REVIEW ARTICLES

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ON THE LABOUR-MANAGED FIRM WITH HOMOTHETIC TECHNOLOGY

*Norman J. IRELAND and Peter J. LAW**

Following Ward (1958), Vanek (1970) and Meade (1972) it is often assumed that the labour-managed firm (LM-firm) chooses levels of factor inputs to maximise income per member.[1] Many papers have focussed primarily on the 'short-run' determination of an optimal membership level assuming membership to be freely variable and that all other inputs are fixed. Meade (1972, 1974) discusses the properties of such a model under certainty and Muzondo (1979) treats the same model in conditions of uncertainty when the expected utility from income per member is maximised by choice of membership level. Two reasons might be suggested for the apparent emphasis in the literature on models in which membership alone is variable. First, the distinction between membership and hired workers constitutes a major difference between LM-firms and profit-maximising firm (PM-firms). Secondly, comparisons of the behaviour of LM and PM-firms tend to be complicated if factors of production in addition to number of workers (membership) are allowed to adjust to optimal levels.[2]

However, in the short run it may be more reasonable to view membership as a fixed rather than variable input. Steinherr and Thisse (1979) and Brewer and Browning (1982) have shown that considerations such as solidarity, compensation for redundancy or even individualistic expected utility maximisation in the presence of redundancy risk may prevent membership reduction.[3] As capital input levels

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[1] Exceptions include the well-known model of Horvat (1967) and contributions in Sertel (1982). In the latter, a model is presented in Chapter 2 where cooperative membership deeds are bought and sold. The LM-firms can sell membership so that the actual net payment to the marginal new member is equal to the outside wage. Thus the firm's equilibrium will be identical to that of a capitalist firm with the same technology. In this paper we will constrain the LM-firm to treat all members in a similar way; then for instance new members cannot be discriminated against.

[2] Dirickx and Sertel (1982) analyse a model with worker effort and capital variable but with a fixed membership. See Sertel (1982).

[3] In Miyazaki and Neary's (1983) self-insurance model, membership is fixed in the short run and members choose a level of compensation payment for any of their number temporarily laid off.

will also tend to be fixed in the short run, it seems sensible to assume that reactions of both capital and number of workers (membership) to parameter changes may only occur after a long period of adjustment — for example with passage of time members will leave the LM-firm and need not be replaced. As Brewer and Browning (1982) remark »there will be a long-run drift to the Vanek membership and supply levels«. In the short run, on the other hand, there may be little significant response in terms of membership or capital input.[4] Thus the long-run response with all inputs variable seems a more appropriate topic for investigation than the analysis of optimal membership levels for fixed levels of all other inputs.

It is the purpose of the present paper to show that the assumption of restricted homotheticity as suggested by Ireland (1981a, Ch. 1) and Bonin (1981) yields extremely strong results within a simple long-run model of the competitive LM-firm. This technology permits easy comparison of output levels in LM and PM-firms both under certainty and uncertainty and also under the assumptions of both fixed and variable labour input per member. The following analysis distinguishes two kinds of long run. The equilibrium of an LM-firm which can adjust all factor inputs and which faces a parametric product price and capital rental is discussed in Section I where various comparative statics results are also derived; and in Section II we describe the comparable equilibrium of a PM-firm. A »very long run« adjustment process which additionally allows entry and exit of firms to equalise profits or members' earnings across industries is considered in Section III, where it is demonstrated that entry has no effect on an LM-firm's output level but reduces that of the PM-firm. In some circumstances the very long run equilibrium of the systems will be characterised by equal output in the two types of firm — such equivalence results are well-known in the literature. However, we also consider reasons why the very long run equilibrium of the two systems may differ. In particular, it is shown that LM and PM-firms respond differently to the presence of uncertainty, with the result that the risk-averse LM-firm will produce a higher output than the corresponding PM-firm in the very long run. Section IV contains some brief conclusions from our analysis.

I HOMOTHETIC TECHNOLOGY AND THE LABOUR-MANAGED FIRM

We will assume that the LM-firm has N identical members and each member has preferences which may be described by the quasi-concave utility function

$$U = U(y, l)$$

where y denotes income per member and l is the level of effort per member. Thus, when capital rental agreements expire or when members retire or leave the firm for other reasons, decisions on new capital input and membership levels are made by reference to (1). The levels of (y, l) must satisfy the budget constraint

$$y = \frac{pQ - rK}{N} \tag{2}$$

where p is the product price, Q is the firm's output level and K is the capital input hired by the firm at rental rate, r.

Several important assumptions are made concerning the nature of technology. The production level, Q, is determined by the strictly increasing function

$$Q = H(Z) \tag{3}$$

where

$$Z = F(K, N, l) \tag{4}$$

The variable Z may be interpreted as an index of inputs and it will be assumed that the production of Z for given l is homogeneous of degree one in (K, N). Thus, at any given level of effort, doubling both capital and membership levels doubles the index of factor inputs, Z. An interior solution is ensured by imposing on H(Z) the general shape shown in Figure 1 which implies a region of increasing returns to scale at low levels of output and decreasing returns at high levels.[5] In short, the production technology is homothetic in (K, N), the relation between outputs and the index of inputs (Figure 1) implies a scale elasticity which declines with output from a value exceeding unity to a value less than unity, and the technology reflects the additional restriction that l does not determine the level of output except through Z. A measure of empirical support for these theoretical assumptions is provided by the work of Ringstad (1974) based on Norwegian establishment data for mining and manufacturing.

The equilibrium of the LM-firm is determined by substituting (2), (3) and (4) into (1) and maximising utility with respect to K and N to yield the first-order conditions.

$$U_y \frac{(pH_zF_K - r)}{N} = 0 \tag{5}$$

$$U_y \frac{(pH_zF_KN - pQ + rK)}{N^2} = 0 \tag{6}$$

[4] Labour input per member (effort or hours worked) might vary in both the short run and the long run.

[5] In his interesting »unified approach« Hey (1981) assumes strict concavity of the production function. However, given this assumption, no interior equilibrium exists for a y-maximising LM-firm with both K and N variable and fixed l per member. For related disoussion on this existence problem see Pestieau and Thisse (1979) and Landsberger and Subotnik (1980).

Utility may also be maximised with respect to l (members jointly chose a common l) or l may be determined by a non-cooperative game.[6] However, (5) and (6) are sufficient to determine the output of the LM-firm under present assumptions, whatever the level of effort, l. Multiply (5) by NK, (6) by N^2 and add to yield

$$U_r [pH_z (F_K K + F_N N) - pH(Z)] = 0 \tag{7}$$

Then, using Euler's theorem on the linear homogeneous function $F(\cdot)$ and noting that $U_r > 0$, we may rewrite (7) as

$$H_z Z - H(Z) = 0 \tag{8}$$

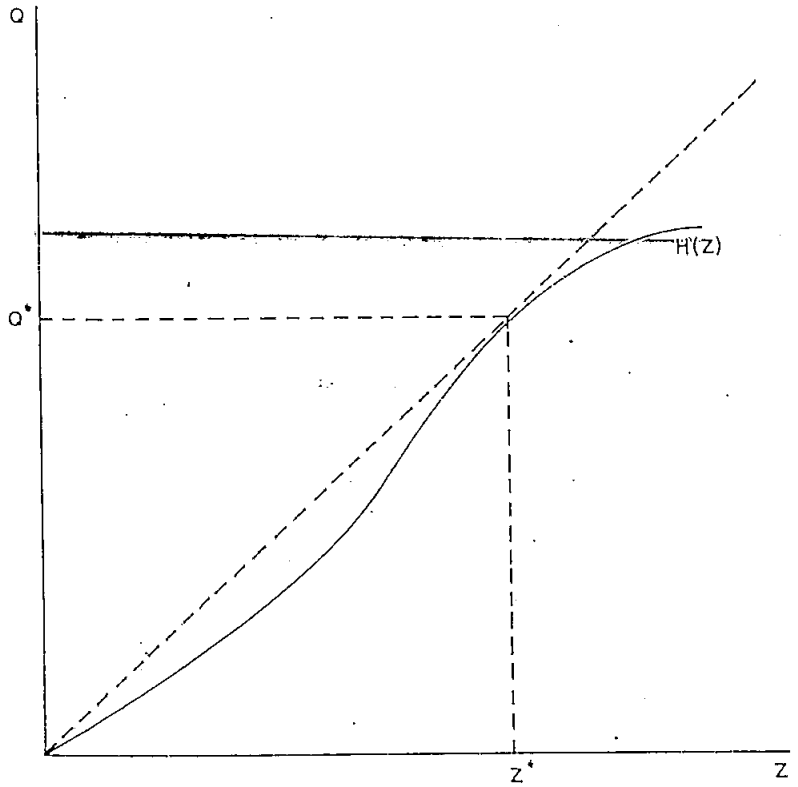

Fig. 1.
*Equilibrium under restricted homothetic technology: average product (H/Z) of the index of inputs is maximised at Z**

The solution to (8) is the point (Z*, Q*) in Figure 1, denoting maximum output per unit of the input index, Z. Note that this solution is purely technologically determined and is independent of (i)

the utility function, (ii) the prices p and r and (iii) the level of effort l.

An explanation for this particularly strong result, and one which has some intuitive appeal, is provided by the dual cost function approach to the equilibrium of the LM-firm.[7] Let the solution to the problem

$$\min_{(K, N, y, l)} \quad rK + yN \tag{9}$$

subject to (1) and (4) be $C(Z, U, r)$ where $C(\cdot)$ denotes the minimum cost of generating Z units of the input index, providing U units of utility per member and paying a rental, r, per unit of capital. Now, $F(\cdot)$ is homogeneous of degree one in (K, N), so this cost function may be written as[8]

$$C = Z.\emptyset(U, r) \tag{10}$$

Thus the LM-firm may be viewed as rewarding its members with the highest level of utility which satisfies the break-even constraint

$$Z.\emptyset(U, r) = pH(Z)$$

that is

$$\emptyset(U, r) = \frac{pH(Z)}{Z} \tag{11}$$

The function $\emptyset$ is increasing in U for any (r, p) so it follows that the highest U is obtained when $Z = Z^*$. Alternatively, rewrite (11) as

$$p = \frac{H^{-1}(Q)}{Q} \emptyset(U, r) = m(Q)\, \emptyset(U, r) \tag{12}$$

and note that the right-hand side is simply the average cost curve of a firm which is faced with a parametric workers' reservation utility level equal to U. Different U values will give rise to different average cost curves, but it is a property of our homothetic system that their minimum with respect to Q is always located at $Q^* = H(Z^*)$. The LM-firm will thus be able to attain a utility level of U^* in Figure 2, where $U^* > U_1$ and U_2 is infeasible at the given (r, p).

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[6] For riscussion of models focusing on the supply of individual effort, see Ireland and Law (1981).

[7] A related approach is taken by Svejnar (1982) in a model of co-determined firms.

[8] Ceteris paribus, doubling N and K doubles both C and Z. Let C_1 be the minimum cost of producing Z_1. Now, suppose that by varying (y, l), Z_1 can be doubled at less than double the cost — say at 2 C_1 — S. Then halving K and N at the new (y, l) level allows Z_1 to be produced at only C_1 — S/2, implying a contradiction. Thus the cost function must be of the form (10).

The cost function approach permits us to determine, in a very simple fashion, the response of the LM-firm to changes in parameters such as product price. We need simply locate the point of tangency between the new price line and the highest attainable average cost curve (which in turn will indicate a maximum possible utility level).

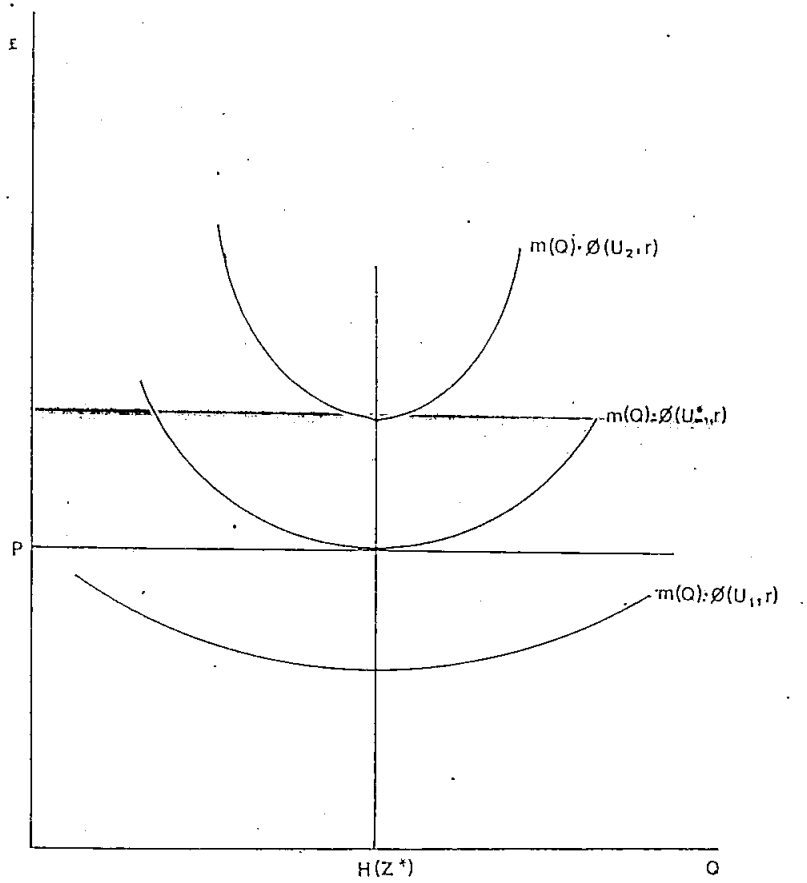

Fig. 2.

Equilibrium of the LM-firm as a problem in cost curve choice

Let the general average cost function be c (Q, U, r), then an optimum will always imply p = c and $c_Q = 0$. Under restricted homotheticity a change in p, r or in the parameters of the utility function which permits a higher level of utility to be obtained will leave equilibrium output unaffected because $c_{QU} = 0$ when $c_Q = \varnothing(\cdot)\, m_Q = 0$. In the absence of this technological assumption, the

output response to, say, a price rise, is determined by the sign of c_{QU}. If $c_{QU} > 0$ then, after the price rise, the new highest attainable average cost function will be upward sloping at the initial output level. An output reduction would then be optimal. And if $c_{QU} < 0$ the LM-firm will increase its output.

II COMPARISONS WITH PROFIT-MAXIMISING FIRMS

We now compare LM and PM-firms with identical homothetic technology assuming, throughout this section, that the number of firms is fixed. The PM-firm hires labour at a wage W which induces the worker to provide l units of effort provided he or she is rewarded with the reservation utility level, U. PM-firms treat the reservation utility level as a given parameter (so that U (W (l), l) = U) and they hire capital at the same rental rate, r, as LM-firms. Now, using (3) and (10) and taking optimisation over the (W, l) and (l, N, K) mixes into account, we may write the PM-firm's profits, π as

$$\pi = pH(Z) - Z.\varnothing(U, r) \tag{13}$$

Maximisation with respect to Z then yields

$$pH_z - \varnothing(U, r) = 0$$

so that using (13) we have

$$H_z Z - H(Z) = -\hat{\pi}/p \tag{14}$$

where $\hat{\pi}$ denotes maximum profits. Referring to Figure 1 it is a clear implication of (14) that as $\hat{\pi} \gtrless 0$ so $Z^{PM} \gtrless Z^*$. Note also, from Figure 2, that since $\hat{\pi} \gtrless 0$ when $U \lessgtr U^*$, then $Z^{PM} \gtrless Z^*$ as $U \lessgtr U^*$. Finally, inferior inputs are ruled out by the assumption of restricted homothetic technology.[9] Thus an increase in the reservation utility level of workers, U, or an increase in r, the capital rental rate, will reduce Z^{PM} and hence Q^{PM}.

The cost function approach, which was outlined above, permits us to relate the comparative statics behaviour of LM and PM-firms in a very simple fashion. Consider an initial equilibrium at which $Q^{LM} = Q^{PM}$ because $\hat{\pi} = 0$ and $U = U^*$. Let α denote a parameter (for

[9] An input is inferior if an increase in its price reduces marginal cost while, of course, increasing average cost. Here both marginal and average cost are positively related to Ø (U, r) and $\varnothing_u, \varnothing_r > 0$. Thus both N and K are non-inferior.

example p or r) which now changes — say in a direction such that the PM-firm can earn positive profits. The LM-firm will respond, as shown in the last section, by moving to a new equilibrium at the minimum point on the highest attainable cost curve. Thus the LM-firm's response to a change in α is identical to the response a PM-firm would make to a change in α and a simultaneous change in reservation utility, U, such that $\hat{\pi}$ remains at zero. Thus we may write

$$\frac{dQ^{LM}}{d\alpha} = \frac{dQ^{PM}}{d\alpha} + \frac{dQ^{PM}}{dU}\frac{dU^*}{d\alpha} \tag{15}$$

The result stated in (15) is completely general and does not depend on the assumption of restricted homotheticity.

III COMPARISONS IN THE VERY LONG RUN

When entry and exit of firms to and from the industry is permitted it is well known that, given identical technologies, LM and PM-industries will be equivalent. Such results are discussed by Drèze (1976) and others, and indeed this equivalence was apparent in the preceding section where $\hat{\pi} = 0$ ($U^* = U$). Non-equivalent behaviour may however arise for a variety of reasons and can be fruitfully studied under the simplification of restricted homothetic technology. Two possible causes of non-equivalence may be mentioned here. First, as Ireland (1981 (b)) has shown, type of firm (LM or PM) to which workers are attached may have direct effects on workers' utilities with behavioural ramifications. Secondly, as Furubotn and Pejovich (1973) and Jensen and Meckling (1979) have argued, incomplete or inappropriate markets for property rights (particularly of capital) in LM-economies may influence firm and industry equilibrium.[10]

Under the assumption of restricted homotheticity, systems differences which do not affect the form of the function H (Z) will leave Z* unaffected. The index of inputs of the PM-firm, Z^{PM}, approaches Z* as profits are competed away by new entry. Thus, in the very long run, output levels in LM and PM-firms will be the same if systems differences are such as to leave both types of firm with the same H (Z) function. Of course, some systems differences may result in differing numbers of firms in the two types of economy and this would be reflected in disparate patterns of resource allocation in the two systems.

Moreover, even if $Z^{PM} = Z^*$, the common level of input index may be generated by different optimal vectors of inputs (K, N, l) in the

[10] Sertel's (1982, Ch. 2) mechanism of a market in deeds of membership effectively completes the market for property rights of capital, but at a cost of reducing the cooperative nature of the LM-firm. For a discussion of this and related issues in the property rights controversy, see Ireland and Law (1982, Ch. 2).

two types of firm. For example, suppose that in the LM system capital equipment must be purchased by the user firm rather than rented and the expected life of such equipment exceeds the typical member's employment horizon with the LM-firm. Then, if members do not have property rights in such capital, the effective user cost of capital exceeds that in a capitalist system where ownership is vested in equity holders. This well-known Furubotn-Pejovich effect may be interpreted in ou model as a higher r in the LM-system and, if l is fixed, this will lead to a lower K/N ratio.[11] Otherwise, the change in K/N depends on the change in l and its consequences. However, whether l is fixed or variable, with homotheticity there will be no change in Z* or in output as a result of the higher user cost of capital in the LM-system. Of course, succeeding generations of members may receive endowments of free capital, implying an asymmetry in the costs of capital which may, in general, prevent Z* from remaining optimal.

One interesting systems difference which will cause output differences in the two types of firm, even with homothetic technology, derives from the distinctive response of LM and PM-firms to uncertainty. If p and r are uncertain, it follows from our analysis of Section I that the LM-firm will select a level of input index, Z* and an output level H(Z*), irrespective of how risk-averse its members may happen to be. Increased uncertainty in the present model leaves output of the LM-firm unaffected.[12] Of course, if we assume that individuals are risk-averse, the number of firms in the LM-industry will be less the greater the risk relative to other industries. The PM-industry, by contrast, will be characterised by firms which produce less than H(Z*).

We may demonstrate this somewhat surprising proposition as follows. First note that the equilibrium entry condition for the PM-industry may be written

$$EV(\pi) = V(O) \tag{16}$$

that is, the expected utility of profits is equal to the utility of not entering the industry. Now, the first-order condition for the firm maximising EV (π) under homothetic technology is

$$H_z Z - H(Z) = \frac{-EV_\pi \pi}{EV_\pi p} \tag{14a}$$

[11] Maximising U (y, l) for a given l imples maximising y with respect to N and K. Let the maximal value be y* (r, p) and note that it is convex in (r, p) which implies $\frac{d\left(\frac{K^*}{N^*}\right)}{dr} < 0$. This result does not depend on homotheticity. On this, and related results using the y* function, see Ireland and Law (1982, Ch. 2).

[12] Our restricted homothetic technology generates a vertical supply curve for the LM-firm. Hey (1981, p. 371) reports that the long-run response of the LM-firm to a change from certain price to random price with the same mean depends on whether the supply curve is upward or downward sloping. This exemplifies the analogy developed by Ireland (1980).

and since $V_{\pi p} > 0$ for all p, r, the sign of (14a) depends on $EV_{\pi\pi}$. In particular if it can be shown that $EV_{\pi\pi} < 0$ then $Z < Z^*$. The sign of $EV_{\pi\pi}$ can be determined by expanding $V(0)$ around $V(\pi)$ to yield

$$V(0) = V(\pi) - V_{\pi}(\pi) \cdot \pi + \tfrac{1}{2} V_{\pi\pi} (\mu\pi) \cdot \pi^2 \qquad (17)$$

where $0 < \mu < 1$. Then, taking expectations of both sides of (17) and using (16) and the assumption of risk-aversion ($V_{\pi\pi}(\cdot) < 0$), yields $EV_{\pi\pi} < 0$. Thus $Z^{PM} < Z^*$ in very long run equilibrium.

Finally it may be remarked that, in the absence of the restricted homotheticity assumption, comparisons of LM-firms under uncertainty would depend on relating the degree of risk aversion in the two types of firm. It is not at all obvious what assumptions could be made on that matter.

IV CONCLUDING COMMENTS

We have shown that the assumption of restricted homotheticity is sufficient to determine output levels over a range of models of the LM-firm under both certainty and uncertainty. The range includes the standard Ward (1958) model in which the firm maximises income per member, each member providing a given fixed labour input. It also includes models of the type discussed by Ireland and Law (1981) which treat N and l symmetrically in the generation of labour services so that $Z = F(lN, K)$. However, our technological assumptions are sufficiently broad to admit models which permit the partial elasticity of output with respect to l and N to differ. This property may be desirable if it is recognised that increasing N dilutes the capital stock by spreading it over more members whereas increasing l merely increases the rate of use of the capital equipment but involves no dilution. Given the technological assumption of restricted homotheticity the output of the LM-firm is independent of the parametric output price and capital rental. If both capital and membership are optimally chosen it is also independent of the level of individual labour input. Moreover the level of uncertainty and the degree of risk-aversion has no effect on the optimal output of the LM-firm.

The dual cost function approach was used to explain the implications of homotheticity and also to offer a simple framework for comparative statics analysis when the homotheticity assumption is relaxed.[13]

Finally, we considered a number of equivalence and non-equivalence results. In particular, it was demonstrated that in free entry very long run equilibrium under uncertainty the LM-firm will have a higher output level than the corresponding PM-firm.

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[13] An alternative approach, based upon how the ratio of marginal products of inputs changes with scale, is presented in Ireland and Law (1982, Ch. 2) for the fixed l case.

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O SAMOUPRAVNOM PREDUZEĆU SA HOMOTETIČKOM TEHNOLOGIJOM

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Rezime

U novijim proučavanjima samoupravnih preduzeća zapaža se sklonost ka usvajanju pretpostavke prema kojoj je kolektiv preduzeća promenljiva veličina samo na dugi rok; ova pretpostavka ima sledeći smisao: prilagođavanje kolektiva preduzeća praćeno je optimalnim prilagođavanjem ostalih inputa. Osnovni cilj ovog članka predstavlja analiza združene ravnoteže samoupravnog preduzeća u odsustvu mogućnosti granskog preorijentisanja preduzeća.

Radi pojednostavljenja analize, pretpostavljamo da se primenjuje (ograničena) homotetička tehnologija, takva da je proizvodnja, za dati nivo radnog napora članova preduzeća, homotetička u pogledu kapitala i broja članova. Usvajamo, takođe, da elastičnost proizvodnje opada sa povećanjem obima proizvodnje, i to od vrednosti iznad 1 do vrednosti ispod 1. Pretpostavljamo, najzad, da samoupravno preduzeće maksimira korisnost svog tipičnog člana, koja je izražena kao funkcija njegovog dohotka (odnosno, viška po članu) i nivoa njegovog radnog napora. Tada optimalni nivoi faktorskih inputa i radnog napora podrazumevaju ravnotežni nivo proizvodnje, koji je određen samo tehnologijom, a promene cene proizvoda ili kapitala, cenovna neizvesnost, radničke preferencije ili radnička nesklonost riziku — ne utiču na ravnotežni nivo proizvodnje.

Troškovi pristup pruža jasniji uvid u ovaj rezultat. Za bilo koji nivo korisnosti svojih članova, samoupravno preduzeće je suočeno sa krivuljom prosečnih troškova koja ima oblik slova U. Za veći nivo

korisnosti, pomenuta krivulja biće, naravno, pomerena naviše, ali će tačka njenog minimuma — ako se primenjuje pretpostavljena tehnologija — odgovarati istom nivou proizvodnje. Kako samoupravno preduzeće nastoji da dosegne najvišu krivulju troškova (to jest, najviši nivo korisnosti), ono se uvek opredeljuje za onaj obim proizvodnje pri kome su prosečni troškovi minimalni.

Izložena analiza se može proširiti. Prvo, mogu se izvesti jednostavne karakteristike onih tehnologija za koje su krivulje ponude pozitivno ili negativno nagnute. Takođe se može dati poređenje sa ravnotežom preduzeća usmerenog ka maksimiranju profita. Konačno, prethodni rezultati omogućavaju proširenje analize na veoma dugi rok, kada je granska preorijentacija preduzeća moguća. Dobro je poznato da će tada ravnoteža grane sastavljene od samoupravnih preduzeća biti ekvivalentna ravnoteži uporedive grane sastavljene od preduzeća usmerenih ka maksimiranju profita, sem ako ne postoje neke razlike u efikasnosti. Jedna od tih razlika tiče se reakcije na cenovnu neizvesnost. Može se, naime, pokazati da — u stanju ravnoteže, na veoma dugi rok, kada je granska preorijentacija preduzeća moguća — samoupravno preduzeće nesklono riziku daje veću proizvodnju nego odgovarajuće preduzeće sklono maksimiranju profita.