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On the optimal production and location of a labor-managed firm

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Abstract. This paper endeavors to introduce *space* into the theory of the Labor-Managed firm (LMF) and to investigate its optimal production and location decisions. It is shown that the degree of returns to scale plays a key role in the determination of optimal production and location for an LMF, in particular, that the optimal location of an LMF is farther away from (closer to) the market as compared to a profit-maximizing firm (PMF) if the production function is of increasing (decreasing) returns to scale. We also demonstrate that the optimum location of an LMF moves closer towards the market as demand increases, regardless of whether the production function is of increasing or decreasing returns to scale. This finding is in sharp contrast with that in a capitalist economy.

JEL classification: R70, D21

1. Introduction

Since the seminal paper on the subject by Ward (1958), a considerable number of studies have dealt with various aspects of the labor-managed economy (see Domar 1966; Vanek 1970; Meade 1974; Gal-Or et al. 1980; Paroush and Kahana 1980; Hey 1981; Hill and Waterson 1983; Mai and Shih 1984; Mai and Hwang 1989; Kahana 1989; Choi and Feinerman 1991; Zhang 1993; Haruna 1996 and others). Their primary objective has been to examine the differences between labor-managed and capitalist economies. These studies have, more specifically, looked into one of the most fundamental issues in the theory of the labor-managed firm (LMF), that is, the comparison of the output policies of an LMF with those of a profit-maximizing firm (PMF). In particular, it has been shown that an LMF produces less output and employs less labor than a PMF under perfect competition (Ward (1958)) or under monopoly (Gal-Or et al. (1980)).

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In recent years, considerable effort has been devoted to the study of the choice of location for a PMF (see for example, Moses 1958; Sakashita 1967; Khalili et al. 1974; Mathur 1979; Eswaran et al. 1981 and Mai 1981). In contrast, the study of the choice of location for a LMF has been greatly neglected.[1] This is particularly surprising, considering that the analysis of cooperative enterprises has practical relevance. This kind of operational system can be found not only in eastern European countries such as the former Yugoslavia and USSR,[2] but also in some modern enterprises in the west. For example, numerous instances of LMFs have been identified in the US. Two of the more interesting clusters are the plywood cooperatives (Gunn 1984; Craig and Pencavel 1992), and employee stock ownership plans (abbreviated to ESOPs, Blasi 1988). In Europe, one of the largest and best known examples of an LMF is the Spanish Mondragon cooperative complex (Whyte and Whyte 1988), some of whose participating companies are leading Spanish exporters. Thomas and Logan (1982) showed that LMFs attracted 4 times as much investment as PMFs, and that they also accrued much higher profits than PMFs. In Italy, LMFs receive strong state support through tax concessions and public contracts; and its famous cooperative Muratori e Comentisti (CMC) is a major constructor of dams and roads in Africa (Earle 1986). LMFs also exist in France (Sibille 1982), the United Kingdom (Wright et al. 1989) and other countries such as Australia, Canada, Denmark, Sweden and Israel, as well as in the continents of Africa, South America and Asia (Bonin et al. 1993). In addition, many hospitals and law firms operate in such a way as to maximize income per head of physicians or lawyers on the staff. However, one is hard-pressed to find studies comparing the locational choice for an LMF with that of a PMF; nor can one find any formal analysis of the effect a change in market demand has on the locational choice of an LMF. The purpose of this paper is to initiate an investigation into these issues by presenting a formal model leading to comparisons of the production and locational choices of LMFs and PMFs, as well as to provide an appraisal of the relationship between production function and an LMF's production and location choices.

The paper is organized as follows. In the next section, a basic model is developed, followed in Sect. 3 by a comparison of equilibrium solutions for an LMF with those of a PMF. Section 4 conducts a comparative static analysis to evaluate the impact of an increase in demand on output when the location of the LMF is endogenously determined, and then compares it with the impact produced when the location is exogenously given. The impact of an increase in demand on the LMF's location is examined in Sect. 5. Some concluding remarks comprise the final section.

2. The basic model

Consider a spatial economy in which the location of a firm is confined to a set of points along a line of length s between I, the site of the input K and

[1] Hsu's work (1983) is an exception, as he considered the location decision of a cooperative firm in a world with price uncertainty. His analysis, however, differs from ours.

[2] See the discussions in Ward (1958), Bonin and Fukuta (1986), Dentsch and Kahana (1988) and so on.

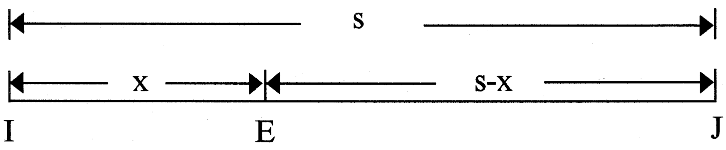

Fig. 1. A line space

the market, and J, the site of the input L as depicted in Fig. 1. We define x as the distance between I and the firm's location point E, and restrict $x \in [0, s]$. The firm uses these two transportable inputs to produce output. The production function of the firm may be specified as:

$$Q = f(L, K), \quad f_L, f_K > 0, \text{ and } f_{LL}, f_{KK} < 0 \tag{1}$$

noting that subscripts or primes are used to denote derivatives in this paper.

Let us assume that the firm faces an inverse demand function for its product at the market site:

$$P = P(Q, \alpha), \quad P_Q < 0, P_\alpha > 0, \text{ and } P_{Q\alpha} = 0 \tag{2}$$

where α is a demand shift parameter (e.g., income).

The profit function is given by:

$$\pi = [P(Q, \alpha) - xt_0(x)]Q - [w + (s - x)t_1(x)]L - [r + xt_2(x)]K - F \tag{3}$$

where w and r are the base prices of L and K, at J and I, respectively; t_0, t_1 and t_2 are transport rates per unit distance of output and inputs, respectively, as a function of x; and F is the amortized sunk cost.

In defining $R(Q, \alpha) \equiv P(Q, \alpha)Q$ as total revenue and $T(Q, x) \equiv xt_0(x)Q + (s - x)t_1(x)L + xt_2(x)K$ as total transport cost, Eq. (3) can be simplified to:

$$\pi = R(Q, \alpha) - T(Q, x) - wL - rK - F \tag{4}$$

In a labor-managed economy, the firm operated so as to maximize income per laborer, as specified by:[3]

$$S \equiv \frac{\pi}{L} + w = \frac{R(Q, \alpha) - T(Q, x) - wL - rK - F}{L} + w \tag{5}$$

For ease of comparison, we shall explore the production and location decisions by choosing x and the output level Q, instead of the input usages L and K, to maximize the firm's income per laborer. Under such circumstances, the first-order conditions are given by:

[3] It is a common practice in the LMF literature to assume that the objective function of a LMF is to maximize surplus per worker. See for example, Hill and Waterson (1983); Kahana (1989); Haruna (1996) and Futagami and Okamura (1996).

$$S_Q = \frac{R_Q(Q,\alpha) - T_Q(Q,x) - wL_Q - rK_Q - (S-w)L_Q}{L} = 0 \tag{6-1}$$

$$S_x = \frac{-T_x(Q,x)}{L} = 0 \tag{6-2}$$

where

$$R_Q = P + QP_Q$$

$$T_Q = xt_0 + (s-x)t_1 L_Q + xt_2 K_Q$$

$$T_x = v_0(x)Q - v_1(x)L + v_2(x)K$$

$$v_0(x) \equiv t_0 + xt_0'$$

$$v_1(x) \equiv t_1 - (s-x)t_1'$$

$$v_2(x) \equiv t_2 + xt_2'$$

It warrants mention that the term L_Q represents a marginal response of labor usage to a change in output. If L_Q is positive (negative), then labor is a normal (inferior) input. A similar argument applies to the term K_Q.

Equation (6) characterizes the equilibrium system under a labor-managed economy. We are now in a position to examine the nature of system (6), as well as to consider some comparative statics.

3. Comparison of the solutions

The purpose of this section is to undertake a comparison of the equilibrium output and location of the LMF and the PMF. To accomplish this, we begin by introducing an economic system shift parameter λ into (6) and rewrite it as:[4]

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[4] A variant of this technique was suggested by Silberberg (1970) and Katz (1984). The comparison of the equilibrium output and location of the LMF and PMF can also be accomplished by the following hypothesized objective function:

$$\beta\left(\frac{R - T - wL - rK - F}{L} + w\right) + (1-\beta)(R - T - wL - rK - F)$$

When $\beta = 0$ ($\beta = 1$), the system is PMF (LMF). Taking the first-derivative with respect to Q yields the following first-order condition:

$$R_Q - T_Q - wL_Q - rK_Q = \frac{\beta}{\beta + (1-\beta)L}(S-w)L_Q \tag{F-1}$$

Setting $\lambda = \dfrac{\beta}{\beta + (1-\beta)L}$, we get Eq. (7-1) and $\dfrac{d\lambda}{d\alpha} = \dfrac{L}{[\beta + (1-\beta)L]^2} > 0$. Moreover, we can derive from (F-1) that $\beta = 0$ ($\beta = 1$), corresponding to $\lambda = 0$ ($\lambda = 1$), therefore the system is PMF (LMF). Hence, this alternative approach is consistent with the one specified in equation (7-1). We owe this point to one of the referees.

$$R_Q(Q, \alpha) - T_Q(Q, x) - wL_Q - rK_Q = \lambda(S - w)L_Q \tag{7-1}$$

$$-T_x(Q, x) = 0 \tag{7-2}$$

From (7), we observe that when $\lambda = 1$, system (7) reduces to that of (6), which is the system of the labor-managed economy. On the other hand, when $\lambda = 0$, the system is identical to that of a capitalist economy where the firm is operated on a profit-maximization basis. Hence, the shift from the system of the capitalist economy to that of the labor-managed economy can be captured by an increase of λ in (7) from 0 to 1.

We assume that at the outset, the firm was organized as a PMF (i.e., $\lambda = 0$) in (7-1). Due to the system changes, the firm becomes an LMF, and then we have $\lambda = 1$. Thus, the shift from the system of the capitalist economy to that of the labor-managed economy raises the right-hand side of (7-1) from zero to a positive or negative value depending on the sign of L_Q. As such, this will have the same effect on the system as an increase of λ in (7).

Totally differentiating (7) with respect to Q, x and λ, and applying Cramer's rule, we obtain:

$$\frac{dQ}{d\lambda} = \frac{-(S - w)L_Q T_{xx}}{D} \lesseqgtr 0 \quad \text{if } L_Q \gtreqless 0 \tag{8}$$

$$\frac{dx}{d\lambda} = \frac{(S - w)L_Q T_{xQ}}{D} \tag{9}$$

where

$$D \equiv \pi_{QQ}\pi_{xx} - \pi_{xQ}^2$$

$$\pi_{QQ} = R_{QQ} - T_{QQ} - wL_{QQ} - rK_{QQ}$$

$$\pi_{xx} = -T_{xx} = -v_0'Q + v_1'L - v_2'K$$

$$\pi_{xQ} = -T_{xQ} = -v_0(x) + v_1(x)L_Q - v_2(x)K_Q$$

Note that the second-order conditions require $D > 0$ and $T_{xx} > 0$.[5]

Let us first examine Eq. (8). Whether the LMF increases or decreases its output, as compared with the capitalistic twin, depends crucially upon the sign of L_Q. Moreover, making use of (6-1) and assuming that the production function is homogeneous of degree n[6], we can derive the following relation-

[5] The condition $T_{xx} > 0$ can be satisfied if we assume transport rates are decreasing and sufficiently convex to the origin with respect to distance. Thus, an interior solution can exist within our framework (see Hwang and Mai 1990).

[6] It should be noted that income-per-worker maximization for a monopolistic LMF with amortized sunk costs satisfies the returns to scale constraint. In other words, the returns to scale constraint and second-order conditions can be satisfied simultaneously, regardless of whether the production function is increasing ($n > 1$), constant ($n = 1$) or decreasing ($n < 1$) returns to scale.

ships: $L_Q = \frac{1}{n}\frac{L}{Q} > 0$, $K_Q = \frac{1}{n}\frac{K}{Q} > 0$ and $LK_Q = KL_Q$.[7] Under such conditions, it immediately follows that $\frac{dQ}{d\lambda} < 0$.[8]

From the above discussions, we can establish:

Proposition 1. *The output of an LMF is smaller (greater) than that of a PMF if labor is a normal (inferior) input.*

This result is similar to the one derived within a nonspatial framework. Note that with a homogeneous production function, all the inputs are normal inputs and an LMF always produces a smaller output level than a PMF.

Next, we turn to (9). With a homogeneous production function, (9) reduces to:

$$\frac{dx}{d\lambda} = \frac{(S-w)Lv_0(n-1)}{n^2 DQ} \gtreqless 0 \quad \text{if } n \gtreqless 1 \tag{9-1}$$

Therefore, we have:

Proposition 2. *Whether the optimum location of an LMF is closer to or farther away from the market, as compared to a PMF, depends on the returns to scale in production. More specifically, the optimum location of an LMF is farther away from (closer to) the market as compared to a PMF if the production function is of increasing (decreasing) returns to scale. They are at the same site if the production function is of constant returns to scale.*

The reasoning behind this proposition is as follows. As noted in Proposition 1, with a homogeneous production function, the output of the LMF is smaller than that of the PMF. It should be further noted that the optimum location is determined as a result of the trade-off between the transportation costs of both

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7 To obtain L_Q and K_Q, we may take total differentiation of the production function as specified in Eq. (1) to get

$$dQ = f_L\, dL + f_K\, dK. \tag{F-2}$$

Meanwhile, applying Euler's theorem, the production function of homogeneity of degree n is given by:

$$nQ = f_L L + f_K K. \tag{F-3}$$

From (F-1) and (F-2), we yield the following equation:

$$f_L L_Q + f_K K_Q = f_L \frac{L}{nQ} + f_K \frac{K}{nQ}. \tag{F-4}$$

This equation must be satisfied in every combination of L and K, which implies $L_Q = \frac{1}{n}\frac{L}{Q}$ and $K_Q = \frac{1}{n}\frac{K}{Q}$ and hence $LK_Q = KL_Q$.

8 This statement is true only if $\pi > 0$, as assumed in the model. It is reversed, however, if $\pi < 0$.

output and inputs. In the case of increasing (decreasing) returns to scale, a smaller output in the LMF results in a greater (smaller) input requirement per unit of output. Hence, a relatively greater (smaller) amount of inputs are transported as compared to output. This provides an incentive for the LMF to move away from (towards) the market in order to save on the transportation costs on inputs.

4. The impact of an increase in demand on output – endogenous versus exogenous location

This section attempts to demonstrate how the optimal output of the LMF is affected by an increase in demand and undertakes a comparison between optimal output policies with *endogenous* location and those with *exogenous* location.

First of all, the output effect with an endogenous location can be evaluated by totally differentiating the system of (6-1) and (6-2) with respect to Q, x and α:

$$\frac{dQ}{d\alpha} = \frac{-1}{nHL}[P_\alpha(n-1)S_{xx}] \tag{10}$$

where $H \equiv S_{QQ}S_{xx} - S_{Qx}^2 > 0$

$$S_{xx} = \frac{1}{L}(-T_{xx})$$

$$S_{QQ} = \frac{1}{L}(R_{QQ} - wL_{QQ} - rK_{QQ} - T_{QQ} - (S-w)L_{QQ})$$

$$S_{Qx} = \frac{1}{L}(-T_{Qx})$$

Since $P_\alpha > 0$, $H > 0$ and $S_{xx} < 0$ by the second-order conditions, it follows from (10) that $\frac{dQ}{d\alpha} \gtreqless 0$ if $n \gtreqless 1$.

Alternatively, by treating the location variable x exogenously, Eq. (6-1) alone is the relevant first-order condition. A simple calculation gives the comparative static result of α on Q, as follows:

$$\left.\frac{dQ}{d\alpha}\right|_{\bar{x}} = \frac{-P_\alpha(n-1)}{nS_{QQ}L} \gtreqless 0 \quad \text{if } n \gtreqless 1 \tag{11}$$

where $S_{QQ} < 0$ by the second-order condition.

To compare $\frac{dQ}{d\alpha}$ with $\left.\frac{dQ}{d\alpha}\right|_{\bar{x}}$, we subtract (11) from (10) to derive:

$$\frac{dQ}{d\alpha} - \left.\frac{dQ}{d\alpha}\right|_{\bar{x}} = \frac{-P_\alpha v_0^2}{n^3 S_{QQ}HL^3}(n-1)^3 \gtreqless 0 \quad \text{if } n \gtreqless 1 \tag{12}$$

Combining (10), (11) and (12), we can establish:

Proposition 3. *Irrespective of whether the location of the LMF is endogenously or exogenously determined, the effect of an increase in demand on the output depends upon the degree of returns to scale in production. If the production function exhibits increasing (decreasing) returns to scale, then the output will increase (decrease) as demand increases. Moreover, in the case of increasing returns to scale, the increase in the optimal output is greater when the location variable is treated endogenously than when it is treated exogenously. The converse is true in the case of decreasing returns to scale.*

To probe deeper into the cause of the deviation of $\frac{dQ}{d\alpha}$ from $\left.\frac{dQ}{d\alpha}\right|_{\bar{x}}$, we can rewrite (12) as:

$$\frac{dQ}{d\alpha} - \left.\frac{dQ}{d\alpha}\right|_{\bar{x}} = \frac{v_0(n-1)}{nS_{QQ}L} \cdot \frac{-P_\alpha v_0}{n^2HL^2}(n-1)^2 = \left.\frac{dQ}{dx}\right|_{\bar{x}} \cdot \frac{dx}{d\alpha} \tag{13}$$

The product of $\left.\frac{dQ}{d\alpha}\right|_{\bar{x}}$ (i.e., the change in Q with respect to x, when x is treated as an exogenous variable) and $\frac{dx}{d\alpha}$ (i.e., the change in x with respect to α) is the location-induced effect resulted from a change in α. It is this effect which apparently creates the deviation of $\frac{dQ}{d\alpha}$ from $\left.\frac{dQ}{d\alpha}\right|_{\bar{x}}$. In fact, it can be seen from (13) that the reason for $\frac{dQ}{d\alpha} > \left.\frac{dQ}{d\alpha}\right|_{\bar{x}}$ is that in the case of increasing returns to scale, an increase in demand induces the LMF to move towards the market (i.e., $\frac{dx}{d\alpha} < 0$), thus causing the output to rise (i.e., $\left.\frac{dQ}{dx}\right|_{\bar{x}} < 0$).

5. The effect of an increase in demand on the optimum location of an LMF

As is well known, in a capitalist economy one of the most important propositions is that the optimum location of a PMF is independent of output or demand function if, and only if, the production function is constant returns to scale. It moves towards (away from) the market as demand increases if the production function is increasing (decreasing) returns to scale. (See for example, Khalili et al. 1974 and Mathur 1979). It is interesting to see whether or not this proposition holds in the case of an LMF.

To pursue this, differentiating totally (6) with respect to Q, x and α, applying Cramer's rule and rearranging terms, we obtain:

$$\frac{dx}{d\alpha} = \frac{-P_\alpha}{n^2HL^2}(n-1)^2 v_0 \tag{14}$$

It immediately follows from (14) that $\frac{dx}{d\alpha} = 0$ if $n = 1$, but $\frac{dx}{d\alpha} < 0$ if $n \neq 1$. These results lead to:

Proposition 4. *The optimum location of an LMF is invariant with respect to a change in demand if, and only if, the production function exhibits constant returns to scale, otherwise it moves towards the market regardless of whether the production function exhibits increasing or decreasing returns to scale.*

Clearly, this proposition runs contrary to the conventional location theory for a capitalist economy. In the case of a PMF, an increase in demand necessarily leads to a rise in output; with an increasing (decreasing) returns to scale, the pull of the market will be greater (less) than that of the input sources, such that the firm will move its optimum location towards (away from) the market. On the other hand, in the case of an LMF, as noted in Proposition 3, if the production function is of increasing (decreasing) returns to scale, output will increase (decrease) as a result of an increase in demand. With an increasing returns to scale, such an increase in output will lead the firm to move towards the market. By the same token, a reduction in output will again move the optimum location towards the market under a decreasing returns to scale. Nevertheless, when the production function is of constant returns to scale, the optimal output does not change as the demand increases, hence the optimum location remains unchanged.

6. Concluding remarks

This paper endeavors to introduce *space* into the theory of the LMF and to investigate its optimal output and location decisions. It is shown that the degree of returns to scale plays a key role in the determination of optimal output and location for an LMF. In particular, we demonstrate that the optimum location of an LMF moves towards the market as demand increases, regardless of whether the production function is of increasing or decreasing returns to scale. This finding is in sharp contrast with that in a capitalist economy.

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