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Welfare Effects of Mechanization: Monopoly and Indivisibility

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1. INTRODUCTION

Discussions of the economic effects of mechanization in less developed countries typically lead to the conclusion that private decision-making leads to over-investment in machinery. This conclusion normally rests on welfare analyses implying that the net private benefits from mechanization exceed its net social benefits. The sources of divergence between private and social benefits commonly include the fact that private calculations take no account of the adverse impact that mechanization may have on income distribution. Moreover, it is often claimed that the market prices on which these private calculations are based are distorted in such a way as to make mechanization privately profitable well beyond the point where its net social returns become negative. The reasons for this include suppression of interest rates, overvalued exchange rates and minimum wage laws: see, for example, [2; 3; 4; 5].

In this note we do not take issue with this line of argument, but we wish to draw attention to two other aspects of the problem which could lead to sub-optimal investment in machines and to their under-utilization. These aspects are usually overlooked but could be important in some cases, especially in the context of the production and processing of agricultural commodities. These issues are (i) monopoly in the market for machine services and (ii) the indivisibility of machines. Either or both of these phenomena can, in itself/themselves, lead to too few machines being supplied from a social standpoint. This is reasonably well understood in the case of monopoly, but the implications of indivisibility of machines are less well recognized. We shall argue our case by considering a hypothetical situation in which income distributional effects are not of interest, there is no uncertainty and the market prices of machines, labour and agricultural products are undistorted. We do not claim that the social returns from mechanization *normally* exceed its private

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returns, although they could in principle, and that the factors which lead to this possibility could be empirically important in some cases.

2. THE MODEL

We assume that "machines" come in indivisible units which are sufficiently large so that only a small number is ever likely to be adopted in any one "village".[1] Attention is focused on the rental market for machine services within the village.[2] The market for machine services in each village is assumed to be separated from those in other villages. Rental of machine services between villages does not occur, because of physical or cultural barriers.

In Figure 1 YY' represents the demand for machine services in a typical village and the marginal cost of supplying these services from a single machine is SS_1. For simplicity, we have made it linear, but nothing important hinges on this. The marginal cost schedule includes all the variable costs (fuel, labour, maintenance, wear-and-tear not covered by maintenance, etc.) of supplying machine services.[3] It does not include the purchase price of the machine itself, which we shall denote by p_m. Also for simplicity, we assume that machines have a fixed life which coincides with the period of measurement in the graphs, after which they have zero scrap value.[4] When there are two machines, the marginal cost of supplying any quantity of services is SS_2, etc.[5]

3. MONOPOLY AND INDIVISIBILITY

First we suppose that the market for machine services is monopolistic. Barriers to entry enable one individual or group to have exclusive access to machines. The

[1] Tractors, harvesting machinery and threshing equipment used in village agriculture are the main examples we have in mind but our analysis will also apply with minor modification to central processing plants for smallholder tea, rubber, etc.

[2] Purchasers of machines may use them on their own farms as well as renting their services out to other producers, but we will disregard the "own production" aspect of the problem to concentrate on the rental aspect.

[3] Marginal costs typically increase due to higher repair and maintenance costs when the machine is used more intensively. Costs of supplying additional units of machine services may also rise when machines are worked during night-time, for example. However, a rising marginal cost curve is not crucial to our argument. What we require is that the marginal cost schedule not decline as steeply as the demand schedule.

[4] Positive scrap value may easily be allowed without affecting the analysis. In this case p_m may be interpreted as the difference between the purchase price and scrap value price of the machine. Alternatively, the analysis may be thought of in annual terms, in which case p_m is interpreted as the annual fixed cost of owning the machine. In the case of zero scrap value $p_m = rp^*_m$ where r is the opportunity cost of credit and p^*_m is the purchase price.

[5] For the SS_2 curve to be of this form, it is not necessary that the machines be purchased simultaneously. Even when they are purchased successively, once they are purchased the machine owners' supply decisions will be determined by the availability of two machines and at any given price twice the previous amount of machine services would be supplied.

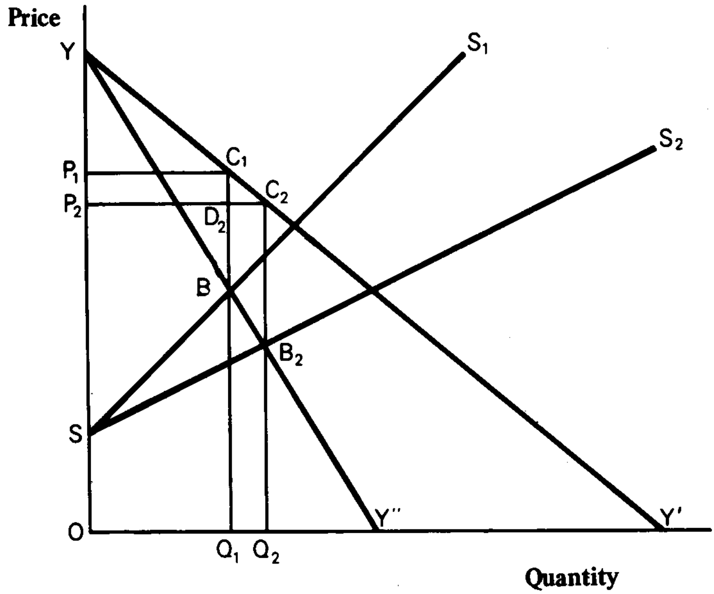

Fig. 1

number of machines purchased and the pricing of machine services are each determined in a profit-maximizing manner. The marginal revenue schedule is YY''. When one machine is purchased, the quantity of services supplied is OQ_1, at which marginal cost is equal to marginal revenue. The price is set at OP_1. Total variable cost is given by the area OSB_1Q_1 and profit is given by $\pi_1 = SB_1C_1P_1 - p_m$. When a second machine is purchased, total profit becomes $\pi_2 = SB_2C_2P_2 - 2p_m$ and the purchase of this machine is privately profitable if $\pi_2 > \pi_1$, or $SB_2C_2P_2 - SB_1C_1P_1 > p_m$.

From a social standpoint, this leads to two kinds of inefficiency. One, given the number of machines, the pricing of machine services above the marginal cost of supplying them leads to sub-optimal utilization of these machines. This feature of monopoly is well understood by all economists and there is no need to dwell upon it here. Two, even given the monopolistic pricing behaviour outlined above, a sub-optimal number of machines may be introduced. The net social return from the purchase of the second machine is given by $SB_2C_2Y - SB_1C_1Y - p_m$. This is equal to the private return to the owner plus the area $P_1C_1C_2P_2$. The second machine may be socially desirable but privately unprofitable. But a similar phenomenon occurs even without monopoly.

4. COMPETITION AND INDIVISIBILITY

In Figure 2 we depict the same demand and cost conditions but we assume that the barriers to entry producing the monopolistic features of the previous analysis are not present. Machine services are assumed to be priced at marginal cost. Net private return from the first machine is the area $SB_1P_1 - p_m$. When a second machine is introduced (say, by a different owner), each machine generates the private return $SD_2P_2 - p_m = SB_2D_2 - p_m$.[6] Purchase of the second machine is privately profitable if this is positive. Now compare this with the net social return from the second machine. Net social return from the first machine is $SB_1Y - p_m$. When a second machine is introduced this becomes $SB_2Y - 2p_m$. The net social return from the second machine is thus $SB_2Y - SB_1Y - p_m = SB_2B_1 - p_m$. This is equal to the net private return plus the area $D_2B_1B_2$. It follows that the second machine may be privately unprofitable but socially desirable. Under our assumptions, private decision-making will lead either to the optimal number of machines being adopted, or to too few. It will not lead to too many.[7]

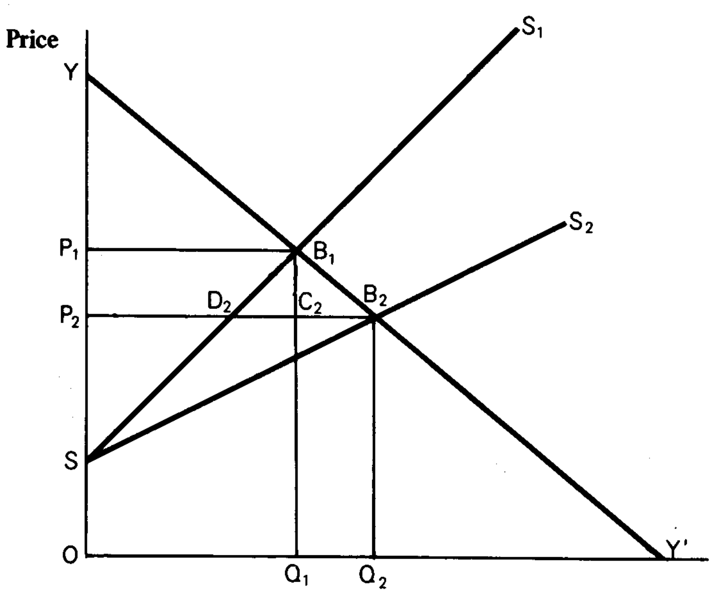

Fig. 2

[6] It is easily shown that the triangles SB_2D_2 and SD_2P_2 are of equal area.

[7] In contrast with the monopoly case, however, under-utilization of the existing number of machines does not occur. Under-investment may occur but under-utilization will not.

The problem arises from the indivisibility of machines. The lumpiness of machines implies that the price effects of introducing a new machine create a divergence between private and social returns. This can be classified as a beneficial external economy of production [1]. A similar phenomenon has been recognized in the literature on public utility pricing, where it is known as the "lumpiness" or "indivisibility" problem [8; 6; 7]. This divergence between private and social returns, represented by the triangle $D_2B_1B_2$, can be decomposed into two parts. In the first part, forcing down the price of machine services lowers the variable cost of supplying a given quantity of machine services, represented by the area $D_2B_1C_2$. In the second part, the economic surplus received by the purchasers of machine services rises, and this effect is represented by the area $C_2B_1B_2$. It is easily seen that if machines were continuously divisible, the divergence between private and social returns would vanish. Generally, we would expect that where the size of the machine is large (as, for example, in the case of central processing plants for rubber or tea), a significant reduction in social welfare could result owing to under-investment in machinery.

5. NUMERICAL EXAMPLE

It may be helpful to illustrate this analysis with a hypothetical numerical example. Let the demand function for machine services be $q = 30 - p$, where q denotes the quantity of machine services and p denotes its price. The marginal cost function for one machine is $m_1 = 5 + 4q$, where m denotes marginal cost. This implies that the marginal cost functions for two and three machines are, respectively, $m_2 = 5 + 2q$ and $m_3 = 5 + 4q/3$. Let $p_m = 27$. The outcome then is that under monopoly only one machine is introduced, while under competition, two are introduced. But the socially optimal number is three.

Under monopoly, one machine is introduced, $q = 4.17$ and $p = 25.83$. In this case, profit is $\pi_1, = 25.08$. If a second machine is introduced, p falls to 23.75 and profit falls to $\pi_2 = 24.13$. The second machine would not be introduced. In the competitive case, two machines are introduced, $q = 8.33$ and $p = 21.67$. For each machine-owner, profit is 7.72. If a third machine is introduced, q would rise to 3.57 and p would fall to 19.29. But net profit for each machine would be $25.51 - 27 = -1.49$. But the net social return from introduction of the third machine exceeds the private return by 4.25 and the net social return is thus 2.76.

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