and worker-owned firms. This is because, in the present framework, the degree of market power in the output market depends on the shape of the demand function of consumers; thus, it does not matter *who* exerts the market power on consumers as far as the distortion created in the output market is concerned. Of course, when the degree of monopsony power over input is uneven between capitalist and worker-owned firms, some differences will arise in the equilibrium output levels between the two enterprise types.

Stewart compared the equilibrium output levels of capitalist and worker-owned firms when they have monopsony power in hiring labor. He considered two kinds of equilibrium, one with a binding labor supply constraint (that requires that the net income per worker be greater than or equal to the wage on the labor supply function), and one without it. When the constraint is binding, a worker-owned firm will produce more than a capitalist firm since a worker-owned firm will try to realize a higher employment level. When the labor supply constraint is not binding, on the other hand, the equilibrium output level of a worker-owned firm can be greater, or less than, that of a capitalist firm, depending on the shape of the marginal outlay curve (which is defined to be the derivative of total wage payment with respect to the employment level) in relation to the employment level that maximizes the net income per worker. The result obtained in the present paper has a somewhat similar appearance to the second case of Stewart, in the sense that the output level of a worker-owned firm may, or may not, be greater than that of a capitalist firm. The logic underlying our result is quite different from that of Stewart, however. In the present model, the difference in the equilibrium output levels between capitalist and worker-owned firms derives from unequal monopsony power exercised by the two firms. Obviously, the difference in reasoning between the two studies begins with how a worker-owned firm is modeled. That is, the worker-owned firm in Stewart is of Illyrian type, whereas in the present paper it is a symmetric counterpart to a capitalist firm with workers having the right to make decisions and claim residual earnings of the firm.

Essentially, such difference in conclusion between the previous contributions and the present study stems from the assumed objective function of the firm. That is, in Ireland and Law, as well as in Stewart, Illyrian labor-managed firms are assumed, where net income

per worker is maximized. In the present paper, on the other hand, the total utility for the owners is maximized regardless of the corporate form. That is, the total profit is maximized in a capitalist firm, the total surplus to workers is maximized in a worker-owned firm, and the total consumer surplus is maximized in a consumer cooperative.

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Appendix A. Proof of Proposition

The next lemma shows that an enterprise form that realizes a higher output level is socially more efficient.

Lemma. *For* $i, j \in \{1, 2, 3\}$ with $i \neq j$,

$$x_i > x_j \Leftrightarrow V(x_i) > V(x_j). \tag{20}$$

Proof. First, in (13), $V'(0) > 0$ by (A.2), $V'(\hat{x}) < 0$ for some $\hat{x}$ by (A.3), V is continuous because v_i', $i \in \{1, 2, 3\}$, is continuous by Assumption, and V' is strictly decreasing as shown in footnote 13. Therefore, there exists a unique x^*.

Next, under a capitalist firm, from (14) and (15), it holds that $w(l) = v_2'(l^0 - l)$, $w'(l) = -v_2''(l^0 - l)$, $p(x) = v_3'(x)$ and $p'(x) = v_3''(x)$. Then, (16) is rewritten as

$$U_1'(x) = n_3[v_3'(x) + v_3''(x)x - v_1'(k^0 - k) - v_2'(l^0 - l) + v_2''(l^0 - l)l] = 0. \tag{21}$$

Since $v_i'' < 0$ for $i \in \{2, 3\}$ by (A.1), $U_1'(x) < V'(x)$ for all $x > 0$. Then, since $U_1'(0) = V'(0) > 0$ by (A.2), $U_1'(\hat{x}) < V'(\hat{x}) < 0$ for some $\hat{x} > 0$ by (A.3), U_1' is continuous because v_i' and v_i'', $i \in \{1, 2, 3\}$, are continuous by Assumption, and U_1' is strictly decreasing as shown in footnote 16, there exists a unique x_1. In particular, since $U_1'(x^*) < V'(x^*) = 0$ as shown earlier, it holds that $x_1 < x^*$. By a similar procedure, we obtain $x_i < x^*$ for $i \in \{2, 3\}$.

Since $V(x)$ is strictly increasing in x over $[0, x^*]$, for $i, j \in \{1, 2, 3\}$ with $i \neq j$, it holds that $x_i > x_j \Leftrightarrow V(x_i) > V(x_j)$. □

Proof of Proposition. Here, we only prove the case of (P.1). The remaining two cases can be proven by a similar procedure.

From (16) and (18), together with (14) and (17), we have

$$U_1'(x_1) - U_2'(x_1) = n_3 \left[\frac{1}{\dot{k}(r_1)} - \frac{1}{\dot{l}(w_1)} \right] \tag{22}$$

where the relations $r'(k_1) = 1/k'(r_1)$ and $w'(l_1) = 1/l'(w_1)$ are used. Hence, it holds that

$$\dot{k}(r_1) < \dot{l}(w_1) \Leftrightarrow U_1'(x_1) > U_2'(x_1). \tag{23}$$

Next suppose that $U_1'(x_1) > U_2'(x_1)$. Notice that U_2' is continuous because v_i' and v_i'', $i \in \{1, 2, 3\}$, are continuous by Assumption, that U_2' is strictly decreasing as shown in footnote 19, that $U_2'(0) = V'(0) > 0$ by (A.2), and that $U_2'(x_1) < U_1'(x_1) = 0$ by assumption. Then, it holds that $x_1 > x_2$. Hence, we have

$$U_1'(x_1) > U_2'(x_1) \Rightarrow x_1 > x_2. \tag{24}$$

Then, from (23) and (24), together with (20) of Lemma, it holds that

$$\dot{k}(r_1) < \dot{l}(w_1) \Rightarrow V(x_1) > V(x_2). \tag{25}$$

Similarly, since

$$U_1'(x_1) - U_3'(x_1) = n_3 \left[\frac{1}{\dot{k}(r_1)} + \frac{1}{\dot{x}(p_1)} \right] \tag{26}$$

it holds that $\dot{k}(r_1) < -\dot{x}(p_1) \Leftrightarrow U_1'(x_1) > U_3'(x_1)$. By a similar procedure as seen earlier, it holds that $U_1'(x_1) > U_3'(x_1) \Rightarrow x_1 > x_3$. Hence, with (20), it holds that

$$\dot{k}(r_1) < -\dot{x}(p_1) \Rightarrow V(x_1) > V(x_3). \tag{27}$$

(25) and (27) complete the proof for the case of (P.1). □

Appendix B. Proof of Remark

We first show that

$$U_i'(x_i) > U_j'(x_i) \Leftrightarrow U_i'(x_j) > U_j'(x_j) \tag{28}$$

for $i, j \in \{1, 2, 3\}$ with $i \neq j$. Suppose that $U_i'(x_i) > U_j'(x_i)$. Notice that U_j' is continuous because v_h' and v_h'', $h \in \{1, 2, 3\}$, are continuous by Assumption, that U_j' is strictly decreasing as shown in footnotes 16, 19, and 21, that $U_j'(0) = V'(0) > 0$ by (A.2), and that $U_j'(x_i) < U_i'(x_i) = 0$ by assumption. Then, it holds that $x_j < x_i$. Since U_i' is also continuous and strictly decreasing, it holds that $U_i'(x_j) > 0$. Then, since $U_j'(x_j) = 0$ by the definition of x_j, it holds that $U_i'(x_j) > U_j'(x_j)$. The reverse direction can be proved in a similar way.

Next, since

$$\dot{k}(r_1) < (>)\dot{l}(w_1) \Leftrightarrow U_1'(x_1) > (<)U_2'(x_1)$$

(see (22)) and

$$\dot{k}(r_2) < (>)\dot{l}(w_2) \Leftrightarrow U_1'(x_2) > (<)U_2'(x_2)$$

it holds from (28) that

$$\begin{aligned}&\dot{k}(r_1) < (>)\dot{l}(w_1)\\ &\quad\Leftrightarrow U_1'(x_1) > (<)U_2'(x_1) \Leftrightarrow U_1'(x_2) > (<)U_2'(x_2) \Leftrightarrow \dot{k}(r_2) < (>)\dot{l}(w_2).\end{aligned} \tag{29}$$

Similarly, it holds that

$$\begin{aligned}&\dot{k}(r_1) < (>) - \dot{x}(p_1)\\ &\quad\Leftrightarrow U_1'(x_1) > (<)U_3'(x_1) \Leftrightarrow U_1'(x_3) > (<)U_3'(x_3) \Leftrightarrow \dot{k}(r_3) < (>) - \dot{x}(p_3)\end{aligned} \tag{30}$$

and

$$\begin{aligned}&\dot{l}(w_2) < (>) - \dot{x}(p_2)\\ &\quad\Leftrightarrow U_2'(x_2) > (<)U_3'(x_2) \Leftrightarrow U_2'(x_3) > (<)U_3'(x_3) \Leftrightarrow \dot{l}(w_3) < (>) - \dot{x}(p_3).\end{aligned} \tag{31}$$

Now, suppose that (P.1) holds. Then, since $\dot{l}(w_1) > \dot{k}(r_1)$ implies $\dot{l}(w_2) > \dot{k}(r_2)$ by (29), (P.2) does not hold. Also, since $-\dot{x}(p_1) > \dot{k}(r_1)$ implies $-\dot{x}(p_3) > \dot{k}(r_3)$ by (30), (P.3) does not hold. Similarly, when (P.2) holds, (P.1) and (P.3) do not hold by (29) and (31), and when (P.3) holds, (P.1) and (P.2) do not hold by (30) and (31). Hence, (P.1) through (P.3) are mutually exclusive.

Finally, suppose that none of (P.1), (P.2) and (P.3) holds. Then, it must hold that $\dot{l}(w_1) < \dot{k}(r_1)$ or $-\dot{x}(p_1) < \dot{k}(r_1)$ (so that (P.1) does not hold), that $\dot{k}(r_2) < \dot{l}(w_2)$ or $-\dot{x}(p_2) < \dot{l}(w_2)$ (so that (P.2) does not hold), and that $\dot{k}(r_3) < -\dot{x}(p_3)$ or $\dot{l}(w_3) < -\dot{x}(p_3)$ (so that (P.3) does not hold).

Let us begin with the conditions with which (P.1) does not hold. Suppose first that

$$\dot{l}(w_1) < \dot{k}(r_1). \tag{32}$$

By (29), (32) implies that

$$\dot{l}(w_2) < \dot{k}(r_2) \tag{33}$$

so that in order for (P.2) not to hold we must have

$$-\dot{x}(p_2) < \dot{l}(w_2). \tag{34}$$

By (31), (34) implies that

$$-\dot{x}(p_3) < \dot{l}(w_3) \tag{35}$$

so that in order for (P.3) not to hold we must have

$$\dot{k}(r_3) < -\dot{x}(p_3). \tag{36}$$

By (30), (36) implies that

$$\dot{k}(r_1) < -\dot{x}(p_1). \tag{37}$$

From (32) through (37), we have

$$\dot{l}(w_1) < \dot{k}(r_1) < -\dot{x}(p_1) \tag{38}$$

$$-\dot{x}(p_2) < \dot{l}(w_2) < \dot{k}(r_2) \tag{39}$$

and

$$\dot{k}(r_3) < -\dot{x}(p_3) < \dot{l}(w_3). \tag{40}$$

By (29)–(31), (38)–(40) are equivalent to

$$U_3'(x_1) < U_1'(x_1) < U_2'(x_1) \tag{41}$$

$$U_1'(x_2) < U_2'(x_2) < U_3'(x_2) \tag{42}$$

$$U_2'(x_3) < U_3'(x_3) < U_1'(x_3) \tag{43}$$

respectively. Since $U_1'(x_1) = 0$ and U_2' and U_3' are strictly decreasing, (41) implies that $x_3 < x_1 < x_2$. Then, since U_3' is strictly decreasing, it must be that $U_3'(x_2) < 0 = U_2'(x_2)$. This contradicts the second inequality of (42). (Also, since U_2' is strictly decreasing, it must be that $U_2'(x_3) > 0 = U_3'(x_3)$. This contradicts the first inequality of (43).) Thus, assuming (32) leads to a contradiction. In the similar way, assuming $-\dot{x}(p_1) < \dot{k}(r_1)$ also leads to a contradiction. Assuming that none of (P.1), (P.2) and (P.3) holds thus leads to a contradiction. (Similarly, starting with the conditions with which (P.2) or (P.3) does not hold, we reach the same conclusion.) Hence, (P.1) through (P.3) are exhaustive. □

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