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FINANCIAL CHOICES OF THE FIRM AS ORGANIZATIONAL DECISIONS

by
T.V.S. RAMAMOHAN RAO *

1. *Production and Finance*

The idea that the output and financial decisions of the firm may be interrelated is not new or novel. It has always been acknowledged that money capital is needed to finance the acquisition of fixed assets as well as the purchase of other factors of production utilized in the manufacture of a given volume of output [1]. The time lag between production and sales receipts will generate some inventories and other working capital requirements as well. See, for instance, Turnovsky (1970, pp. 1062 ff) and Vickers (1968; 1978, pp. 42ff; 1987, pp. 26ff). On the supply side, the nature of the product market and the implicit profit generating potential limits the quantum of finances available to the firm. Conversely, the availability and the costs of finance (considered in conjunction with the perceptions of the managers regarding the risk involved in using alternative financial instruments) can define the extent to which the firm can capitalize on profitable market opportunities. In general, the product market environment determines the financial decisions and conversely. Some implications of this interdependence, for the theory of finance, have been outlined in McInnes and Carleton (1982).

Recently, Williamson (1986; 1988a; 1988b, pp. 567ff) and Holstrom and Tirole (1989) reconsidered the financial choices of the firm in an organizational context. In particular, debt and equity have been looked upon as alternative organizational mechanisms for financing the investment and production of the firm. This approach suggests a consideration of the

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[1] One of the earliest examples is GURLEY and SHAW (1960). See especially the model developed by Enthoven in the appendix.

behavioral constraints, imposed on the management, by a specific financial mix in addition to the costs of financing. For instance, debt financing involves not only a fixed market interest rate but also a first charge for the repayment of principal in case of default or bankruptcy. On the other hand, increased equity participation will mean a greater scrutiny of the decisions of the firm by outside shareholders. The threat of takeover and the risks associated with the loss of control define the boundaries within which debt and equity participation will be sought by the management in finalizing its investment and production decisions. See also DeAlessi and Fische (1987) where they argued that the debt equity ratio will be the same as that of nonspecific to specific assets.

Stafford and Vaughan (1979, p. 17) as well as Grossman and Hart (1982) pointed out that only value maximizing firms tend to make efficient choices of production as well as financial mix. As such, the alternative governance structures of the firm, to the extent they reduce the motivation for profit maximization, are likely to lead to inefficiencies of various kinds. However, it appears that no systematic attempt has been made to examine the efficiency effects of discretionary managerial behavior on the interrelationship between the production and financial choices of the management.

Rao (1989) examined the economic efficiency of mixed organizational forms and nonprice decisions of the firm in a neoclassical framework. In particular, it was pointed out that the welfare effects can be traced to changes in the (a) cost curves, (b) demand curves, and (c) managerial motivations. The sources and the extent of changes in welfare have been examined by introducing the concepts of internal and external pressure. Firstly, note that competitive product markets eliminate profits in the long run and consequently generate internal pressure on the management to keep the costs of production at the lowest possible level. This would probably be true even in the choice of organizational forms. However, it cannot be claimed that imperfect product markets will be necessarily characterized by a lack of internal pressure. Stated differently, internal pressure or the lack of it will be fundamentally related to ownership rights and incentive mechanisms within organizations rather than the market structure itself. Secondly, there have been many situations in which the nonprice and other decision processes of the firm had an influence on the market demand for the firm. This difference from the competitive market assumptions can be viewed as the fundamental specification of the lack of external pressure. The emergence of the lack of internal and/or external pressure can be shown to reduce social welfare.

The primary purpose of the present study is to show that this approach is valid even in the context of the financial decisions of the firm. Section II will outline the essential aspects of the problem specification. A simple model will be developed in Section III to demonstrate the validity of the above stated results. Section IV will be devoted to other important extensions. Section V brings together certain unresolved research issues.

2. *Essential Aspects of Specification*

In the initial stages the Modigliani and Miller (1958) theorem, given its postulated perfect capital market assumptions, justified the dichotomization of the production and financial decisions of the firm. See, for instance, Jensen and Meckling (1976, p. 333) and Vickers (1987). Taken as a normative theory it has the virtue of indicating that if the product and capital markets are competitive and the firms pursue the objective of maximizing the market value of the firm (present discounted value of cashflows) the management will choose efficient levels of factors of production, outputs, and financial mix. In practice, the absence of competitive markets raises doubts about the independence of the output and financial decisions as well as their economic efficiency. Further, as Jensen and Meckling (1976) pointed out, the existence of positive and differential costs associated with bankruptcy and other financial instruments invalidates this theory.

Several attempts have been made in the past to examine the issue of interdependence and its economic implications. The following major strands of thought can be identified.

McInnes and Carleton (1982, p. 959) considered the possibility that financial markets can fully and unambiguously evaluate the position of the output markets and the implications of different methods of financing for the cost of producing a given output on the market. If such is the case the output and financial decisions can be considered to be independent of one another and the economic efficiency of one set of decisions implies that of the other. However, in practice, the information flows cannot be costless and so efficient.

On occasions it was pointed out that the financial availability constraint is the most important aspect of the interaction. Vickers (1978, pp. 42ff; and 1987, pp. 73ff), for instance, argued that for a given volume of output the firms would economize on those factors of production which require more money and/or costly financing. McInnes and Carleton (1982), on the other hand, suggested the possibility that output will be reduced in such a way that the financial constraint is binding. The net effect of the inelasticity of the supply of finances depends upon the elasticity of substitution between the factors of production.

Given any one source of finances, such as retained earnings, the firm may experience a limit on the supply of finances. However, given the innumerable financial innovations and sources of funds, the cost of finances rather than the availability is likely to be more limiting. Most of the studies adopt this viewpoint. In general, debt servicing involves fixed interest obligations. On the other hand, equity participation, even when a minimum dividend payment rate is stipulated, does not make the cost of financing equally rigid. However, as Feldstein et al. (1979) and others argued, the costs of finance to the firm, for providing a given volume of output, depends on both the debt equity ratio as well as the dividend payout ratio. Jensen and Meckling (1976) and Dotan and Ravid (1985, p. 515) pointed out that the future cashflows of the firm depend on the product market as well as the financial arrangements so that they tend to be more closely related over time.

While equity participation from outside (i.e., individuals not related to the management) may reduce the cost of financing investments and the production of a given volume of output it tends to generate a risk to the management in the form of a takeover threat. It would therefore be essential to examine the managerial responses to risk in any appraisal of the efficiency of the financial arrangements. Some general theoretical formulations are available in Aiginger (1987). The various options and some empirical tests in the financial market context have been reported in Grabowski and Muller (1972), Muller (1986, pp. 148ff), and Contini (1989). Further, Grossman and Hart (1982, pp. 108ff) pointed out that the firm's financial structure determines the efficiency of bankruptcy as a source of discipline of the management. In particular, the greater the debt equity ratio the more conscious the management will be of the need to generate adequate profits (because managers lose the perquisites of their position when the firm goes bankrupt).

Jensen and Meckling (1976, p. 305) as well as Grossman and Hart (1982) argued that the management may make an attempt to reduce the impact of external shareholding by share ownership, in varying degrees, among themselves. For, in general, the greater the fraction of shares (especially voting rights) owned by the management the less the chance of a successful takeover and greater the managerial discretion. See also Stulz (1988, p. 26). It appears from the evidence presented in Brickley et al. (1988) that even financial institutions, who own shares and are not under the influence of management, can only have a very limited effect on the behavior of the management.

In the extreme case, the management may even design and implement complex organizational structures in such a way that outsiders can be effectively kept away (i.e., ownership does not result in any effective control) and the interaction between the real and financial decisions minimized. Dann and DeAngelo (1988, p. 15) provided some evidence in this context. In general, the management cannot be expected to have such a high degree of control.

Consider the influence of finance on the demand curve for the firm. This can take several manifestations. Firstly, there will be a goodwill cost and shift to the left of the demand curve for the firm's products whenever there is a quantitative financial constraint limiting the ability of the firm to produce, hold inventory or extend credit to the retail outlets. Secondly, an increase in the costs of obtaining funds from any source of financing can limit the ability of the firm to attract new customers or maintaining the existing level of demand. Thirdly, Jensen and Meckling (1976, p. 341) gave an example of the manufacturers of sophisticated computer equipment where the market demand crucially depends upon the ability of the firm to maintain equipment as well as provide the requisite hardware and software development. It may be argued that while a favorable financial position improves the market position of such a firm an increase in liquidity problems tend to reduce it.

In sum, the effect of financial decisions on social welfare can be through one or more of the following factors:

(a) a quantitative constraint on the supply of financial resources,

(b) effect of changes in the financial mix on the cost of finances,

(c) the degree to which the management can control voting rights by its own equity participation and/or reduce internal pressure to maximize profits,

(d) the attitudes of the management towards residual financial risk, and

(e) the extent of lack of external pressure and the management's influence on the demand.

These aspects and their welfare implications will be considered in the sequel.

3. *The Basic Model* [2]

Consider the case of a firm which utilizes two resources, x_1 = fixed factor, and x_2 = variable factor, to produce an output Y. Let the demand curve for the product of the firm be represented by

$$p = p(Y);\ p_1 = dp/dY < 0$$

The management of the firm has a choice of the output level Y as well.

The cost of purchasing the resources x_1, x_2 needs to be financed. Assume that the firm either borrows an amount B (debt) or utilizes internally generated sources [3] such as retained earnings (I). Then it is obvious that

$$p_1 x_1 + p_2 x_2 = B + I \tag{1}$$

must be satisfied. Let the market rate of interest on debt be $r(B)$; $r_1 \geq 0$. Assume that the management does not impute any cost to the use of internal financial sources. The cost of producing output Y can now be written as

$$C(Y) = p_1 x_1 + p_2 x_2 + Br(B) \tag{2}$$

This approach was basically suggested by Vickers (1978, pp. 10 ff; 1987, pp. 28 ff).

For purposes of the analysis of the present section social welfare will be defined as the total utility gain to the consumers of the products of the firm less the costs of production. That is,

$W(Y)$ = total social welfare

$$= \int_0^Y p(y)\,dy - C(Y)$$

Conceptually, the net additional to the welfare of the society from the production of a unit of output is the highest if the factors of production are chosen, for given input prices, so as to minimize the cost of production. In general, this is one of the first requirements of welfare maximization.

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[2] Throughout the present study a static modelling framework will be adopted and the interaction of the investment and financial decisions will be ignored. However, some extensions are possible along the lines of KOUTSOYANNIS (1987), LOON (1983) and ODAGIRI (1981).

[3] Depreciation reserves, reserves and surpluses, and provisions for taxes will also have to be taken into account. Each of these sources of funds, to the extent they are meant to fulfill a specific need may be at best partially substitutable.

Given this framework, welfare implications of managerial choices can be ascertained by examining (a) the input choices for a given level of output, as well as (b) the choice of the level of output. It is well known that the allocative inefficiency in the actual choice of Y by the firm is a result of the product market imperfection and the consequent inability of the firm to convert consumer utility into profit. This aspect of the specification need not be pursued any further. The input choices for a given Y generate the essential welfare changes in the organizational context. For, originating from Williamson (1964, 1970), it was argued that in imperfect product markets, there is a possibility that the managers of the firms will be choosing input combinations for a given Y which can result in higher cost. This will be the result whenever the management has an explicit preference for the use of any one of the factors of production beyond that which is implied by its contribution to cost alone. The excessive cost results in a welfare loss which will be designated as managerial inefficiency. The present study focuses on this aspect alone.

One result is immediately obvious. Let the management of the firm be motivated to maximize profits. Then, for any given Y, the input choices must be such as to minimize the cost of production of Y so long as $p = p(Y)$ and not a function of the input choices. Hence, there will be no managerial inefficiency in such an environment.

Within the framework of the present model the management is free to choose x_1 alone. For, given the production function and the financial constraint represented by equation (1) all other inputs are determined if x_1 is known. The analysis can therefore be restricted to a consideration of the efficient choice of x_1 and its interaction with the financial variables.

To outline the basic interaction between the real and financial variables consider the case where the firm maximizes profits. Then, for a given Y, x_1 and x_2 will be chosen to minimize $C(Y)$. If I is assumed to be given exogenously [4], then

$$B = p_1 x_1 + p_2 x_2 - I$$

Further, by the nature of the neoclassical production function, it follows that

$$x_2 = x_2(Y, x_1)$$

[4] The distribution of profits between retentions and other uses cannot be determined only by the profit-making criterion. Consideration of the growth of firms, if it is taken as an alternative to profit maximization, may determine the optimal I. Hence, in the rest of the analysis of this section I will be taken to be exogenous.

Consequently, the choice of x_1 satisfies the equation

$$[p_1 + p_2(\partial x_2/\partial x_1)][1 + (1 + \epsilon) r(B)] = 0 \quad (3)$$

where $\epsilon = Br_1(B)/r(B)$ is the elasticity of the interest rate w.r. to B. Observe that if $r(B) = r$, independent of B, i.e., the capital markets are competitive, then $\epsilon = 0$ and the choice of x_1 will satisfy the equation

$$p_1 + p_2(\partial x_2/\partial x_1) = 0$$

since $(1 + r)$ is then independent of the choice of x_1. That is, it will be such as to minimize

$$C(Y) = p_1 x_1 + p_2 x_2$$

without any interaction with the financial variables. This, in essence, is the Modigliani and Miller theorem. In the more general case where $\epsilon > 0$ it can be readily verified that [5]

$$x_1 = x_1(\epsilon); \ \partial x_1/\partial \epsilon < 0.$$

The following example is sufficiently illustrative. Let the production function be

$$Y = f(x_1, x_2) = (x_1 x_2)^{1/2}$$

Then the x_2 requirement along an isoquant is given by

$$x_2 = Y^2/x_1$$

and the x_1 choice itself satisfies the equation

$$p_1 = p_2(Y^2/x_1) - [p_1 - p_2(Y^2/x_1)] r(B)(1 + \epsilon) \quad (3a)$$

It should be obvious that when $\epsilon = 0$, $p_1 = p_2(Y^2/x_1)$. However, $[p_1 - p_2(Y^2/x_1)]$ is positive in the neighborhood of this x_1 since costs are no

[5] One further observation is in order. The $x_1(\epsilon)$ so defined depends on the parametric choice of I. As such it is possible to conceptualize a choice of I to maximize π. The results of this section can be taken to be derived from such an optimal I. However, it is somewhat doubtful if the I choice is motivated by these considerations. Even if other organizational goals predominate the rest of the analysis is valid for the corresponding optimal choice of I. The economic efficiency of the choice of I can also be examined in a similar framework. Some basic conceptual controversies arising in such a context have been outlined in detail in RAO (1989).

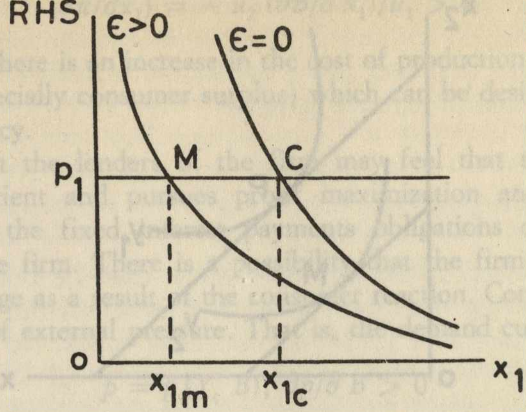

Fig. 1

longer minimum. Hence, given that $\epsilon > 0$ the choice of x_1 as can be verified from Fig. 1, would be such that x_1 decreases as ϵ increases. For, the imperfection in the capital market makes the firm choose M instead of C. It is also obvious that the welfare maximizing as well as profit maximizing choices of output will be lower as a result of the capital market imperfection. However, the only inefficiency, in the context of the neoclassical welfare paradigm, is the allocative inefficiency in the choice of the output level Y.

One further aspect needs to be considered. On occasions the firm may provide credit to its customers in the process of conducting sales. Suppose this is proportional to $Yp(Y)$. If B is the source of finances the firm would still choose x_1 to minimize costs for a given output but the Y itself would be reduced [6]. This contributes to allocative inefficiency. The models of Herendeen (1975), Vickers (1978), and Hite (1979) considered this aspect in some detail.

Depending on the profitability of production, which is determined by the nature of the market demand curve, there may be a limit on the amount of B which the firm can borrow. Let M be such a limit. Then the firm will

[6] This can be contested. For, after all, the possibility of obtaining credit from the firm may shift its demand curve to the right. The gains to the consumers from this may be difficult to determine *a priori*.

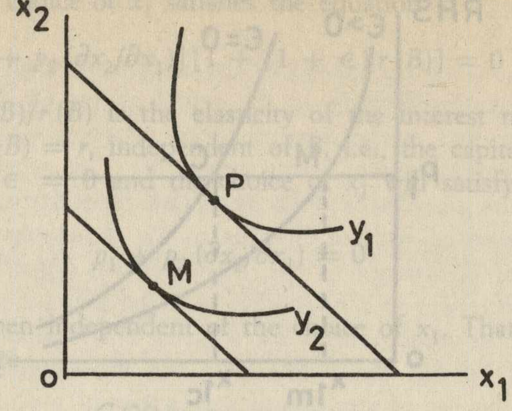

FIG. 2

reduce the output from P to M in Fig. 2 without affecting the cost minimizing choice of inputs to produce Y_2. That is, quantitative financial constraints of this nature add to the allocative inefficiency alone [7].

Borrowing from external sources in an imperfect capital market may (a) increase cost, (b) create an uncertainty regarding the availability of adequate finances, and/or (c) a possibility that profits are reduced to a point where the firm cannot even meet the fixed interest obligations [8]. In such a case the management may show a preference against increases in B. This is very well documented in the context of the choice of x_1. See, for instance, DeAlessi and Fische (1987). A lack of internal pressure is indicated. Let the preferences of the management be represented by

$$u(\pi, B);\ u_1 > 0,\ u_2 < 0$$

Consider the management's choice of x_1 for a given Y in such a context. Clearly, it would satisfy the equation

[7] In RAO (1989) it was pointed out that some constraints on the management of the firm are imposed from the outside; either from the market or the motivations of workers, consumers etc. The other type of constraints are self imposed and are a result of managerial motivations. The first kind of constraints can only contribute to allocative inefficiency. Only the latter can be said to generate managerial inefficiency through the implied cost changes.

[8] Much of the literature on the discretionary managerial behavior emerges from BERLE and MEANS (1968). WILLIAMSON's work (1964, 1970) had a fundamental bearing on most of the subsequent developments.

$$(\partial \pi / \partial x_1) = - u_2 (\partial B / \partial x_1) / u_1 > 0$$

Consequently, there is an increase in the cost of production and a reduction in welfare (especially consumer surplus) which can be designated as managerial inefficiency.

Recall that the lenders of the firm may feel that the management would be efficient and pursues profit maximization and/or growth in output [9] given the fixed interest payments obligations on the financial resources of the firm. There is a possibility that the firm would derive a market advantage as a result of the consumer reaction. Consequently, there can be a lack of external pressure. That is, the demand curve will become

$$p = p(Y, B); \ \partial p / \partial B > 0$$

It can be shown that there will be an additional welfare loss even when the management maximizes π. For, the choice of x_1 does not minimize the cost of producing a given Y any longer. In particular, the choice of x_1 would be such that

$$p_1 = - p_2 (\partial x_2 / \partial x_1) + [- r(1 + \epsilon) + (\partial p / \partial B)] (\partial B / \partial x_1) \qquad (6)$$

Since $\partial p / \partial B > 0$ the expression on the right hand side of this equation is greater than that in (3a). It can therefore be inferred that this adds to the managerial inefficiency in the form of a further reduction in the consumer surplus.

When there is a limit on the supply of outside finances, either market induced or self imposed due to managerial preferences, it is necessary to reconsider the choice of I since it can no longer be considered as parametric. Recall that

$$C(Y) = p_1 x_1 + p_2 x_2 + Br(B)$$

where

$$p_1 x_1 + p_2 x_2 = B + I$$

Given Y and the choice of x_1, both B and I would be determined by the constraint. Hence, all aspects of the foregoing analysis carry over even if B is taken as parametric and I as the decision variable.

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[9] RAO (1989) noted that if growth is along this dimension there will be no lack of internal pressure to minimize costs of production for a given Y. There will be a cost increase if this is replaced by a preference for the growth in x_1. These two different approaches to the growth of the firm are represented in BAUMOL (1959) and PENROSE (1959) respectively.

It is evident from this analysis that the interaction between the real and financial variables, resulting from the capital market imperfection, generates a welfare loss over and above the allocative inefficiency if there is a lack of internal and/or external pressure.

4. *Capital vs. Money Markets*

It was assumed in the previous section that the firm obtains its finances by borrowing from the market at a predetermined interest rate to supplement the internally generated sources of funds. No distinction was made between the long term needs to finance capital formation and the short run working capital requirements. However, in practice, the amount of finances needed for these distinct requirements as well as the relative risks necessitate the use of alternative sources of finance and governance structures [10].

A single owner unit experiences a significant liability in case of default. A joint stock company would come into existence to spread the risks among the various shareholders. This would, however, entail at least partial ownership and control (voting rights) by shareholders. It is necessary to examine the implications of this organizational choice for the interaction between the real and financial aspects and the consequent effects on the efficiency of production and financial decisions [11].

In this context the financial markets have two segments: (a) the market for ownership of assets (capital markets), and (b) the market for short term borrowing and lending (money market). Recent innovations made the financial instruments in both the markets rather extensive. But, for purposes of analytical clarity the issue of common stock will be consid-

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[10] An increase in the asset specificity may make the use of short term borrowing to finance such assets impractical, risky, and more expensive. Long term assets with a high degree of specificity will then be financed through the capital market. This is essentially the position of WILLIAMSON (1988a, 1988b) and DEALESSI and FISCHE (1987). Neither of these authors considered the impact of the changes in the motivations of the management on the optimal choice of the capital assets and the financial mix.

[11] WILLIAMSON (1986) argued that common ownership and collective governance of specific capital assets may reduce the shareholder's concern that asset values are dissipated if management is handed over to a few. Organizational economies may arise in the implementation of such governance structures for other reasons as well. DEMSETZ (1988, and elsewhere), detailed such considerations. Organization specific transaction costs can be subject to a variety of economies of scope. This argument and its implications will not be pursued further in this study.

ered as the major instrument in capital markets. Borrowing (or bonding) and lending at a fixed market determined interest rate will be taken as the primary activity of the money market [12].

The implications of capital market transactions for the cost of capital to the firm have been well documented. The shareholders obtain a short term dividend payment as well as capital gains in the long run when the share prices increase. In their portfolio choice, the shareholders would be willing to tradeoff short run dividend payments in favor of long term capital gains. Hence, even if there is a minimum dividend payout rate that must be paid it will be less than the market interest rate for long term borrowing. Dividend payments are generally not added to the cost of production for the firm since these capital market payments are a share of profits to the firm. Even if the obligatory minimum dividends are added as a cost [13] (since they may then be independent of the profit generated) the total cost of producing a given level of output would still be lower than what it would be if all the finances are obtained from the money market alone. This cost reduction, implicit in the use of the capital market, is as important as the sharing of risks while considering the interaction of the real and financial decisions in the theory of the firm.

The utilization of alternative financial arrangements will have important implications for the governance of the firm. For, it was pointed out that the shareholders, as owners of the firm, would utilize their voting rights to make the management of the firm pursue their interest. In particular, if they are oriented toward long term capital gains instead of short term profits

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[12] Unfortunately such rigid distinctions cannot be made in any practical context. The difficulty is especially acute in the context of financial resources generated by the firm internally. For instance, depreciation reserves have the stated purpose of financing capital assets. However, there are many instances where the management of the firm may utilize these funds for short term working capital requirements. The extent of substitutability and its implications for efficient organization of the firm are somewhat nebulous. Detailed empirical information may be necessary before any formal theoretical structures can be developed.

[13] Dividend payments will have to be treated in the same way as a bonus paid to the workers out of profits. They constitute basically a redistribution of profits and rents among fixed factors and specific assets of the firm. Traditional costing conventions may include these in costs. Then, from a welfare economics viewpoint an increase in dividend payments will reduce the welfare of the consumers of the final products of the firm. However, such a direct relationship of dividends to costs is not acceptable. See WOOD (1971, p. 65). An increase in dividend payments reduces the availability of internal funds to finance capital assets as well as working capital and results in an increased borrowing from the market. This will indirectly increase the cost of production. Since the cost effect of increased borrowing is directly accounted for in the following analysis there will be no further indirect cost effects of increased dividend payments.

there would be an overcapitalization and excessive growth of the firm. However, as Berle and Means (1968) remarked, the separation of ownership from control may reduce the efficacy of the shareholders in enforcing their objectives on the management of the firm.

The alternative governance structures may result in rather diverse managerial motivations as well. Firstly, it has been recognized that the diffused shareholding and the absence of commitments to pay for the finances at a fixed rate has a tendency to dilute the necessity to maximize profits and maintain efficiency of production. Secondly, to the extent that the management's ownership of the shares of the firm may be limited they do not value sharing of profits as much as obtaining perquisites and security of jobs which are not necessarily limited by profit maximization. In other words, an increase in the managerial control of firms results in a tradeoff of profits for other objectives [14].

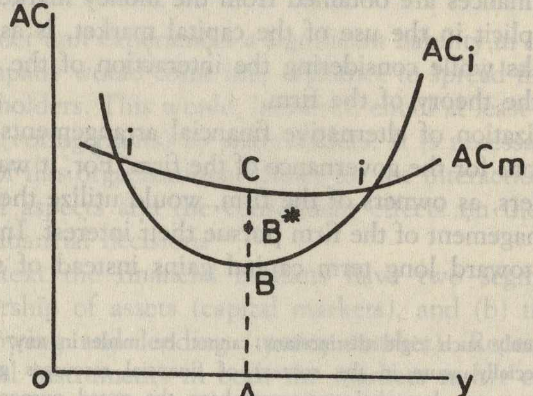

FIG. 3

The cost reduction and the consequent possibility of generating greater profit may itself be a source of discretionary managerial behavior. Referring to Fig. 3, adapted from Coase (1937), let AC_m represent the average cost of

[14] The conventional argument is that discretionary managerial behavior arises due to the separation of ownership from the management and the resulting loss of control by the shareholders. But in the present interpretation of organizational choice the urge, on the part of the management, to avoid the risks of external control is more dominant. In other words, risk aversion rather than the pursuit of other managerial objectives explains the lack of internal pressure.

producing a given level of output when production is organized through market borrowing and AC_i the average cost under the alternative of utilizing the capital market. The alternative governance structure is then beneficial between the points marked as i. For, assume that A is the volume of output produced. AC is the average cost if the market mode of borrowing is utilized. AB is the minimum possible average cost of production under the alternative governance structure, i.e., using the capital market in conjunction with borrowing. The positive difference BC in the cost is the primary motivation for the use of the capital market. The actual level of costs, which can be obtained for the given level of output, will generally exceed the minimum AB possible. For, as Williamson (1964, p. 11) pointed out, when the difference BC is small and survival is narrowly bounded, the management would approximate B. The discretion available to the management would then be low. If, however, BC is large, the managers may not be forced to initiate efficient action until the actual B^* obtained approaches C. It can be argued that the management may channel discretionary profits to pursue other objectives.

In general, it can only be claimed that the objective of profit maximization is diluted. However, empirical evidence on the original source of change as well as the exact nature of the change in the managerial motivations remains ambiguous. It is essential to recognize that the cost increases created by managerial choices and consequent welfare losses are at the apex of the analysis of the welfare changes brought about by nonprice competition and organizational decisions of the firm.

A formal analysis of the welfare effects of the interaction between the real and financial decisions of the firm can now be presented along conventional lines. Let x_1^* be the stock of capital at the beginning of the time period and let additional investments bring it up to x_1 during a given interval of time. It will be assumed that an amount S^* of common stock is outstanding. Let S represent the new issues of common stock (of par value unity and current market price p^*) during time t [15]. Then, the additional finances raised from the stock market can be denoted by $p^* S$ and will be used [16],

[15] TURNOVSKY (1970, pp. 1065 ff) considered the possible differences that arise in the analysis due to the distinction between the book values and market value of equity in calculating the debt-equity ratios.

[16] Very often, new stock is sold at par. In such a case p^* will have to be set equal to 1 in the rest of the analysis. No new insights are obtained. However, there would be a need to independently explain the changes in the market value of shares and the consequent capital gains to shareholders. This would be a requirement if shareholder's preferences should be made a component of social welfare valuations. The model must then be respecified in a dynamic framework.

along with accumulated reserves and surpluses, to finance new capital formation [17]. That is,

$$P(x_1 - x_1^*) = p^* S + R + A \tag{7}$$

where P is the market price of new capital goods, R, is the total accumulated reserves and surpluses (including depreciation reserves), and A is the addition to R from current profit. Denote by p_1 the imputed user cost per unit of capital stock x_1 per unit of time. Then, the current cost of using x_1 in the production process can be represented by $x_1 p_1$. Consider the cost of purchasing the variable factor x_2. Let p_2 be the market price per unit of x_2. Then, it will be postulated that the short term financial requirement is fulfilled by either internal sources or market borrowing. Let

$$p_2 x_2 = B + I \tag{8}$$

where I is the part of current profits of the firm which are retained to finance working capital requirements. In its turn, I is determined by the equation

$$\pi = d(S + S^*) + I + A \tag{9}$$

where d = dividends per share of common stock.

As in the previous section it will be assumed that the production function of the firm is $Y = f(x_1, x_2)$. Further, following Vickers (1968, 1978) it will be postulated that the total cost of production is

$$C(Y) = p_1 x_1 + p_2 x_2 + Br(B, p^* S) \tag{10}$$

where $r(B, p^* S)$ is the market interest rate on borrowing. For, as Vickers (1987, p. 61 and p. 33) argued "the higher the debt equity ratio, or the higher the degree of financial leverage at work in the firm, the greater will be the risk of exposure of both the creditors, that is the debt holders, and the residual owners". Hence, the firm will have to pay a higher rate of interest on its debt capital as the debt equity ratio increases [18].

The problem for the management is to choose x_1, B, d, I, S and A. However, they cannot choose all of these variables independently in view of

[17] This specification makes a rather strong assumption that management does not utilize any long term borrowing to finance capital assets. To that extent market borrowing at fixed interest rates is a short term feature in the present analysis. Suitable modifications, by introducing the option of long term debt, do not appear to alter the results fundamentally.

[18] Strictly speaking the total equity cannot be represented by p^*S alone. However, it can be shown that the following results are not qualitatively affected.

the accounting relationships [19]. The classical Lintner (1956) debate about the dividend policy being primary (exogenously given to the management) is a case in point.

It is therefore necessary to specify which of the variables will be actively chosen by the management while leaving the others as residual. There is no consensus in the literature about the appropriate choice. In general, any two of these variables can be specified as active decisions while the others are determined by the accounting identities. However, the results will not be fundamentally affected by the choice.

The following analytical procedure will be adopted in the rest of this section in order to present a consistent view of the decision making process. Firstly, consider the choice of the combination of the physical inputs x_1 and x_2 along an isoquant. If x_1 is chosen, it follows from the specification of the production function that $x_2 = x_2(Y, x_1)$ will be fixed for a given Y. x_1 will therefore be taken as one of the decision variables. Secondly, the management will be assumed to confront a target dividend payout ratio which is set by the shareholders. That is, a takeover threat may be posed, even if it is not realized *ex post*, when the rate of dividend falls below this target. Risk averse managers can be taken to behave in such a way as to avoid all the private costs of potential takeover. The choice of d is therefore exogenous [20]. Thirdly, every reduction in the debt equity ratio implies a greater control of outside shareholders. The management would make an attempt to fix an optimal debt equity ratio keeping the financial requirements in perspective.

From an operational viewpoint these decisions can be considered as equivalent to a choice of x_1 and S. For, suppose both these quantities are fixed. Then, equation (7) implies that A is determined as a residual. The definition of costs of production in equation (10) suggests that equation (9) specifies the requirements of I. Finally, from equation (8), it can be deduced that

$$B = p_2 x_2 (Y, x_1) - I$$

so that the amount of debt will also be determined. In sum, it can be stated

[19] It should also be reiterated that nonprice and organizational decisions may neither have any implications for the costs of the firm nor do they necessarily get to be chosen on profit maximization considerations. These aspects have been extensively reviewed in HOLSTROM and TIROLE (1989, especially section 4).

[20] The literature on the primacy of dividend decisions is rather extensive. Relatively recent useful references are HAKANNSON (1982), FELDSTEIN and GREEN (1983), and EASTERBROOK (1984).

that x_1 and S are the active decisions of the management and the others are residual choices.

There is a further requirement of specifying the managerial objectives to complete the analysis. Assume the existence of external pressure from the product markets on the management. Then, from a purely normative viewpoint it is necessary to consider the conditions under which cost minimizing choices would be made. The maximization of (a) either the static profit function, or (b) the market value of the firm (represented by the discounted present value of cashflows) will ensure the fulfillment of the internal pressure requirement. In practice, the management of the firm may pursue other objectives either as a response to the risk of loss of control and/or other discretionary objectives arising from the private interests of the management. The normative choices, implicit in the profit maximization postulate, will be considered initially so that the identification of the sources of inefficiency can proceed systematically.

The allocative inefficiency in the choice of Y resulting from the product market imperfection is well known. However, the managerial choices of inputs x_1 and the financial arrangements represented by the decision regarding S can result in a cost increase, over and above the minimum possible, and add to the inefficiency of the firm. To emphasize this aspect of the specification it may first be noted that if the management experiences external pressure and pursues the objective of maximizing profits then it will minimize costs of every given level of output Y in its choice of physical inputs and other financial variables. With this in perspective consider the choice of x_1 and S, for a given Y, so as to minimize

$$C = \text{cost of conducting sales of } Y \text{ units of output}$$
$$= p_1 x_1 + p_2 x_2 (Y, x_1) + Br(B, p^* S)$$

where B can be determined implicitly from the equation

$$B[1 - r(B, p^* S)] = -Yp(Y) + p_1 x_1 + P(x_1 - x_1^*) + + 2p_2 x_2 (Y, x_1) + d(S + S^*) - p^* S - R \quad (11)$$

Viewing B as a function of x_1 and $p^* S$ it can be verified from equation (11) that

$$\partial B/\partial x_1 = [p_1 + P + 2(\partial x_2/\partial x_1)]/[1 - r(1 + \epsilon)], \text{ and}$$
$$\partial B/\partial p^* S = [(d/p^*) + Br_2 - 1]/[1 - r(1 + \epsilon)] \quad (12)$$

Consequently, the choice of x_1 and S would be such as to satisfy the equations

$$[p_1 + p_2 (\partial x_2/\partial x_1)] [1 + r(1 + \epsilon)] = (p_1 - P) r (1 + \epsilon), \text{ and}$$

$$Br_2 = r(1 + \epsilon) [1 - (d/p^*)] \qquad (13)$$

Let the capital market be competitive. That is, $r(B, p^* S) = r$ (a constant) and $\epsilon = 0$. Further, the price P of capital goods can be taken to be the present discounted value of p_1. That is, $P = (1 + r) p_1/r$. Hence, the first part of equation (13) reduces to

$$p_1 + p_2 (\partial x_2/\partial x_1) = p_1 (1 + 2r)$$

In general, since the expression on the right hand side is positive, a construction similar to Fig. 1 will imply that there will be a tendency on the part of the management to utilize a larger capital stock compared to x_{1m} but less than x_{1c}. This result holds though cost minimization is being pursued. To an extent this result is a consequence of the cost reduction implicit in the use of the capital market for fixed asset financing since the risk of takeover and related managerial disutilities are not taken into account [21]. However, in the general case when $\epsilon > 0$ it can be verified that

$$x_1 = x_1 (\epsilon); \; \partial x_1/\partial \epsilon < 0$$

Consider the choice of the relative proportions between debt and equity. If S increases by one unit, there is an increase in interest payments by an amount $Br_2 p^*$. However, there is a concomitant reduction in the amount of market borrowings B as specified in equation (12). Therefore, the interest payments will be reduced by an amount

$$rp^* (1 + \epsilon) [1 - (d/p^*)]$$

These two quantities must be equal if the debt equity ratio is optimal [22]. This is the second part of [23] equation (13).

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[21] The changes in the choice of Y associated with specific financial variables, as outlined in HOLSTROM and TIROLE (1989, p. 103), refer mostly to allocative inefficiency concepts alone. For, as evident from the present analysis, cost minimization for a given Y is still being pursued when both external and internal pressures prevail.

[22] There are two other contrasting viewpoints regarding the determination of the optimal debt equity ratio. One of these is the viewpoint of DEALESSI and FISCHE (1987) mentioned earlier. The other is that there is an institutionally determined leverage which is binding and that this homemade leverage is not acceptable. It is difficult to comment further on these within the limits of the present model.

[23] Though, in general, it is obvious that B/p^*S and consequently the debt equity ratio is a

The inelasticity in the supply of finances from any particular source cannot have the same effect in the generalized model as it was in the previous section. For, the degree of substitutability between the short term and long term sources of funds, their relative costs, and relative risks will determine the ultimate outcome. Managerial choices may entail certain cost increases and corresponding welfare losses. This aspect of the problem has always been controversial in the literature on the interrelationship between the real and financial variables.

Suppose the interest rate on debt is positively related to the amount of borrowing. Then, the availability of less expensive alternatives may even induce the management to shift away from the use of this market source even at the risk of some loss of control. Suppose the lack of internal pressure can be concretely represented in the form of a preference function

$$u(\pi, B);\ u_1 > 0,\ u_2 < 0$$

The choice of x_1 by the management, would now take the form

$$\partial\pi/\partial x_1 = -2\,(u_2/u_1)\,[p_1 + p_2\,(\partial x_2/\partial x_1)]/[1 - r(1 + \epsilon)] > 0 \quad (14)$$

This would imply an increase in the cost of production so that some managerial inefficiency will be apparent in addition to the allocative inefficiency in the choice of Y.

The largeness of the size of the firm, which is a result of the diversity of financing available to it, may enable it to obtain certain economies of scope, diversify into both vertically and horizontally related activities and generate certain market advantages for itself. Even the possibility that it would have better relationships with both sundry debtors and sundry creditors may enable it to expand its market and/or create certain preemptive competitive barriers both to other incumbent firms in the product market as

function of x_1 and x_2 it is not possible to say that the debt equity ratio should be equal to x_1/x_2 without further assumptions. The transaction cost theories claim this impressionistically and have yet to establish this result concretely. The best argument that can be put forward on the present evidence is the following. Though the direct costs of equity financing are low the transaction costs are high. This can be explained by noting that (*a*) the costs of flotation of common stock as well as retiring it, (*b*) the costs associated with ownership and eventual capital gains which need to be paid to outside shareholders if they choose to redeem the stock, and (*c*) the managerial costs of risk of loss of control are all high and significant in comparison to the relatively low transaction costs of debt financing. Hence, (*a*) the relatively much larger frequency of short term transactions, (*b*) the inability to liquidate fixed assets at short notice, as well as (*c*) the ownership rights associated with equity financing make debt the more suitable instrument for short term nonspecific assets and equity financing suitable for specific assets of a long term nature. See also DEALESSI and FISCHE (1987).

well as to potential entrants. This has generally been designated as the lack of external pressure. As outlined earlier, this leads to an additional welfare loss even if the management continues to maximize π. The primary reason for this is that cost minimization in the decision making process does not hold any longer. A formal verification of this statement consists in noting that the x_1 choice would be such that

$$[p_1 + p_2 (\partial x_2/\partial x_1)] [1 + r(1 + \epsilon)] = (p_1 - P) r (1 + \epsilon) + Y (\partial p/B) (\partial B/\partial x_1) \quad (15)$$

The expression on the right hand side is greater than that in the first part of equation (13) since

$$p = p(Y, B); \; \partial p/\partial B > 0.$$

It is clear from this presentation that managerial inefficiency may be a result of the lack of internal and/or external pressure. That is, in general, these effects are additive [24].

In sum, it can be concluded that cost minimization, for a given output level, is contingent upon the existence of external pressure from the product market as well as internal pressure arising out of managerial motivations. Profit maximization [25], so long as it remains the managerial objective, assures economic efficiency in the decision making of the firm. However, ownership by outside stockholders may yet induce the management of the firm to make decisions which do not lead to the minimum possible cost. For, this type of ownership may not result in the requisite control in the decision making process. Even under these circumstances it appears that there would be a reduction in cost below the purely market mode of borrowing at a fixed interest rate even if the costs are not the minimum possible. Hence, the lack of internal pressure reduces the consumer welfare

[24] It should be noted that throughout this section both x_1 and S have been taken to be the choices of the management. Consequently, the efficiency in the choice of S should also be considered explicitly. In contrast to the choice of x_1 which is bought on the market the choice of S is organization related. However, in the neoclassical welfare economics framework, which is being adopted here, the efficiency in the choice of S is related to cost minimization for a given Y. The choice of S, in turn, affects the cost curve only through B and the changes in the interest rates. It can then be inferred that the analysis of the efficiency of S would be analogous to that of x_1 and all the foregoing results carry over with minor algebraic modifications. The details will not be presented since the reader can readily work them out.

[25] The objective of growth of output of the firm can also be shown to preserve this internal pressure.

below the maximum attainable but still generates a level of welfare which is above that possible in the absence of alternative organizational and/or governance structures. The lack of external pressure will be more damaging from a welfare viewpoint. For, in such a case there is an increase in output price over and above the consumer valuation of the product but the managerial propensities may be such that costs will eventually catch up with the higher prices.

5. *Some Further Issues*

The financial choices, when viewed as governance structures, have been shown to affect consumer welfare in the following manner: (a) So long as the firm has internal pressure to maximize profits and/or market value of the firm and specific financial choices do not have the effect of reducing external pressure both the choices of the financial and real variables by the management would be efficient. (b) So long as the alternative governance structures have the effect of reducing external pressure there will be inefficiency even if the firm is a profit maximizer. (c) The absence of internal pressure can, in general, create inefficiency. This effect will be in addition to the other.

However, it can be expected that the alternative organizational structure becomes viable only if there is some cost reduction in contrast to the purely market mode. The welfare gains obtained from the alternative governance mechanism may not be the maximum that can be expected. This is the only notion of inefficiency which can be sustained in such organizational contexts.

Much of the literature on vertical integration accepts transaction costs as a component of the cost of producing a given level of output. In particular, the Coase (1937) diagram in Fig. 3 could not be drawn without it. The make vs. buy decision is actively a result of these transaction cost considerations. Though the transaction costs of using the capital markets are equally important and the alternative governance structures in the financial context also resemble a make vs. buy decision the same costing procedure has not yet been accepted. Extending the cost curves of this study, which were taken from Vickers (1978, 1987), to include the Williamson (1988a, 1988b) and DeAlessi and Fische (1987) argument can however be shown to validate the basic propositions stated earlier.

The major problem is of course that most of the implicit transaction costs in this framework refer to managerial attitude towards loss of control and/or takeover. Objectively defined costs of flotation and redemption of common stock will be more readily acceptable as components of transaction costs within the framework of neoclassical welfare economics. But the subjective preferences of the shareholders and managers cannot be included in the normative framework without further analysis.

The concept of welfare maximum itself needs to be reexamined in the presence of stock market financing. The basic problem is that the cost minimization requirement of welfare maximum will have to be defined after taking into account the managerial and shareholder attitudes towards the risks associated with the seperation of ownership from control. Gravelle (1982) and DeAlessi (1983) argued that the profit, which is a share of the owners and managers of the firm in the total welfare generated by the production of the firm, should be replaced by the sum of the utilities of the management and the shareholders as they perceive it. This would, however, be counter to the neoclassical welfare paradigm which emphasizes the net utility, over the social cost of production, to the consumers of the product. It is clear that there is a welfare loss over and above the allocative inefficiency induced by the product market imperfection. Its precise specification may yet be contested.

One of the requirements for further progress is an appropriate specification of the welfare/preferences of the shareholders. For the ownership of common stock of the firm they receive short run returns in the form of dividends and long term capital gains due to the increase in share prices. How they evaluate the tradeoff between the two has to be made more concrete. It would even be necessary to empirically evaluate the constraints they place on dividends and its primacy from their viewpoint.

The problem with the specification of managerial preferences is analogous. The tradeoff between the risk of loss of control and the reduction in the direct costs of finance implicit in the different organizational structures is as yet not clear. On occasions it has been observed that the management utilizes long term sources of funds, such as depreciation reserves and accumulated reserves and surpluses, to finance short term working capital requirements. This saves the costs of borrowing from the money market. But the managerial attitude towards the foregone long term alternatives, if any, is not concretely identified and specified.

There has been an ambiguity concerning the active decision choices of the management and the residual choices which are governed by the accounting identities. To an extent this dichotomy depends on the perceived market prospects. However, a detailed specification may yet be necessary to identify the welfare effects of different external market conditions.

It may therefore be concluded that there are several unresolved research issues even though Williamson's suggestion, that debt and equity financing should be considered as alternative governance structures, is fundamental and enables considerable progress in examining the behavior of firms under monopolistic competition.

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SCELTE FINANZIARIE DELL'IMPRESA COME DECISIONI ORGANIZZATIVE

L'articolo esamina le scelte finanziarie dell'impresa considerate come decisioni organizzative e illustra le loro implicazioni in termini di costi di produzione e motivazioni manageriali. Viene poi analizzato l'effetto di queste scelte organizzative sulla struttura del mercato. Infine, in uno schema neoclassico, vengono descritte le implicazioni di questi cambiamenti sul benessere.

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A POST-KEYNESIAN ANALYSIS OF THIRD WORLD MILITARY EXPENDITURES

by
ROBERT LOONEY *

Introduction

One of the most disturbing trends in developing countries in recent years has been the rapid growth in defense spending. While the decade 1975-85 saw more than a 30 percent increase in defense spending in real terms, third world countries as a whole showed an even greater propensity to spend on armaments and security – a rise of over 50 percent in defense spending during the same period (Deger and West, 1987, p. 1).

While the willingness of political leaders to pursue national objectives through military means is hardly unique to the third world, the military burdens of many less developing countries greatly exceed the levels even the most sympathetic observers would concede are adequate for national security needs. In fact there is increasing evidence (Mullins, 1987, ch. 2; McKinlay, 1989, chs. 1, 2) that the growth in military power and the willingness to employ it are not directly related to the state's economic performance or to the level of economic development. The net result of these trends is that some of the world's poorest nations, as measured in terms of Gross National Product (GNP), are among the most heavily armed.

While the real resources devoted to national defense by developing countries has more than doubled over the last decade, there has been very little investigation by development analysts of the causes of this phenomenon.

> The decisions with respect to military expenditures and arms imports are generally viewed as being governed by exogenous factors, outside the considerations bearing on allocation of public resources for development and civilian government services, and presented as a kind of budgetary Hobson's choice (Deger and West, 1987, p. XXI).

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Recently, however, the magnitude of budgetary allocations to national defense and the austerity imposed by severe constraints on the resources available to third world governments have stimulated a new interest in accounting for the purposes and consequences of military expenditures.

> There is, however, little evidence of a consensus with respect to the appropriate weighing of factors in an explanation of the allocation of resources to national defense or in a generally-applicable model of the interaction between security and economic performance (Deger and West, 1987, p. XXI).

Even at the conceptual level, economic theory does not provide any clear prediction of how the net impact of an increase in the military burden would influence growth, development, or welfare (Taylor, 1981, p. 1). Classical theory, for example, would predict on the basis of resource allocation that increases in defense will decrease investment and/or civilian consumption and thus reduce growth or welfare.

Keynesian theory, on the other hand, implies that in the presence of inadequate effective demand the operation of the income multiplier would imply an increase in national product, resulting from increased expenditures. More specifically, Keynesians generally assume, at least in the case of the developed countries, that in situations of excess capacity, operating with substantial excess capacity, additional demand and output from expanded military expenditure will increase capacity utilization, thereby increasing the rate of profit and possibly accelerating investment (Treddenick, 1985, 79-80). Clearly, whether Classical or Keynesian effects predominate will determine the net impact of defense expenditures on growth (Deger and Smith, 1985, p. 15; Deger, 1986, ch. 4).

Because of the concentration of defense plants in the developed countries, most economists have tacitly assumed that if Keynesian defense related effects are operative, their impacts would be most likely felt in these economies. The developing countries, being more supply constrained and generally lacking indigenous defense industries, would be more logical places to find the Classical mechanisms operative (Looney, 1989c).

Perhaps for these reasons, Marxists have also focused their analysis of the causes and consequences of military expenditures largely on the advanced countries.

At least for the United States, recent empirical studies have not supported the Marxian interpretation of defense expenditures (Looney and Mehay, 1989). In addition, Marxists have had a hard time countering the argument why, given the relatively capital intensive nature of defense industries, the rate of return on these activities has not fallen over time. One way to get around this apparent contradiction in Marxist analysis is to assume that capitalist governments purchase armaments at negotiated prices. They tax civilian incomes and profit and redistribute the revenue in such a manner that the favored military producers receive a disproportionately higher return on their investment.

While some evidence supporting this proposition has been found in the third world, particularly in military regimes (Looney, 1989b), some conceptual problems still exist.

> Still, such government intervention cannot overcome the decline in the average rate of profit. Rather than buttressing modern capitalism as contemporary Marxist economists would have it, military production hastens the fall in the rate of profit, and therefore, can serve only to identify the internal contradictions Marx had forecast (Looney, 1989b).

> Probably because of the lack of a consistent theory of defense expenditures applicable to all countries, the major examinations to date on possible defense-growth relationships in the third world have been for the most part undertaken with resort to a theoretical empirically based macroeconomics (Deger and West, 1987, p. 10).

Because the results of this analysis have tended to vary with sample size and period covered, few definitive conclusions as to the net impact of increased allocations to defense can be made. For example, several studies have indicated negative effects are likely, while others have found positive associations (Chan, 1985, 1987). Since there is so little theoretical analysis underlying this work, it is impossible to choose between competing interpretations of the impacts likely to be associated with third world military expenditures.

The purpose of this paper is to merge several elements in the Classical, Keynesian and Marxist approaches to the analysis of third world military expenditures. The aim is to develop an empirically testable post-keynesian framework. Hopefully, this approach will be capable of providing insights not only as to the likely economic impacts associated with third world military expenditures, but, perhaps what is more important, a partial understanding of the motivations underlying these expenditures.

A Post Keynesian Framework

One of the major attractions of the post-keynesian approach to the analysis of the ramifications of third world military expenditures is that it provides an explanation of economic growth and income distribution (Looney, 1989d) – with the two viewed as being directly linked to one another (Eichner, 1978; Cornwall, 1978). The key determinant to both is investment, whether measured against total national income or viewed as the percentage change over time.

In this regard higher military spending may have significant multiplier effects, particularly if concentrated on the acquisition of domestic equipment and supplies. It is also possible with excess industrial capacity, that positive industrial linkages to the non-military private sector exist. It follows that the demand generation emanating from the military may, through increased capacity utilization, expand output and thus increase the rate of return on capital, investment, and possibly increase growth (Deger and Smith, 1985, p. 50).

If this assessment is correct, we need to distinguish between the first order and second order effects of military spending. The immediate direct impact of a rise in military spending is likely to be higher demand, production, and employment. These favorable effects, however, may be offset significantly by the indirect effects of military expenditures in reducing private savings and investment, which will in turn hurt longer run increases in productivity and growth (Deger and Sen, 1983).

Therefore both the direct and indirect effects of these expenditures must be considered in a net assessment of their economic impact. At the risk of over simplification, there are four main perspectives to this assessment (Chan, 1985, p. 415). The first, the "modernization" model, is most closely associated with Benoit (1973, 1978). Benoit acknowledged that military expenditures can have several unfavorable consequences:

1. Income shift (increased military spending necessarily reduces the civilian domestic product);

2. Military productivity effect (compared with the civilian sector, the government sector is characterized by slower productivity increases); and

3. Investment effect (military spending crowds out civilian investment).

However, given his finding of a positive relationship between the defense burden and economic growth in the third world, Benoit stressed some compensating favorable factors:

1. The military helps to introduce modern skills and attitudes;

2. The military's capital expenditures (e.g., roads, bridges, airports) have alternative civilian uses and help to strengthen a country's economic infrastructure; and

3. Defense spending leads to mild inflation which in turn, encour-

ages fuller utilization of production facilities. In Benoit's view, these indirect positive effects of defense spending outweigh its direct or indirect negative effects on economic growth.

Part of the problem in applying a post-keynesian approach to third world defense issues stems from the fact that developing countries are far from homogeneous. One would expect the impact of increased defense expenditures on the Brazilian economy to vary somewhat from that experienced in Chad. Similarly, countries with an indigenous arms industry (Looney, 1988, ch. 4) should experience *ceteris paribus* different defense/income multipliers than those found in non producing nations (where *ceteris paribus* a larger proportion of increased military expenditures is likely to wind up in imported weapons).

How governments allocate expenditures can have a significant impact on the relative incomes of the middle- and high-income groups. A major middle-income group is made up of professionals and administrators employed by the public sector. By raising the salaries of these emplyees, the government can easily improve the position of the middle class. On the other hand, an increase in purchases of military hardware would increase the relative incomes of influential middlemen and contractors.

A recent study of Saudi Arabian public sector expenditures illustrates this phenomenon. Here Kavoussi (1983, pp. 75-76) notes that in the aftermath of the oil price increases of 1973, government expenditure clearly shifted from wage and salary payments to purchases of military goods and investment in machinery and construction. By 1979, the share of wages and salaries in total government expenditure had been reduced to one half of the 1973 level. In contrast, during the same period, the share of investment increased twenty percentage points to about one-half of all public sector outlays. Immediately after the oil price increase, the proportion of government expenditure spent on military purchases increased from 25 to 35 percent and remained at that level until 1977. The slowdown in the growth of military expenditures in 1978 caused a larger increase in the share of investment than in the share of wages and salaries.

Due to the lack of reliable data on income distribution, we assume below that changes in the share of consumption in GDP are reflective of income distributional changes. That is, since the lower income groups consume a large portion of their incomes, a reduction in the share of private consumption in gross domestic production indicates a deterioration in the distribution of income.

In short, if the post-keynesian approach toward third world military expenditures is correct, we should expect significantly different patterns of growth and distribution associated with military expenditures in arms producing and non producing countries.

Impact of Military Expenditures on Consumption and Investment

Without excess capacity, increased military expenditures will either reduce civilian consumption or else capital formation and thus growth. *A priori* the impact of the military burden on private consumption after controlling for savings, government revenues and the resource balance, could either be positive or negative. However, taxes and savings should reduce the share of private consumption in *GDP*, with larger deficits in the balance of payments facilitating increases in the share of consumption in *GDP*:

$$PRB = f\,[AS\,(-),\ RBB\,(-),\ RTCRYB\,(-),\ MEP(?)].$$

Where:

PRB	= the average share of private consumption in *GDP*, 1970-82
AS	= average savings rate, 1970-82
RBB	= the average resource balance as a % of *GDP*, 1970-82
RTCRYB	= average government revenues as a % of *GDP*, 1970-82
GETYB	= average government expenditures as a % of *GDP*, 1970-82
MEP	= average per capita military expenditures, 1970-82

For the non-Producers:

$$(1)\ PRB = -\,0.49\,AS - 0.33\,RBB - 0.41\,RTCRYB + 0.56\,MEP$$
$$\quad(-\,2.44)\quad(-\,3.27)\quad(-\,2.58)\quad(3.47)$$

$$df = 30;\ r2 = 0.751;\ F = 19.04$$

For the Producers:

$$(2)\ PRB = -\,0.77\,AS - 0.18\,RBB - 0.03\,RTCRYB - 0.75\,MEP$$
$$\quad(-\,5.38)\quad(-\,1.46)\quad(-\,1.02)\quad(-\,5.26)$$

$$df = 17;\ r2 = 0.768;\ F = 18.48$$

An interesting pattern therefore exists whereby the military burden appears to be associated with higher consumption in the non arms producing countries. In sharp contrast, increases in the military burden appear to come at the expense of consumption in the arms producing nations.

In contrast, the impact of the military burden on the share of investment in *GDP* (*GDIB*) is reversed, i.e., the military burden is associated with increased levels of investment in the arms producing countries and decreased levels of investment in the non-producing countries. More specifically:

Non-Producers:

$$(3)\quad GDIB = \underset{(6.47)}{0.88\,AS} - \underset{(-\,4.57)}{0.61\,RBB} + \underset{(4.31)}{0.48\,GETYB} - \underset{(-\,3.59)}{0.41\,MEP}$$

$df = 293$; $r2 = 0.775$; $F = 20.08$

Producers:

$$(4)\quad GDIB = \underset{(6.05)}{0.98\,AS} - \underset{(-\,4.34)}{0.74\,RBB} - \underset{(-\,1.35)}{0.48\,GETYB} + \underset{(2.86)}{0.55\,MEP}$$

$df = 17$; $r2 = 0.762$; $F = 10.41$

Where:

GDIB = the average share of investment in *GDP*, 1970-1982
GETYB = the share of government expenditure in *GDP*, 1970-82

How can these differential impacts of the defense burden – increased investment and reduced consumption – associated with increased defense burdens in the arms producing countries and vice versa for non-producers, be explained?

Interestingly enough, these results are consistent with those likely to be found as a result of economic disarticulation (Taylor and Bacha, 1976). Particularly in the case of semi-industrialized LDCs, there is likely to be a group of dynamic leading industries specializing in production of automobiles, machinery, consume durables and military equipment. Higher arms spending selectively stimulates demand for products from precisely these sectors.

The resulting output increases require employment of relatively skilled and managerial workers at high incomes; their "modern" tastes as consumers causes a second round of leading sector demand. If extra demand were met by diversion of capacity from industries producing commodities favored by less skilled workers and the poor, then the stage would be set for a growth process supported by a squeeze on wage goods. Investment would be stimulated by the increase in output in leading sectors, adding still more demand pressure. There would be additional generation of high income consumer purchases and so on.

The whole process operates under a resource constraint, but it is evaded by diversion of capacity from sectors producing wage goods in the process; only the poor lose by slow growth of production in commodities suited to their needs (Taylor 1981, p. 4).

The net effect might also be to lower the overall output to capital ratio, as observed above for the arms producers, because wage goods tend to be more labor intensive than arms production or consumer durables.

This sort of mechanism can support faster growth when there are significant differences in consumption patterns between poor and rich, for example, in demands for food and consumer durables.

The net effect in the arms producing countries would be a more likely increase (than in the case of non-producers) in investment (due to direct linkages) and declines in overall private consumption (since lower income groups consume a higher proportion of their incomes) associated with increases in the military burden. While the same investment and consumption could conceivably occur in the arms producing countries, the likelihood is that there would be much less. In fact, these countries might experience a more direct positive relationship between added personnel and consumption with increased military burdens and reduced levels of investment due to few direct linkages associated with an increased military burden.

These are precisely the patterns for arms and non-arms producers identified by the empirical analysis above.

Inflationary Impacts of Defense Expenditures

It is possible that the linkages between the defense burden and consumption observed for the arms producing countries could, instead of the mechanisms outlined above, be caused by inflation and the resulting forced savings impact on private consumption (together with a stimulating impact on overall investment).

According to this line of reasoning, one might also expect the inflationary impact of increased defense expenditures to be greater for the arms producers (due to capacity constraints and policies of domestic absorption). Non-arms producers could, in part, meet added military burdens through constant price imports.

In fact, a number of writers have argued that defense spending raises demand without increasing supply, and, therefore, that it does not contribute to current or future standards of living. Moreover, because more of this spending goes to the procurement of capital goods than do other forms of government spending, it is more inflationary. It is also less resistant to prices and wage increases as military procurement from domestic suppliers is often negotiated on a cost-plus basis. Thus, defense spending may be disproportionately a cause of cost push inflation.

Finally, because officials are usually reluctant either to raise taxes or to cut back other spending to finance additional defense expenditures, their resort to budget deficits and public debt tends to generate further inflationary pressure (Chan, 1985, p. 418).

According to this line of reasoning, the inflationary impacts of increased military budgets might be expected to be higher in the arms producing countries.

To test for the inflationary impact of increased defense burdens, a simple model was developed whereby inflation between 1970 and 1982 (*INFB*) was postulated to be influenced positively by:

1. inflation in the 1960-70 period (*INFA*) – to control for chance high or low inflation countries
2. the average per capita military expenditure (*MEP*), 1970-82; and
3. the average share of public consumption (*PCB*) in *GDP* 1970-82 (*PCB*).

Public consumption was introduced to correct for any biases that might occur from a high correlation between overall public sector consumption and the military burden, i.e., the higher the share of public consumption in *GDP ceteris paribus* the greater the aggregate consumption demand and the fewer the private sector consumer goods available to meet that demand.

The results were as follows:

Producing Countries:

$$(5) \qquad INFB = \underset{(3.09)}{0.62\ PCB} + \underset{(7.71)}{0.80\ INFA} - \underset{(-\ 2.19)}{2.19\ MEP}$$

$$df = 17;\ r2 = 0.854;\ F = 27.49$$

Non-Producing Countries:

$$(6) \quad INFB = 0.21\ PCB + 0.76\ INFA + 0.02\ MEP$$
$$(-2.14) \quad (7.79) \quad (0.24)$$

$$df = 28;\ r2 = 0.614;\ F = 12.36$$

The negative impact of the military burden in the producing countries clearly invalidates the forced savings explanation of falling private consumption and increased investment found with increased military burdens. The income distributional demand profile alteration and resource shift mechanism outlined above (in the discussion of private consumption) tends to be supported, or at least not invalidated, by the observed patterns of military burden and inflation.

With regard to the impact on growth of defense expenditures, while Benoit's suggestion that defense spending could encourage fuller utilization of the existing productive facilities may be particularly relevant for the defense producers, it has much less relevance for the non-producers. The latter countries are likely to be more constrained by supply. The supposed benefits of defense spending may simply impose additional burdens on the economy through expanded salaries, etc., producing excess demand for goods and services in general. The net result might well be slower, rather than faster, economic growth.

Impact of Military Expenditures on Productivity

A more subtle effect military expenditures may have on the economies of developing countries may be through the impact of military expenditure on absorptive capacity. If cooperating factors, such as technical personnel, infrastructure, vital intermediate imports, craft skills, and so forth are diverted to the military as a consequence of defense spending, then the productivity (or rate of return) of investment will drop. The result will be a reduction in the demand for new productive capital formation and a deceleration in overall economic growth.

On the other hand the counter argument would claim that defense expenditure has a high productivity enhancement effect, since it contributes to skill formation, technical and vocational training, and the creation of new infrastructure (Deger and Sen, 1983, p. 50). In like fashion, skills imparted by military education and drill (knowing how to drive, functional numeracy and literacy, craft skills, etc.) remain with trainees for life. If soldiers are mostly conscripts, they may rapidly carry their acquired learning back to productive use in civilian life.

Regardless of which mechanism predominates, the net impact of increased military burden on the productivity of capital should manifest itself in changes in the output capital ratio (*ICOR*) (here defined as the growth in real *GDP* 1970-82 divided by the growth in domestic capital formation over the same period).

If the net effect of an increase in the military burden is to reduce the productivity of capital (and presumably its rate of return), increased defense expenditures should have a negative sign when regressed on *ICOR*. Several other factors could, however, simultaneously reduce overall productivity and must therefore be controlled for.

These include:

1. The growth in public sector consumption (*PCGB*) i.e., an expansion in "unproductive" public sector consumption might divert resources from production capital formation.

2. Inflation (*INFB*) might also reduce capital productivity and/or absorption through diversion of investment towards more speculative activity.

The model used to test for the possible effects of military expenditures was therefore specified as:

$$ICOR = f[PCGB\,(-),\ INFB\,(-),\ MEP\,(-)]$$

where:

PCGB = the growth in real public consumption, 1970-82
INFB = the rate of inflation, 1970-82
MEP = the average military expenditure per capita, 1970-82.

The results:

Producing Countries:

(7) $$ICOR = -\ 0.14\ PCGB + 0.42\ INFB - 0.87\ MEP$$
$$(-\ 0.98) \qquad (3.06) \qquad (-\ 7.16)$$

$df = 18$; $r2 = 0.808$; $F = 21.16$

Non-Producing Countries:

$$(8) \quad ICOR = \underset{(1.24)}{0.21\ PCGB} - \underset{(-\ 1.40)}{0.22\ INFB} - \underset{(-\ 0.75)}{0.12\ MEP}$$

$df = 38$; $r2 = 0.114$; $F = 1.51$

The results for the arms producers indicate that increased military burdens have a highly significant and negative impact on the productivity of investment. The non-arms producers, in sharp contrast do not experience any statistically significant impacts of military expenditure on investment productivity.

In sum, the empirical results tend to confirm one of the hypotheses outlined earlier: increased military expenditures in countries with an indigenous arms industry may result in that industry (due to government priorities on defense and defense related activities) pre-empting scarce managerial, scientific and technical inputs from the private sector. The net result being one of reducing the rate of return (as proxied by the incremental capital output ratio) on investment.

Determinants of Military Expenditures

Traditionally, the bulk of the literature (Maizels and Nissanke, 1987) on third world military expenditure has stressed external or strategic-political variables as critical in affecting allocations to defense. Recent research (Looney, 1988; Looney and Frederiksen, 1988) however, indicates that overall expenditure constraints may ultimately set the actual range in which military expenditures are likely to fall.

In terms of the producers and non-producers, the results of a small model linking arms production, resource constraints, military expenditures and arms imports (Looney, 1989a), demonstrated that a high proportion of the various measures of resources allocated to the military in arms producing countries can be accounted for by internal (economic) factors. On the other hand, non-producer environments were found to be relatively more susceptible to external factors. Apparently, the possession of an indigenous arms industry results in ongoing demands to maintain relatively high (and stable) levels of defense expenditures.

Extending these findings, the general form of the military expenditure relationship was specified as:

$$MEP = f[GNPPER\,(+),\ GDB\,(?),\ PCB\,(+)]$$

Where:

MEP = the average level of per capita military expenditures, 1970-82
$GNPPER$ = the average per capita income, 1970-82
GDB = the average share of government borrowing in GDP, 1970-82
PCB = the average share of government consumption in GDP, 1970-82

The results:

Producing Countries:

$$(10) \quad MEP = \underset{(2.22)}{0.21\ GNPPER} + \underset{(-\ 3.37)}{0.29\ GDB} + \underset{(2.94)}{0.43\ PCB}$$

$r2 = 0.921;\ F = 142.18$

Non-Producers:

$$(11) \quad MEP = \underset{(4.73)}{0.59\ GNPPER} - \underset{(-\ 5.82)}{0.46\ GDB} + \underset{(0.87)}{0.09\ PCB}$$

$r2 = 0.892;\ F = 122.36$

Apparently the governments of non-producing countries may not face the same political pressures to maintain high levels of defense expenditures during periods of low external threat simply to maintain employment in defense plants. In these countries, there is not a strong link between militar-y expenditures and government borrowing. Nor is there a close relationship between military espenditures and the share of resources accounted for by government consumption.

For the arms producers, hardly any output from defense plants is absorbed by external markets. This places great pressure on internal sales to sustain efficient levels of production. Arms producers appear to respond to this need by resorting to borrowing to sustain defense expenditures. In addition the close link between military expenditures and the share of government consumption in GDP suggests some sort of "Military Keynesian-ism" based on stimulating demand in defense plants during deflationary periods (Looney, 1989b; Looney and Frederiksen, 1987; and Looney 1989c).

In addition, the producing countries appear to finance a large part of their military expenditures with external debt and therefore are not necessarily shifting domestic resources away from productive activities to produce arms. Tighter controls on foreign lending to these countries would undoubtedly make arms production somewhat less attractive.

The Impact of Military Expenditures on Overall Growth

The analysis in the previous sections suggested several mechanisms through which increased military burdens may, depending on whether or not the country is an arms producer, impact on the growth process. As shown above, arms producers are characterized by a shift in income from households to the public sector associated with increases in the military burden. While this shift does not appear to be inflationary in and of itself, there is reason to believe the net impact on income distribution may be regressive. In sharp contrast, non-arms producers appear to shift resources toward the private sector (in the form of increased consumption) as the military burden increases.

A priori one can argue that the net impact of these income distributional shifts might be one of increased or decreased growth. A logical case could also be that, given the many other factors impinging on third world growth rates, the overall impact of increased military burdens is likely to be rather insignificant.

Operationally, the role of the military burden (*MEP*) in effecting overall growth in third world countries was examined by determining its impact on the margin after other growth inducing and inhibiting factors had been accounted for (Looney and Frederiksen, 1986):

$$GDPGB = f[GDIGB\,(+),\ INFB\,(-),\ RBB\,(+),\ MEP\,(?)]$$

Where:

GDPGB = average rate of growth of real *GDP*, 1970-82
GDIGB = the growth in investment, 1970-82
INFB = the rate of inflation, 1970-82
RBB = the average resource balance as a % of *GDP*, 1970-82
MEP = the average share of military expenditures in *GNP*, 1970-82

The results:

Arms Producing Countries:

$$(9) \quad GDPGB = 0.74\ GDIGB - 0.29\ INFB + 0.40\ RBB + 0.35\ MEP$$
$$(3.80) \qquad (-\ 1.62) \qquad (2.62) \qquad (2.09)$$

$df = 19$; $r2 = 0.736$; $F = 10.50$

Non-Producing Countries:

$$(10) \quad GDPGB = 0.92\ GDIGB - 0.15\ INFB + 0.05\ RBB - 0.59\ MEP$$
$$(7.24) \qquad (-\ 1.87) \qquad (0.52) \qquad (-\ 4.23)$$

$df = 45$; $r2 = 0.639$; $F = 19..27$

Again a contrasting pattern appears whereby the military burden tends to inhibit growth in the non-producing countries and stimulate it in the arms producing countries.

Conclusions

Benoit's work on the impact of military expenditures has attracted considerable attention over the past twenty years for at least three reasons:

1. His analytical reasoning is persuasive in the sense that there is good economic logic behind the claim that defense expenditures can, at least in the short run, increase overall growth.

2. He produced economic evidence in support of his claim as to the macroeconomic impact of defense expenditures.

3. His analysis shows that the transmission mechanisms of defense efforts to the rest of the economy may be substantially different in developing countries from those in the advanced industrial economies.

The present study has shown that a post-keynesian approach to the defense growth debate provides a useful framework for interactions between defense spending, the distribution of income, investment and overall economic growth. The analysis above provides some additional insights into the dynamics affecting the ultimate impact of defense expenditures on overall economic growth.

Specifically it appears that the macro-linkages from the arms industry to the economy enable third world arms producers to minimize the adverse impacts on the economy often associated with increased military burdens. The mechanism through which this process occurs, however, appears to worsen the overall income distribution through the shifting of resources from wage goods to investment. More fundamentally the lowering of overall productivity of investment stemming from increased military expenditures is likely to take a long run toll on growth through reducing the amount of investment flowing into productive capital formation.

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ANALISI POST-KEYNESIANA DELLE SPESE MILITARI DEL TERZO MONDO

Scopo di questo articolo è di riunire vari elementi degli approcci classico, keynesiano e marxista all'analisi delle spese militari del Terzo Mondo. Sulla base

di questa sintesi risulta che un approccio post-keynesiano al dibattito sull'aumento della difesa fornisce un utile schema per le interazioni fra spese di difesa, distribuzione del reddito, investimento e crescita economica generale. Inoltre, questo schema fornisce ulteriori intuizioni sulla dinamica di ciò che determina in definitiva l'impatto delle spese per la difesa sulla crescita economica globale.

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UN MODELLO DI ALLOCAZIONE OTTIMALE DEL TEMPO CON DIFFERENTI TECNOLOGIE

di
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1. *Introduzione*

È noto che la teoria dell'ottima allocazione delle risorse individuali nell'arco della vita si è ripartita in piú filoni di ricerca. Inizialmente si è considerato l'allocazione del tempo tra due attività costituite dal lavoro e dall'istruzione. In un momento successivo sono stati elaborati dei modelli piú complessi che includevano, tra le possibili attività, anche il consumo di beni (in proporzioni fisse), riallacciandosi cosí alla teoria del consumatore.

Un altro modo di considerare la letteratura sorta in materia, nota piú comunemente come teoria del capitale umano [1], è quello di distinguere tra le funzioni di produzione del capitale umano. Nei modelli del « learning by doing » l'efficienza nella produzione di reddito e di capitale umano aumenta automaticamente anche durante l'attività lavorativa, cioè la funzione di produzione del capitale dipende dal tempo impiegato sia nell'istruzione sia nel lavoro. Invece, nei modelli dell'« on the job training » le due attività di produzione sono completamente separate, cosicchè il capitale umano non può essere ottenuto congiuntamente con il reddito (v. Killingsworth, 1982 e Moreh, 1980, 1985).

Noi seguiremo l'approccio dell'« on the job training », in quanto ci proponiamo di esaminare il comportamento ottimale dell'individuo in presenza di un « trade-off » tra guadagni attuali e futuri. Infatti il soggetto econo-

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[1] La nascita della teoria del capitale umano viene posta da Blaug (1976) nel 1960, anche se la prima rassegna in materia fu pubblicata nel *Journal of Political Economy* nel 1962. Il problema dell'allocazione del tempo nell'investimento in se stessi è stato l'elemento caratterizzante della teoria in oggetto.

mico, se vuole disporre in futuro di maggiori guadagni per unità di tempo, deve sacrificare parte dei guadagni attuali, spendendo una frazione delle proprie risorse nell'acquisizione di maggiore capacità di reddito (v. anche Brunetta e Venturini, 1987). Nell'ambito di questo gruppo i modelli di maggiore rilevanza sono stati quelli proposti da Ben-Porath (1967) e da Sheshinski (1968). Sheshinski, che è stato il primo ad utilizzare la teoria del controllo ottimo in questo ambito, propose lo studio dell'allocazione del tempo fisico tra istruzione e lavoro, mentre Ben-Porath analizzò successivamente l'effetto della presenza di un paniere di beni utilizzabile nell'acquisizione di capitale umano. Cosí Ben-Porath introdusse l'idea di una funzione di produzione del capitale umano (pur derivandola da Becker): « *we have added here a production function of human capital and explored some of the implications of its properties for the optimal path of accumulation of human capital and the life cycle of earnings* » (Ben-Porath, 1970, pag. 363).

Questa funzione costituisce l'elemento chiave di tutta la letteratura sorta in seguito. È stato detto – Landsberger e Passy (1976) – che i modelli di Sheshinski e Ben-Porath « *are both conceptually embedded within the same theoretical structure* » e che « *the differences lie mainly in the specific way the constraints are formulated* » (ib., pag. 137). Queste affermazioni sono solo parzialmente vere, in quanto da un lato solo Sheshinski ha derivato correttamente le proprie conclusioni, mentre dall'altro le interpretazioni della realtà proposte sono alquanto diverse. Infatti Sheshinski intende il capitale umano come un indice delle qualità individuali misurato dal tempo dedicato allo studio ed indipendente da condizioni soggettive. Tale posizione ci pare inaccettabile perché non permette di cogliere le differenze dei comportamenti individuali dovuti alle diversità di efficienza nell'apprendimento. Pertanto ipotizziamo che il capitale umano aumenti in modo non proporzionale l'efficienza del tempo impiegato nel lavoro e nell'istruzione, abbandonando cosí la comoda e irrealistica ipotesi che « *all uses of time are purely and equally augmented by human capital* » (Killingsworth, 1982, pag. 270). In questo senso il nostro lavoro propone un modello piú generale, che ricomprende al suo interno gran parte dell'analisi condotta dagli autori sopra citati.

Illustriamo brevemente la struttura dell'articolo. Nella Sezione 2 esponiamo il modello proposto. Nella Sezione 3 ne determiniamo le soluzioni sotto differenti ipotesi sull'efficienza nelle due attività di produzione (una discussione completa è presentata nell'appendice). Nella Sezione 4 viene analizzato il significato economico delle conclusioni raggiunte. Anticipiamo i seguenti risultati:

a) In tutti i casi non si riscontrano sostanziali diversità con riferimento alla sequenza delle fasi che compongono il ciclo vitale dell'individuo, ovvero, se il periodo di programmazione è sufficientemente ampio, il soggetto si dedica prima all'attività di pura istruzione (tutto il tempo è utilizzato nello studio), poi all'« on the job training » (attività mista), ed infine al puro lavoro (tutto il tempo è destinato al lavoro).

b) La « sensitivity analysis » mostra, invece, delle differenze notevoli nelle diverse ipotesi. Infatti il prezzo ombra del capitale umano presenta degli andamenti particolari (né immediatamente intuibili, né congruenti con l'impostazione « classica » della teoria del capitale umano) a seconda che l'individuo sia piú produttivo nel lavoro o nello studio. Inoltre il tasso salariale ed il salario d'entrata nel mercato del lavoro risentono sia di fattori soggettivi dipendenti dalle diverse capacità di produzione di capitale umano, sia, nel caso di un mercato del lavoro imperfetto, dell'elasticità del tasso salariale rispetto al capitale umano.

2. *Formulazione del modello*

Supponiamo (come in Sheshinski) che in ogni istante $t \, (0 \leq t \leq T)$, l'individuo possa allocare una unità di tempo o nell'attività remunerata (lavoro) o nell'istruzione, che fornisce il cosiddetto capitale umano. In generale, indicata con $u\,(t)$ la frazione di tempo destinata all'istruzione o accumulazione di capitale umano all'istante t, risulta

$$0 \leq u\,(t) \leq 1 \tag{2.1}$$

e quindi $1 - u\,(t)$ è la frazione di tempo destinata al lavoro.

L'obiettivo dell'individuo è quello di massimizzare, rispetto al controllo $u\,(t)$ (funzione continua a tratti), i guadagni globalmente percepiti nell'arco della vita lavorativa, di durata conosciuta pari a T, ed attualizzati all'istante iniziale della programmazione. La funzione obiettivo è allora

$$\int_0^T e^{-rt}\, w\,[K\,(t)]\,[1 - u\,(t)]\,dt, \tag{2.2}$$

dove r è il tasso d'interesse, esogeno e costante in $[0, T]$, $K\,(t)$ è lo stock del capitale umano all'istante t e $w\,(K)$ il tasso salariale. Assumiamo $w\,(K)$ funzione concava del capitale umano (come ipotizzato da Sheshinski), tale che:

$$w'\,(K) > 0,\; w''\,(K) < 0,\; w\,(0) \geq 0,\; w'\,(0) = +\,\infty\,. \tag{2.3}$$

L'ipotesi $w'(0) = +\infty$ può essere indebolita supponendo $w'(0)$ sufficientemente elevata. Seguendo in parte l'elaborazione di Ben-Porath, assumiamo poi che l'output di capitale umano dipenda linearmente dal tempo impiegato per il suo ottenimento e sia, invece, funzione concava dello stesso capitale, cioè:

$$Q = u\, h(K);$$

$$h'(K) > 0,\ h''(K) < 0,\ h(0) \geq 0,\ h'(0) > \delta + r,\ h'(\infty) = 0. \qquad (2.4)$$

Allora il capitale umano è un fattore che aumenta l'efficenza nell'utilizzo del tempo (« time-augmenting ») per tutte le attività in cui viene impiegato. Ovvero un aumento dello stock K rende l'individuo piú produttivo sia nell'istruzione che nel mercato del lavoro. In sostanza il modello afferma che i datori di lavoro pagano i lavoratori in base al capitale umano accumulato; inoltre la funzione di produzione prospettata in (2.4) coglie anche l'idea di una diversità nella capacità di apprendimento degli individui (assente in Sheshinski).

Poiché si ipotizza che il capitale umano sia soggetto al fenomeno del deprezzamento (dovuto ad es. al cambiamento tecnologico), l'equazione differenziale che descrive l'andamento dello stesso è:

$$\dot{K} = u(t)\, h(K) - \delta K \qquad \text{con } 0 < \delta < 1, \qquad (2.5)$$

ove il tasso di deprezzamento δ è esogeno e costante in $[0, T]$. Avendo ipotizzato $h(K) \geq 0$, si può dimostrare che, in corrispondenza di un qualunque controllo $u(t)$, le soluzioni $K(t)$ dell'equazione differenziale (2.5), con condizione iniziale $K(0) = K_0 \geq 0$ e definite sull'intervallo $[0, T]$, sono funzioni non negative. Inoltre, se $K_0 > 0$, risulta $K(t) > 0$ per ogni $t \in [0, T]$.-

Quindi il nostro problema consiste nel massimizzare la funzione obiettivo rappresentata dai guadagni globali (2.2) rispetto al controllo $u(t)$, con $U = [0, 1]$ regione ammissibile (cioè $u(t) \in U$ per qualunque $t \in [0, T]$), ove la variabile di stato è soggetta al vincolo differenziale (2.5). Questo problema è inquadrabile come uno di controllo ottimale, in cui l'hamiltoniano è:

$$H \equiv p_0 e^{-rt} w(K)(1 - u) + p_1 [u\, h(K) - \delta K]. \qquad (2.6)$$

Come noto, il Principio di Massimo di Pontryagin fornisce le condizioni necessarie di ottimalità (v. Seierstad-Sydseter, 1987, teorema n. 2, pag. 85) che, nel nostro caso, divengono:

$$\hat{p}\,(t) = (p_0, p_1\,(t)) \neq (0, 0), \tag{2.7}$$

$$\operatorname*{Max}_{u \in U} H\,[K^*\,(t), u, \hat{p}\,(t), t] = H\,[K^*\,(t), u^*\,(t), \hat{p}\,(t), t], \tag{2.8}$$

$$\dot{p}_1 = -p_0\, e^{-rt}\, w'\,[K^*\,(t)]\,[1 - u^*\,(t)] - p_1\,(t)\,\{u^*\,(t)\, h'\,[K^*\,(t)] - \delta\}, \tag{2.9}$$

Inoltre, poiché $K\,(T)$ è libero, risulta (v. Seierstad-Sydseter, 1987, nota 5, pag. 86):

$$p_0 = 1, \tag{2.10}$$

$$p_1\,(T) = 0 \text{ (condizione di trasversalità)}. \tag{2.11}$$

In seguito per comodità p_1 verrà sempre indicato con p. Come conseguenza della non negatività di $p\,(t)$, si può facilmente dimostrare che vale la condizione:

$$\hat{H}\,(K, p\,(t), t) = \operatorname*{Max}_{u \in U} H\,(K, u, p\,(t), t) \tag{2.12}$$

è una funzione reale di K, t, concava in K per ogni t, K.

Allora, in base al teorema di Arrow (v. Seierstad-Sydseter, 1987, teorema n. 5, pag. 107), ogni coppia ammissibile $(K^*\,(t), u^*\,(t))$ che soddisfa il sistema (2.7)-(2.12) risolve il problema di massimizzazione. Quindi le condizioni (2.7)-(2.11) sono necessarie e sufficienti per il verificarsi dell'ottimalità.

Posto poi $q = e^{rt}\,p$, le (2.8), (2.9) e (2.11) si trasformano nelle:

$$\text{se } w\,(K^*)/h\,(K^*) > q \text{ allora } u^*\,(t) = 0, \tag{2.8a}$$

$$\text{se } w\,(K^*)/h\,(K^*) = q \text{ allora } u^*\,(t) \in [0, 1], \tag{2.8b}$$

$$\text{se } w\,(K^*)/h\,(K^*) < q \text{ allora } u^*\,(t) = 1, \tag{2.8c}$$

$$\dot{q} = -\,w'\,(K^*)\,(1 - u^*) + q\,[\delta + r - u^*\,h'\,(K^*)], \tag{2.13}$$

$$q\,(T) = 0, \tag{2.14}$$

dove, per semplicità di notazione, è stata omessa la variabile tempo in $K^*\,(t)$, $q\,(t)$, $u^*\,(t)$. Tale semplificazione verrà adottata anche successivamente, quando opportuno.

Sia $F\,(K) = w\,(K)/h\,(K)$; supponiamo poi che $w\,(\cdot)$ ed $h\,(\cdot)$, e quindi $F\,(\cdot)$, siano funzioni sufficientemente regolari (derivabili almeno due volte). Il comportamento della funzione F non è univocamente determinato, poiché $w(K)$ ed $h(K)$ sono ambedue crescenti e concave. Allora possiamo distinguere *almeno* i seguenti tre casi:

a) $F(K)$ è costante,

b) $F(K)$ è monotona crescente,

c) $F(K)$ è monotona decrescente.

È evidente che sono possibili, ed analizzabili, molte altre situazioni, ma pur sempre ottenibili come combinazioni di questi tre casi.

Prima di passare all'esame del modello, osserviamo che, qualunque sia il comportamento di $F(K)$, se $K_0 > 0$ o $[w(0)/h(0)] > 0$, l'ultima fase della vita individuale è caratterizzata da un'attività costituita dal solo lavoro, che denominiamo « puro lavoro ». Infatti, supposto per assurdo $u^*(t) \neq 0$ in $[t_0, T]$, per (2.8b) e (2.8c) è $q(t) \geq w[K^*(t)]/h[K^*(t)] > 0$; tale condizione risulta incompatibile con (2.14) (infatti se $K_0 > 0$ allora $K(t) > 0$ e quindi pure $w/h > 0$ per ogni t).

Nel paragrafo successivo procederemo alla soluzione del modello, tralasciando il caso piú elementare con $F(K)$ costante, che può essere facilmente risolto con $h(K)$ e $w(K)$ generiche. In tale ipotesi, se $K_0 > 0$, i sentieri ottimali del controllo $u^*(t)$ e dello stock di capitale umano $K^*(t)$ hanno andamenti simili a quelli esaminati nel paragrafo seguente; invece, il prezzo ombra del capitale umano $p(t)$ risulta sempre decrescente su $[0, T]$ [2].

3. *Soluzione del modello*

Il modello, che qui proponiamo per uno studio dei casi b) e c) considerati nel paragrafo precedente, si caratterizza per l'ipotesi:

$$w(K) = K^{\alpha}; h(K) = K^{\beta}; \text{ ovvero } F(K) = K^{\alpha - \beta}, \tag{3.1}$$

con $\alpha, \beta \in]0,1[$. Quindi α è l'elasticità del tasso salariale rispetto al capitale umano, mentre β è l'elasticità della produzione del capitale umano rispetto allo stesso capitale (ovviamente se $\alpha = \beta$ ricadiamo nel caso a)). Naturalmente l'andamento della funzione $F(K)$ dipende espressamente dal valore assunto dalle due elasticità giacché $F(K)$ è crescente e concava nel caso $\alpha > \beta$, mentre è decrescente e convessa nell'ipotesi $\alpha < \beta$. Inoltre se $K > 1$ e $\alpha > \beta$ oppure se $0 < K < 1$ e $\alpha < \beta$, l'individuo risulta piú

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[2] In questo caso il modello è risolvibile per $K_0 = 0$, purché $h(0) > 0$ (e quindi $w(0) > 0$) e $h'(0) \in R$. Inoltre se la produttività iniziale del capitale umano non è molto elevata, cioè $h'(0) < ((\delta + r)/1 - e^{-(\delta + r)T})$, allora all'individuo conviene dedicarsi solamente al puro lavoro senza mai incrementare, nell'arco della vita, lo stock di capitale umano.

efficiente sul lavoro; invece se $K > 1$ e $\alpha < \beta$ oppure se $0 < K < 1$ e $\alpha > \beta$, l'individuo è piú efficiente nell'istruzione.

Quindi in questo modello le funzioni di produzione del reddito e del capitale umano sono due Cobb-Douglas a rendimenti crescenti espresse, rispettivamente, da:

$$E(t) = [1 - u(t)]\,[K(t)]^{\alpha}, \qquad Q(t) = u(t)\,[K(t)]^{\beta}.$$

La specializzazione della funzione del tasso salariale e della produzione di capitale umano, non appaiono incrinare la generalità dello studio intrapreso, poiché il nostro obiettivo è l'analisi del comportamento individuale al variare delle caratteristiche dell'efficienza relativa $F(K)$. Inoltre supponiamo $K_0 > 0$. Tale ipotesi pare ragionevole poiché il capitale umano è qualcosa di diverso dalla semplice istruzione cumulata (come in Sheshinski); per noi il capitale è un indice delle qualità individuali (o dell'efficienza del soggetto), che possono essere innate o derivate da un periodo di istruzione obbligatoria.

Le equazioni (2.5), (2.13) che regolano l'andamento del capitale umano $K(t)$ e della variabile $q(t)$ in condizioni di ottimalità, divengono:

$$\left[\begin{array}{l} \dot{K} = u(t)\,K^{\beta} - \delta K \\ \dot{q} = q\,(\delta + r - u(t)\,\beta K^{\beta-1}) - \alpha K^{\alpha-1}\,[1 - u(t)]. \end{array}\right. \tag{3.2}$$

Per ottenere le traiettorie che descrivono le soluzioni ottimali nello spazio delle fasi risolviamo il sistema (3.2) quando il controllo $u(t)$ è una funzione costante, cioè per $u(t) = \underline{u}$ per ogni t, con $\underline{u} \in [0, 1]$. In particolare, tenendo conto di (2.8a), (2.8b) e (2.8c), distinguiamo i casi in cui $\underline{u}$ è un estremo ($\underline{u} = 0$ o $\underline{u} = 1$) oppure $\underline{u}$ è un punto interno dell'intervallo [0, 1].

Inoltre, per rendere piú agile l'esposizione, vengono qui riportate senza dimostrazione alcune proprietà rinviando, quando opportuno, all'appendice per una trattazione piú particolareggiata e, ove possibile, piú generale.

Esaminiamo dapprima il caso in cui $u(t) = 1$ per ogni t. Il sistema (3.2) diviene allora:

$$\left[\begin{array}{l} \dot{K} = K^{\beta} - \delta K \\ \dot{q} = q\,[\delta + r - \beta K^{\beta-1}] \end{array}\right. \tag{3.3}$$

e con $K_1 = [\beta/(\delta + r)]^{1/1-\beta}$, $K_2 = (1/\delta)^{1/1-\beta}$ $(K_1 < K_2)$ risulta:

$$\dot{q} \gtreqless 0 \leftrightarrow K \gtreqless K_1, \quad \dot{K} \gtreqless 0 \leftrightarrow K \gtreqless K_2.$$

Si può dimostrare che il sistema (3.3) ammette un'unica soluzione $(K(t), q(t))$ che soddisfa la condizione $0 < K(0) = K_0 < K_2$ e che passa per un punto assegnato $(\underline{K}, \underline{q})$, con $K_0 < \underline{K} < K_2$, $\underline{q} > 0$. La funzione $K(t)$ è monotona crescente, la $q(t)$ è convessa, e per $t \rightarrow +\infty$ risulta $K(t) \rightarrow K_2$, $q(t) \rightarrow +\infty$. Sono pertanto univocamente determinati $q_0 = q(0)$ ed il tempo finito in cui la traiettoria passa per $(\underline{K}, \underline{q})$.

Quanto ora visto si può riassumere (v. anche le Figg. [A.1], [A.2] in appendice) con la seguente rappresentazione geometrica della traiettoria nello spazio delle fasi.

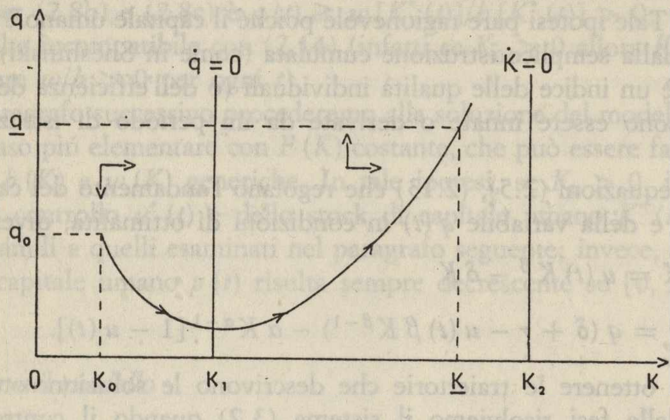


FIG. 1

Esaminiamo ora il caso in cui $u(t) = 0$ per qualunque t. Il sistema (3.2) diviene ora:

$$\begin{cases} \dot{K} = -\delta K \\ \dot{q} = q(\delta + r) - \alpha K^{\alpha-1} \end{cases} \tag{3.4}$$

e quindi risulta:

$$\dot{q} \gtreqless 0 \leftrightarrow q \gtreqless \alpha K^{\alpha-1} / (\delta + r), \qquad \dot{K} \leq 0 \leftrightarrow K \geq 0.$$

Nello spazio delle fasi, il luogo $\dot{K} = 0$ coincide con l'asse delle ordinate, ed il luogo $\dot{q} = 0$ corrisponde al grafico della funzione $q = (\alpha K^{\alpha-1})/(\delta + r)$. Si può facilmente vedere che, assegnato t_0 e $(\underline{K}, \underline{q})$ con $\underline{K}, \underline{q} > 0$, il sistema

(3.4) ammette un'unica soluzione definita su $[t_0, +\infty[$, tale che $K(t_0) = \underline{K}$, $q(t_0) = \underline{q}$.

Per rendere soddisfatta la (2.14), interessa determinare sotto quali condizioni su $(\underline{K}, \underline{q})$, la funzione $q(t)$ interseca l'asse delle t. A tal fine considerata la funzione, definita per $K > 0$ da $\Phi(K) = (\alpha K^{\alpha-1})/(\delta\alpha + r)$, si può dimostrare che se $\underline{q} < \Phi(\underline{K})$ allora la $q(t)$ è, per un ben determinato t_1, positiva in $[t_0, t_1[$ e diviene negativa in $]t_1, +\infty[$, mentre non si annulla mai se $\underline{q} \geq \Phi(\underline{K})$. Inoltre se $\underline{q} > \Phi(\underline{K})$ allora per $t \to +\infty$ risulta $q(t) \to +\infty$. Infine è agevole constatare che $\Phi(K)$ è monotona decrescente, e che $\Phi(K) > (\alpha K^{\alpha-1})/(\delta + r)$ per ogni K.

Quanto appena visto con riferimento al sistema (3.4) (v. anche le Figg. [A.3] e [A.4] in appendice), può essere utilmente descritto mediante la seguente rappresentazione geometrica nello spazio delle fasi:

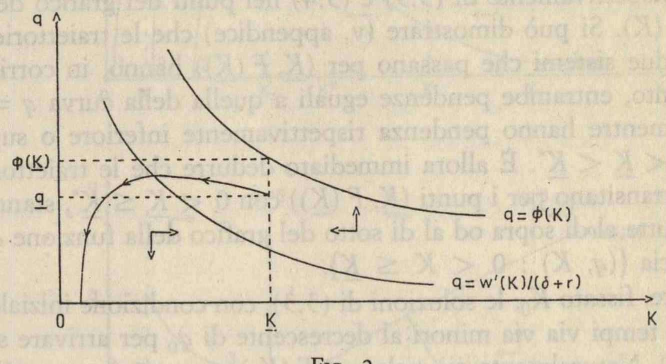


FIG. 2

Poiché il sistema (3.4) è autonomo, se $\underline{q} < \Phi(\underline{K})$ l'intervallo di tempo $\Delta t = t_1 - t_0$, in cui la soluzione passa da $(\underline{K}, \underline{q})$ ad un punto sull'asse delle K, non dipende da t_0 (a parità delle altre condizioni).

Interessa ancora trovare i punti in cui i grafici delle funzioni $q = w'(K)/(\delta + r)$ e $q = \Phi(K)$ intersecano quello della funzione $q = F(K)$; essi si ottengono rispettivamente in corrispondenza dei seguenti valori:

$$K_3 = [\alpha/(\delta + r)]^{1/1-\beta}, \qquad K_4 = [\alpha/(r + \delta\alpha)]^{1/1-\beta}.$$

È immediato constatare che $F(K) \gtrless \Phi(K)$ se e solo se $K \gtrless K_4$. Osservato che i sistemi (3.3) e (3.4) non ammettono posizioni di equilibrio (tranne quella banale), ai fini della determinazione di eventuali punti stazionari della soluzione ottimale, consideriamo il sistema (3.2) nel caso in cui $u(t) = \underline{u} \in]0, 1[$, per ogni t. Quindi, avendo presente la condizione (2.8c), cerchiamo le soluzioni $(K, q, \underline{u}$ del sistema di equazioni $\dot{K} = 0$, $\dot{q} = 0$ e $q = F(K)$. Si verifica facilmente che esiste una unica soluzione data da:

$$\underline{K}^* = [\alpha/(r + \delta(1 + \alpha - \beta))]^{1/1-\beta}, \qquad \underline{q}^* = (\underline{K}^*)^{\alpha-\beta}, \qquad \underline{u}^* = \delta\, \underline{K}^{*\,1-\beta}.$$

Sussistono anche le seguenti relazioni:

$$K_1 < K_2,\ K_3 < K_2,\ K_3 < K_4,\ \underline{K}^* < K_2,\ \underline{K}^* < K_4;$$

$$K_3 \gtreqless \underline{K}^* \gtreqless K_1 \leftrightarrow \alpha \gtreqless \beta.$$

Prima di determinare la soluzione ottimale del nostro problema conviene studiare nello spazio delle fasi le pendenze $\dot{q}/\dot{K}$ delle traiettorie soluzioni rispettivamente di (3.3) e (3.4) nei punti del grafico della funzione $q = F(K)$. Si può dimostrare (v. appendice) che le traiettorie soluzioni di questi due sistemi che passano per $(\underline{K}, F(\underline{K}))$ hanno, in corrispondenza di tale punto, entrambe pendenze eguali a quella della curva $q = F(K)$ se $\underline{K} = \underline{K}^*$, mentre hanno pendenza rispettivamente inferiore o superiore ad essa se $0 < \underline{K} < \underline{K}^*$. È allora immediato dedurre che le traiettorie (3.3) e (3.4) che transitano per i punti $(\underline{K}, F(\underline{K}))$ con $0 < \underline{K} \leq \underline{K}^*$, stanno rispettivamente tutte al di sopra od al di sotto del grafico della funzione $q = F(K)$ nella striscia $\{(q, K) : 0 < K \leq \underline{K}\}$.

Inoltre, fissato K_0, le soluzioni di (3.3), con condizione iniziale (K_0, q_0), impiegano tempi via via minori al decrescente di q_0 per arrivare sulla curva $q = F(K)$. Naturalmente ciò vale per $F(K_0) \leq q_0 \leq \hat{q}_0$, ove $(K_0, \hat{q}_0)$ fornisce la condizione iniziale della soluzione che passa per $(\underline{K}^*, \underline{q}^*)$. Si può anche verificare che per ogni $\underline{K} \in]0, \underline{K}^*]$, le traiettorie di (3.4), che passano per $(\underline{K}, F(\underline{K}))$, giungono sull'asse delle ascisse impiegando tempi $\underline{T}$ via via minori al decrescere di $\underline{K}$[3].

Premettiamo, come illustrazione alla discussione successiva, i seguenti diagrammi di fase, il primo relativo al caso $\alpha < \beta$ ed il secondo al caso

[3] Infatti tramite (A.4) si ottiene l'equazione:

$$F(K) = q = \int_0^T e^{-(\delta + r)t} w'(K e^{-\delta t})\, dt,$$

che nel nostro caso è equivalente alla $1 - e^{-(\delta + r)T} = K^{1-\beta}(r + \delta\alpha)/\alpha$, da cui discende poi quanto affermato.

$\alpha > \beta$. Osserviamo che per $\beta = 0$ riotteniamo il diagramma tracciato da Sheshinski (1968).

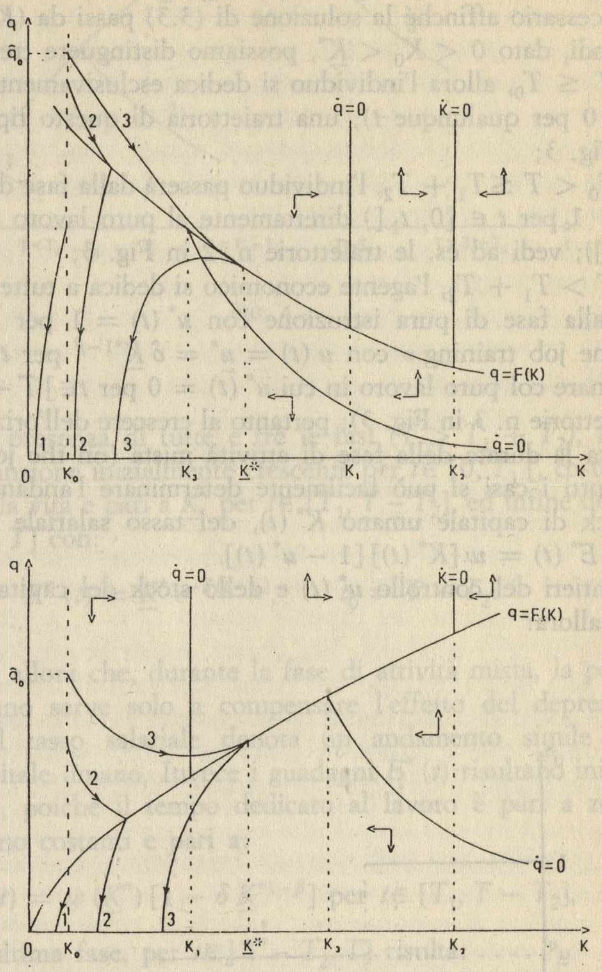


FIG. 3

A questo punto siamo in grado di caratterizzare l'andamento della terna ottimale ($K^*(t)$, $q(t)$, $u^*(t)$) nel caso – piú interessante dal punto di vista dello studio delle fasi che compongono il ciclo vitale dell'individuo –

in cui il capitale umano iniziale non sia molto elevato (piú precisamente con $\underline{K}^* \geq K_0 > 0$). Indichiamo con T_0 e T_2 gli intervalli di tempo impiegati dalla soluzione di (3.4) per arrivare nello spazio delle fasi sull'asse delle ascisse rispettivamente da $(K_0, F(K_0))$ e $(\underline{K}^*, \underline{q}^*)$. Sia infine T_1 l'intervallo di tempo necessario affinché la soluzione di (3.3) passi da $(K_0, \hat{q}_0)$ a $(\underline{K}^*, \underline{q}^*)$.

Quindi, dato $0 < K_0 < \underline{K}^*$, possiamo distinguere tre casi:

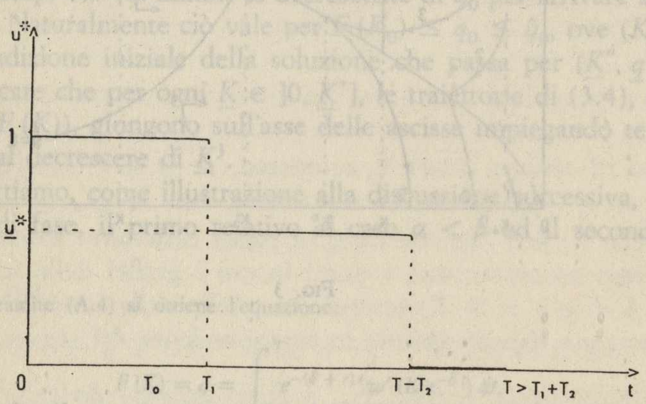
1) se $T \leq T_0$, allora l'individuo si dedica esclusivamente al puro lavoro ($u^*(t) = 0$ per qualunque t); una traiettoria di questo tipo è indicata col n. 1 in Fig. 3;

2) se $T_0 < T \leq T_1 + T_2$, l'individuo passerà dalla fase di pura istruzione ($u^*(t) = 1$ per $t \in [0, t_1[$) direttamente al puro lavoro ($u^*(t) = 0$ per $t \in]\, t_1\, T]$); vedi ad es. le traiettorie n. 2 in Fig. 3;

3) se $T > T_1 + T_2$, l'agente economico si dedica a tutte e tre le attività, ovvero dalla fase di pura istruzione con $u^*(t) = 1$ per $t \in [0, T_1[$ passa all'« on the job training » con $u(t) = \underline{u}^* = \delta\, \underline{K}^{*1-\beta}$ per $t \in [T_1, T - T_2]$, per terminare col puro lavoro in cui $u^*(t) = 0$ per $t \in]\, T - T_2, T]$ (vedi ad es. le traiettorie n. 3 in Fig. 3); pertanto al crescere dell'orizzonte temporale T aumenta la durata della fase di attività mista (on the job training).

In tutti i casi si può facilmente determinare l'andamento nel tempo dello stock di capitale umano $K^*(t)$, del tasso salariale $w[K^*(t)]$ e dei guadagni $E^*(t) = w[K^*(t)][1 - u^*(t)]$.

I sentieri del controllo $u^*(t)$ e dello stock del capitale umano $K^*(t)$ risultano allora:



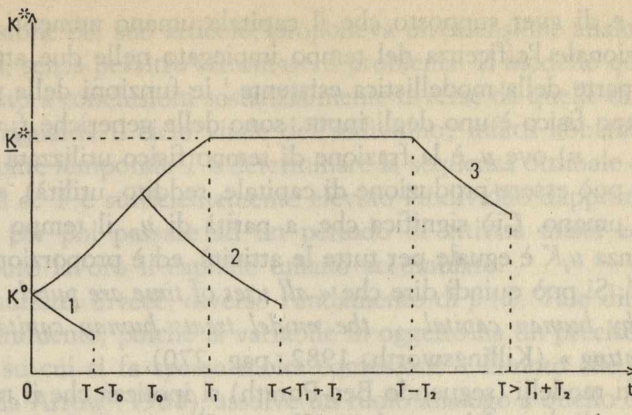


FIG. 4

Quindi, in presenza di tutte e tre le fasi ($T > T_1 + T_2$), il capitale umano risulta funzione inizialmente crescente per $t \in [0, T_1[$, costante nella seconda fase della vita e pari a $\underline{K}^*$ per $t \in [T_1, T - T_2]$, ed infine decrescente per $t \in]T - T_2, T]$ con:

$$K^*(t) = \underline{K}^* e^{-\delta(t-t_0)}, \qquad t_0 = T - T_2.$$

È evidente allora che, durante la fase di attività mista, la produzione di capitale umano serve solo a compensare l'effetto del deprezzamento. Naturalmente il tasso salariale denota un andamento simile a quello palesato dal capitale umano. Invece i guadagni $E^*(t)$ risultano inizialmente nulli in $[0, T_1[$, poiché il tempo dedicato al lavoro è pari a zero; nella seconda fase sono costanti e pari a:

$$E^*(t) = w(\underline{K}^*)[1 - \delta \underline{K}^{*1-\beta}] \text{ per } t \in [T_1, T - T_2],$$

ed infine, nell'ultima fase, per $t \in]T - T_2, T]$ risulta:

$$E^*(t) = w[\underline{K}^* e^{-\delta(t-t_0)}].$$

4. *Un commento ai modelli proposti*

Abbiamo detto che la novità della nostra formulazione risiede nell'aver introdotto una funzione di produzione del capitale umano (a differenza di

Sheshinski) e di aver supposto che il capitale umano aumenti in maniera non proporzionale l'efficenza del tempo impiegato nelle due attività. Invece, in gran parte della modellistica esistente [4] le funzioni della produzione, in cui il tempo fisico è uno degli input, sono delle generiche $f_i = f_i(u_i K,.)$ (con $i = 1, ..., n$) ove u_i è la frazione di tempo fisico utilizzata nell'i-esima attività (che può essere produzione di capitale, reddito, utilità), e K lo stock del capitale umano. Ciò significa che, a parità di u_i, il tempo espresso in unità efficienza $u_i K$ è eguale per tutte le attività, ed è proporzionale al capitale umano [5]. Si può quindi dire che « *all uses of time are purely and equally augmented by human capital* ... *the model treats human capital as purely time augmenting* » (Killingsworth, 1982, pag. 270).

In molti modelli (seguendo Ben-Porath) si ipotizza che il tassa salariale sia funzione lineare del capitale $w(K) = a K$, $(a > 0)$ [6], mentre l'output del capitale umano è una funzione Cobb Douglas $Q = b\, u^{\tau} K^{\sigma} D^{\pi}$ $(b > 0)$, ove D è un opportuno paniere di beni destinati all'istruzione. Purtroppo sia Ben-Porath che altri autori, come Heckman (1976), si sono limitati allo studio di soluzioni interne $(0 < u < 1)$. In questo modo non vengono considerate tutte le cosiddette « fasi » che compongono la vita dell'agente economico, e che nel nostro caso sono la pura istruzione, l'« on the job training » ed il puro lavoro.

L'idea che il capitale umano agisca in maniera diversa nei due processi di produzione era già implicita in Sheshinski, il quale ipotizzava come funzione di produzione del capitale umano $Q = u$, e come funzione dei guadagni $E = (1 - u)\, w(K)$. Per questo autore la produzione di capitale umano è data semplicemente dal tempo dedicato all'istruzione e quindi il capitale umano è identificato con le ore complessive trascorse in tale attività. Però, assumere che i lavoratori siano produttivi solo in base al tempo dedicato allo studio, è un'ipotesi decisamente discutibile. Infatti Sheshinski,

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[4] Vedi ad es. HECKMAN (1976), BLINDER e WEISS (1976), KILLINGSWORTH (1982).

[5] Un'eccezione è costituita dal modello proposto in GRAHAM (1981). Da un punto di vista analitico il modello è di scarso interesse, poiché è un semplice modello biperiodale, con funzione obiettivo costituita da una funzione d'utilità. Comunque la conclusione piú interessante di questo modello è l'esistenza di una correlazione (non precisata), tra accumulazione di capitale umano e ricchezza finanziaria iniziale. Questa, se positiva, potrebbe giustificare il perpetuarsi delle diseguaglianze sociali. Invece nel modello di Blinder e Weiss è stato dimostrato – v. DRIFFILL (1980) – che sussiste una correlazione negativa tra ricchezza finanziaria iniziale e capitale umano, mentre in HECKMAN (1976) l'accumulazione di capitale umano non è influenzata da variazioni della ricchezza finanziaria iniziale. Osserviamo che queste conclusioni appaiono gli aspetti piú deboli di tali modelli della teoria del consumatore con capitale umano.

[6] Quindi la funzione di produzione del reddito è $E = a K (1 - u)$.

nella conclusione del suo articolo, proponeva un'estensione analoga a quella qui condotta, senza peraltro affrontare il problema. Il modello qui elaborato non ha portato a conclusioni sostanzialmente diverse da quelle di Sheshinski per quanto riguarda il ciclo vitale dell'individuo; infatti abbiamo ritrovato che è l'orizzonte temporale T a determinare la sequenza ottimale delle fasi di attività. Solo se T è sufficientemente elevato l'individuo dapprima si dedica allo studio, per poi passare ad un periodo di attività mista ed utilizzare infine nel puro lavoro il capitale umano accumulato.

Può risultare, invece, diverso l'andamento di $p(t)$. Tale differenziazione non è ininfluente, poiché la variabile in oggetto ha un preciso significato economico, su cui si fa spesso molta confusione [7]. È noto che $p(0)$, come dimostrato da Arrow (1968), assolve un ruolo analogo a quello dei moltiplicatori di Lagrange, ed è il prezzo « ombra » del capitale umano valutato all'istante iniziale. Infatti $p(0)$ misura il contributo di un'unità aggiuntiva di capitale umano in $t = 0$ alla funzione valore ottimale [8].

In letteratura è apparso naturale estendere questa interpretazione economica di $p(0)$ a $p(t)$, in corrispondenza a qualunque t. Qui $p(t)$ misura la variazione della funzione valore ottimale V (v. nota 8) *su tutto l'arco temporale* $[0, T]$ (e non sul solo intervallo $[t, T]$) per una variazione unitaria della variabile di stato K in t. Piú precisamente, assegnato K_0, definiamo l'estremo superiore della funzione obiettivo:

$$V(\underline{t}, v) = \sup \left\{ \int_0^T e^{-rt} w(K)(1-u)\, dt \ :\ (K(t), u(t)) \text{ ammissibile} \right\} \quad (4.1)$$

[7] Osserviamo comunque che il prezzo ombra del capitale umano è $p(t)$ e non $q(t)$, come affermato da Sheshinski (v. anche la nota successiva). Quindi la crescenza di q non implica quella di p, mentre invece la crescenza di p implica quella di q.

[8] Viene detta « optimal value function » la funzione V della variabile K_0, a valori nella retta compatta, definita come l'estremo superiore della funzione obiettivo di corrispondenza di un qualunque valore di K_0 per il quale esista una coppia $(K(t), u(t))$ ammissibile. Nel nostro caso risulta:

$$V(K_0) = \sup \left\{ \int_0^T e^{-rt} w(K)(1-u)\, dt \ :\ (K(t), u(t)) \text{ ammissibile} \right\}$$

Ricordiamo che una coppia $(K(t), u(t))$ si dice ammissibile se $u(t)$ è continua a tratti e $K(t)$ è una funzione continua e derivabile nei punti di continuità di $u(t)$, soluzione dell'equazione differenziale (2.5) con condizione iniziale K_0. Quindi, se esiste una coppia $(K^*(t), u^*(t))$ ottimale in corrispondenza di K_0, allora $V(K_0)$ è un valore reale pari all'integrale calcolato in corrispondenza di quella coppia ottimale. Si dimostra (v. ARROW, 1968) che, sotto opportune condizioni (soddisfatte nel nostro modello), se in corrispondenza del valore iniziale K_0 esiste una terna ottimale $(K^*(t), u^*(t), p(t))$, allora $V(\cdot)$ è, in un intorno di K_0, una funzione reale, derivabile in K_0 con $\partial V / \partial K_0 = p(0)$.

dove l'insieme delle coppie ammissibili $(K(t), u(t))$ è diverso da quello considerato per $p(0)$. Qui infatti una coppia si dice ammissibile se $u(t)$ è continuo a tratti e $K(t)$ è una soluzione dell'eq. differenziale (2.5), ovunque continua, tranne che in $\underline{t}$ dove $v = K(\underline{t}+) - K(\underline{t}-)$. Cerchiamo cioè di massimizzare la funzione obiettivo con funzioni $K(t)$ ovunque continue tranne che nel punto $\underline{t}$, ove le variabili di stato presentano un salto di ampiezza v assegnata (per $v = 0$ si ha ovviamente l'usuale problema di controllo ottimale). Questo è un problema di massimo con salti nella variabile di stato, e si dimostra, sotto opportune condizioni (v. Seierstad-Sydseter, 1987, teorema n. 9), peraltro soddisfatte nel nostro problema, che, supposta esistere una soluzione ottimale $(K^*(t), p(t), u^*(t))$ per $v = 0$, allora la « optimal value function » $V(\underline{t}, v)$ assume valori reali in corrispondenza di coppie ottimali, in un intorno di $v = 0$; inoltre essa è derivabile rispetto a v in $(\underline{t}, 0)$ e risulta:

$$\left.\frac{\partial V}{\partial v}\right|_{(\underline{t},\, 0)} = p(\underline{t}) \tag{4.2}$$

Solo con queste necessarie precisazioni possiamo dire che $p(\underline{t})$ misura quanto l'individuo sarebbe disposto a cedere per ottenere un'unità aggiuntiva di capitale umano in $\underline{t}$.

Risulta anche evidente la spiegazione economica della condizione di trasversalità (2.11); infatti nell'istante finale del periodo di programmazione un'unità aggiuntiva di capitale umano non può aumentare il valore della funzione obiettivo e quindi il prezzo di tale unità è nullo.

Poiché $p(t)$ misura la variazione di V, valutata nell'istante iniziale, $q(t) = e^{rt} p(t)$ è il prezzo ombra corrente del capitale umano. Quindi è significativo esaminare solo l'andamento del prezzo valutato all'inizio del periodo di programmazione (e non $q(t)$) evidenziando le cause che lo determinano. Per le ragioni viste sopra non sono giustificati « facili » ragionamenti basati sul principio del « ceteris paribus » per spiegare economicamente l'andamento di $p(t)$. Infatti variazioni dello stock di capitale in t possono modificare notevolmente la traiettoria ottimale in esame, poiché è stato osservato che « *changes in these parameters* (nel nostro modello K_0, α, β, r, δ, $\underline{t}$, v) *will change the optimal control as well as the optimal path. In applications it is often important to study these changes, but general results of any practical value turn out to be very complicated, and hard to apply. The reason is obvious. A change in one or more of the parameters might change the optimal solution in a variety of ways. For instance, a bang-bang control might change to a continuous control, switch-point might change drastically,* *etc.* » (Seierstad-Sydseter, 1987, pag. 219). Allora una variazione unitaria del capitale in $\underline{t}$ modifica il problema originario di massimizzazione della (2.2.) nel problema (4.1), e quindi, in generale, modifica la soluzione ottimale ($K^*(t), u^*(t)$) su tutto l'intervallo $[0, T]$. Ad es., se $T > T_1 + T_2$ e $\underline{t} < T_1$ (ovvero l'individuo si dedica a tutte e tre le attività ed il salto di capitale avviene nella prima fase di pura istruzione), l'individuo programma un periodo di tempo minore di pura istruzione compensato da un periodo maggiore di « on the job training ». Invece per $\underline{t} > T - T_2$ (salto durante l'attività di puro lavoro) aumenta il periodo di tempo dedicato al puro lavoro e diminuisce quello dell'« on the job training ». Proprio in base a queste considerazioni appare evidente che discussioni relative alle sole equazioni differenziali del prezzo (come in Landsberger e Passy, 1976) non sono del tutto significative [9].

Nella letteratura è ricorrente l'affermazione che il prezzo ombra è decrescente su tutto l'arco temporale $[0, T]$, qualunque sia la fase della vita dell'individuo (v. ad es. Becker, 1962, 1975). La causa di questo fatto viene indicata nella diminuzione del tempo futuro in cui si può impiegare profittevolmente il capitale umano accumulato. Tale giustificazione è solo parzialmente vera, in quanto, come vedremo nel nostro modello, il prezzo ombra può risultare crescente, sia nella fase di pura istruzione che in quella di puro lavoro. Osserviamo preliminarmente che dalla (2.9) si ottiene rispettivamente:

$$\text{con } u^*(t) = 1 \qquad \dot{p} = p\{\delta - h'[K^*(t)]\}, \tag{4.3}$$

$$\text{con } u^*(t) = 0 \qquad \dot{p} = \delta p - e^{-rt} w'[K^*(t)]. \tag{4.4}$$

Era già stato adombrato da Landsberger e Passy (1976) che altre cause possono influire sull'andamento di $p(t)$, oltre alla riduzione dell'intervallo di tempo $T - \underline{t}$ in cui impiegare la variazione del capitale umano in $\underline{t}$. La (4.3), ad es., mostra proprio come nella fase di pura istruzione entrino in gioco anche la produttività marginale del capitale umano ed il suo tasso di deprezzamento. Infatti se non si lavora, il deprezzamento rende preferibile disporre di un'unità aggiuntiva di capitale umano in prossimità della fine

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[9] La differenza sostanziale tra la nostra impostazione e quella degli autori citati è che essi hanno osservato correttamente, in relazione ai modelli di Sheshinski e Ben-Porath, che: « *it should be noticed that besides the direct interest in the time distribution of the shadow price of human capital the results presented here indicate that different optimal trajectories for the control can be expected from the two models* » (ib., pag. 144 la sottolineatura è nostra), senza peraltro dimostrare quanto affermato.

del periodo di pura istruzione, in quanto tale unità si è deprezzata per un periodo di tempo minore. D'altro canto un'unità aggiuntiva rende piú efficienti nell'ottenimento di ulteriore capitale umano, nonché permette di raggiungere prima la posizione d'equilibrio ($\underline{K}^*$, $\underline{q}^*$). L'effetto complessivo determina quindi la crescenza o decrescenza nel tempo del prezzo ombra. Nel nostro modello, dalle (4.3) – (4.4), si possono ottenere le condizioni sotto le quali, per valori di T sufficientemente elevati, il prezzo ombra risulta crescente in un certo intervallo di tempo [10]. Queste sono:

$$r/\delta < (\alpha - \beta)(1 - \beta)/\beta \quad \text{se} \quad u^*(t) = 1, \tag{4.5}$$

$$r/\delta < (\beta - \alpha) \quad \text{se} \quad u^*(t) = 0, \tag{4.6}$$

e mostrano che l'andamento del prezzo ombra dipende dai valori di α, β,δ ed r.

Consideriamo dapprima la fase di puro lavoro ($u^*(t) = 0$). Qui il prezzo ombra del capitale umano può essere crescente solo se $\alpha < \beta$, ovvero se la funzione $F(K)$ è decrescente, ed r è piccolo relativamente a δ. Questo risultato è contro la comune intuizione. Infatti, come già detto, si afferma generalmente che dedicandosi al puro lavoro, un'unità aggiuntiva rende di piú se è acquisita prima, poiché è possibile utilizzarla per un periodo di tempo maggiore. Invece secondo la (4.4) anche con $u^*(t) = 0$ è possibile che il prezzo ombra sia crescente se lo stesso prezzo, ponderato con il deprezzamento, è maggiore del tasso salariale marginale valutato all'origine. Poiché nella fase del puro lavoro il capitale umano diminuisce nel tempo (quindi decrescono anche il tasso salariale ed i guadagni), questo risultato appare, in prima analisi, inaspettato se si ragiona in base all'usuale principio del « ceteris paribus ». Infatti, se si suppone di avere, in un qualsiasi istante $\underline{t}$ del periodo di puro lavoro, una variazione aggiuntiva (unitaria) del capitale, mantenendo inalterata la soluzione ottimale in $[0, T]$ allora si deve ammettere, dato l'andamento del capitale umano, che tale unità sarebbe maggiormente produttiva se ottenuta all'istante iniziale di questa fase. Ma questo ragionamento si basa proprio sull'assunto dell'invarianza della programmazione ottimale in $[0, T]$. Invece abbiamo già osservato che variazioni

[10] Risulta immediato calcolare, per $u = 1$, l'unico valore di K in corrispondenza del quale la (4.3) si annulla. Affinché $p(t)$ risulti crescente in un opportuno intervallo di tempo, è necessario che tale valore di K sia inferiore a $\underline{K}^*$.

Invece per $u = 0$, essendo $\dot{p} = -e^{-rt}[w'(K) - \delta q]$, risulta $\dot{p} > 0$ se e solo se $q > [w'(K)/\delta]$. Allora, calcolato l'unico valore di K in corrispondenza del quale $w'(K)/\delta = F(K)$, anche in tal caso, affinché $p(t)$ risulti crescente in un opportuno intervallo di tempo è necessario che tale valore di k sia inferiore a $\underline{K}^*$.

dello stato possono provocare modifiche anche nel controllo e quindi pure nei sentieri programmati sin dall'istante iniziale. È allora del tutto naturale che la condizione (4.6) tenga conto anche di β pur essendo $u^*(t) = 0$. Osserviamo infine, a parziale giustificazione della (4.6), che anche in questo caso il tasso di deprezzamento favorisce lo spostamento in avanti di un'unità aggiuntiva di capitale umano, in quanto tale unità subisce l'effetto del deterioramento per un periodo di tempo minore. A sfavore di questo spostamento gioca il tasso d'interesse r, poiché diminuisce il valore attuale dei guadagni futuri aggiuntivi.

È evidente che, durante la fase di istruzione (con $u^*(t) = 1$), il prezzo può essere crescente solo se $\alpha > \beta$, cioè se la funzione $F(K)$ è crescente. L'effetto del tasso d'interesse e del deprezzamento è analogo a quanto visto sopra. Inoltre, se l'elasticità della produzione di capitale umano è sufficientemente piccola rispetto a quella del tasso salariale, la condizione (4.5) può essere soddisfatta. Ciò non deve stupire, in quanto un individuo poco produttivo nell'istruzione non ha interesse ad avere subito un'unità aggiuntiva di capitale a causa del maggiore effetto del deterioramento (deve pure risultare δ sufficientemente grande rispetto ad r) relativamente all'incremento di capitale che ne può ricavare. In situazioni con rapida evoluzione tecnologica e con tassi d'interesse bassi, a causa degli effetti evidenziati, può succedere che alla fine della fase di pura istruzione sia piú conveniente per certi soggetti aspettare per ottenere un'unità aggiuntiva di capitale.

Un ultimo risultato riguarda una semplice applicazione della cosiddetta « sensitivity analysis ». Consideriamo la « optimal value function » come funzione di uno o piú parametri, cioè nel nostro caso:

$$V(\underline{\mu}) = \sup \left\{ \int_0^T e^{-rt} w(K)(1-u)\, dt : (K(t), u(t)) \text{ ammissibile} \right\}, \qquad (4.7)$$

dove $\mu = (\mu_i)$ è un vettore in R^s che rappresenta i parametri del modello, e $[K(t), u(t)]$ sono le coppie ammissibili per l'usuale problema di controllo ottimale (a differenza di quanto visto nella (4.1)). Sotto opportune ipotesi (v. Seierstad-Sydseter, 1987, pag. 217) e supposta inoltre $(K^*(t), u^*(t), p(t))$ soluzione ottimale per (4.7) in corrispondenza di $\mu = \underline{\mu}$ (con $\underline{\mu}$ un dato vettore in R^s), allora $V(\mu)$, in un opportuno intorno di $\underline{\mu}$, assume valori reali ed è differenziabile in $\underline{\mu}$ con:

$$\frac{\partial V(\underline{\mu})}{\partial \mu_i} = \int_0^T \frac{\partial H(K^*(t), u^*(t), p(t), \underline{\mu}, t)}{\partial \mu_i} dt, \qquad i = 1, \dots, s \qquad (4.8)$$

(v. anche Malanowski, 1984). Applicando tale risultato nel nostro modello è facile verificare che:

$$\frac{\partial V}{\partial \delta} < 0, \qquad \frac{\partial V}{\partial r} < 0. \tag{4.9}$$

Quindi un aumento del tasso di deprezzamento e del tasso d'interesse riducono, come ovvio, i guadagni globali valutati all'origine. Analogamente risulta:

$$\frac{\partial V}{\partial \alpha} > 0, \qquad \frac{\partial V}{\partial \beta} > 0. \tag{4.10}$$

Come appare intuitivo, la seconda relazione mostra che, in un mercato del lavoro perfetto (uguale tasso salariale per ogni individuo, a parità di K), coloro che sono piú efficienti nella produzione di capitale umano hanno maggiori guadagni globali. La prima (pure di immediata comprensione) è significativa solo in un mercato del lavoro imperfetto, dove individui con pari capitale umano percepiscono tassi salariali diversi. Inoltre, nel nostro modello, se T è sufficientemente elevato, è possibile analizzare come varia il tasso salariale d'entrata nel mercato del lavoro considerando il capitale umano corrispondente:

$$\frac{\partial \underline{K}^*}{\partial \alpha} = \underline{K}^* (1-\beta)^{-1} [r + \delta (1-\beta)]/[\alpha (r + \delta (1 + \alpha - \beta))] > 0, \tag{4.11}$$

$$\frac{\partial \underline{K}^*}{\partial \beta} = \underline{K}^* (1-\beta)^{-2} \{\ln [\alpha/(r + \delta (1 + \alpha - \beta))] + (1-\beta)\, \delta/(r + \delta (1 + \alpha - \beta))\} \gtrless 0. \tag{4.12}$$

La prima relazione mostra come, in un mercato del lavoro imperfetto, gli individui con maggior elasticità del tasso salariale (a parità di abilità nella produzione di capitale umano) entrano nel mercato del lavoro con capitale umano maggiore, dovuto ad un periodo maggiore di pura istruzione. Questi individui, invece, trascorrono (sempre nell'ipotesi $T > T_1 + T_2$) un periodo minore nella fase di puro lavoro, come è immediato dedurre osservando che $\partial T_2/\partial \alpha < 0$ [11]. Come già visto in (4.10), l'effetto complessi-

[11] Ponendo $K = \underline{K}^*$, $q = (\underline{K}^*)^{\alpha-\beta}$, $w(K) = K^\alpha$ in (A.3) e (A.4), si può ricavare facilmente T_2 risolvendo l'equazione

$$q - \int_0^{T_2} e^{-(\delta + r)t} w'[K(t)]\, dt = 0$$

Si ottiene cosí $T_2 = -(\delta\alpha + r)^{-1} \ln \{1 - (\delta\alpha + r)/[\delta\alpha + r + \delta(1-\beta)]\}$ e quindi $\partial T_2/\partial \alpha < 0$.

vo è un aumento dei guadagni globali. La seconda relazione, che ha significato in un mercato del lavoro perfetto, afferma che maggiore abilità nella produzione di capitale umano non aumenta necessariamente il tasso salariale d'entrata nel mercato del lavoro. Non è quindi evidente se i maggiori guadagni globali dovuti ad un incremento di β (v. la (4.10)) siano imputabili a periodi maggiori trascorsi nelle attività di pura istruzione o puro lavoro. Comunque se $\underline{K}^* > 1$, si vede immediatamente che $\partial \underline{K}^* / \partial \beta > 0$. Infine, se T è sufficientemente grande, possiamo pure descrivere l'andamento nel tempo della produttività relativa del soggetto. In questo caso si alternano periodi di tempo in cui l'individuo è piú efficiente nel lavoro ad altri in cui è piú efficiente nell'istruzione.

APPENDICE

Consideriamo il sistema costituito dalle equazioni (2.5) e (2.13), con generiche funzioni $w(K), h(K)$:

$$\begin{cases} \dot{K} = u(t)\, h(K) - \delta K \\ \dot{q} = q\,[\delta + r - u(t)\, h'(K)] - w'(K)\,[1 - u(t)] \end{cases} \tag{A.1}$$

con (A.1a). Si vede facilmente che nelle ipotesi (2.3)-(2.4) esistono K_1, $K_2\,(K_1 < K_2)$ tali che:

$$\dot{q} \gtreqless 0 \leftrightarrow \delta + r \gtreqless h'(K) \leftrightarrow K \gtreqless K_1 \text{ e}$$

$$\dot{K} \gtreqless 0 \leftrightarrow h(K) \gtreqless \delta K \leftrightarrow K \gtreqless K_2.$$

Ovviamente per questo sistema non esistono posizioni d'equilibrio (eccetto il caso banale $(K, q) = (0,0)$ se $h(0) = 0$). Determiniamo ora l'unica soluzione del sistema (A.1a) che soddisfa alla condizione $K_2 > K(0) = K_0 > 0$, e che passa per un punto assegnato $(\underline{K}, \underline{q})$ con $K_0 < \underline{K} < K_2, \underline{q} > 0$. Consideriamo dapprima l'equazione differenziale relativa al capitale umano, con condizione iniziale $K(0) = K_0$. Modificando opportunamente il ragionamento condotto in Pontriaguine (1975, pag. 114), si dimostra che la soluzione non prolungabile $K(t)$ (con $t \geq 0$) di tale equazione è definita su $[0, +\infty[$, e che $K(t)$ è ivi monotona crescente con:

$$\lim_{t \to +\infty} K(t) = K_2.$$

Quindi l'andamento di $K(t)$ è descritto dal seguente grafico:

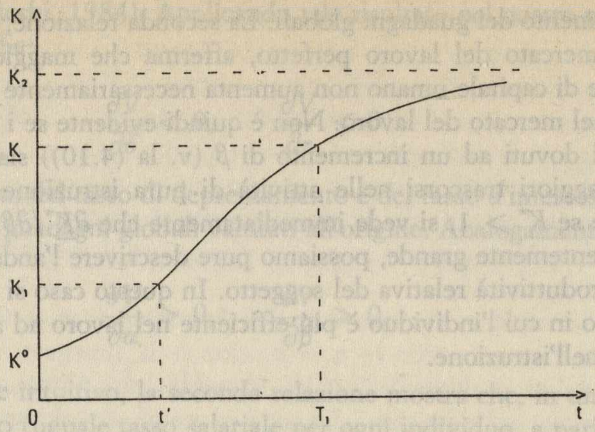

FIG. [A.1]

ove $K(t') = K_1$, $K(T_1) = \underline{K}$ (e quindi $h'[K(t')] = \delta + r$).

La seconda equazione differenziale di (A.1a) è omogenea e quindi la soluzione cercata è:

$$q(t) = q_0 e^{\int_0^t A(\tau)\, d\tau}, \tag{A.2}$$

ove

$$A(t) = \delta + r - h'[K(t)], \qquad q_0 = \frac{\underline{q}}{\int_0^{T_1} A(\tau)\, d\tau}.$$

In base all'andamento di $K(t)$ è immediatamente deducibile quello della funzione convessa $q(t)$, qui sotto rappresentata:

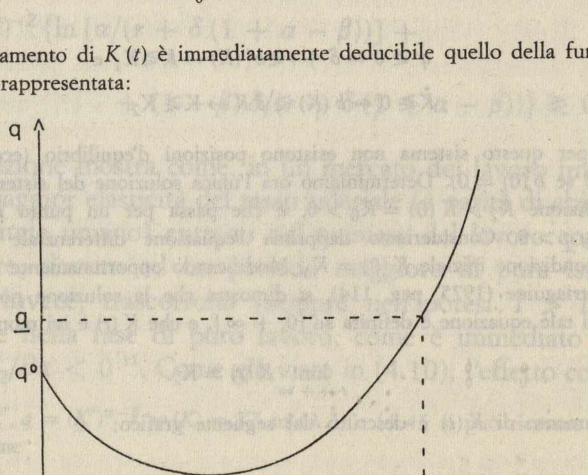

FIG. [A.2]

È evidente che, per $t \to +\infty, A(t) \to \delta + r - h'(K_2) > 0$, e quindi $q(t) \to +\infty$. Risulta cosí determinato il tempo T_1 in cui l'unica soluzione del sistema (A.1a) transita in $(\underline{K}, \underline{q})$. Quanto ora visto si trova riassunto nella Fig. 1 del terzo paragrafo. Esaminiamo ora il caso $u(t) = 0$ per qualunque t, ed indichiamo con (A.1b) il corrispondente sistema. Si vede facilmente che $\dot{q} \gtreqless 0 \leftrightarrow q \gtreqless w'(K)/(\delta + r)$ e $\dot{K} \leq 0 \leftrightarrow K \geq 0$. Il luogo $\dot{q} = 0$ rappresenta una funzione decrescente di K (che tende asintoticamente a $+\infty$ per $K \to 0$ se $w'(0) - +\infty$). Quindi se $w'(0) = +\infty$ non esistono posizioni d'equilibrio per il sistema (A.1b), Se, invece, $w'(0) \in R$, allora esiste un'unica posizione d'equilibrio di (A.1b) data da $(0, w'(0)/(\delta + r))$.

Si può facilmente vedere che, assegnato t_0 e $(\underline{K}, \underline{q})$ con $\underline{K}, \underline{q} > 0$, il sistema ora considerato ammette un'unica soluzione in $[t_0, +\infty[$, tale che $K(t_0) = \underline{K}$, $q(t_0) = \underline{q}$. La soluzione della equazione differenziale del capitale umano è in $[t_0, +\infty[$:

$$K(t) = \underline{K} e^{-\delta(t - t_0)} \tag{A.3}$$

Allora la seconda equazione di (A.1b), tenendo conto di (A.3) e della condizione iniziale $q(t_0) = \underline{q}$, ha come soluzione in $[t_0, +\infty[$:

$$q(t) = e^{(\delta + r)(t - t_0)} \left[\underline{q} - \int_{t_0}^{t} e^{-(\delta + r)(t - t_0)} w'(\underline{K} e^{-\delta(t - t_0)}) \, dt \right] \tag{A.4}$$

Posto

$$\Phi(\underline{K}) = \int_{0}^{+\infty} e^{-(\delta + r)t} w'(\underline{K} e^{-\delta t}) \, dt, \tag{A.5}$$

poiché $e^{-(\delta + r)t} w'[K(t)]$ è infinitesima per $t \to +\infty$ di ordine superiore ad e^{-rt}, si vede immediatamente che $\Phi(\underline{K})$ risulta una funzione a valori reali, definita per $\underline{K} > 0$, positiva decrescente; inoltre, essendo $w'(\cdot)$ e $K(\cdot)$ funzioni decrescenti, si ha

$$\Phi(\underline{K}) > \int_{0}^{+\infty} e^{-(\delta + r)t} w'(\underline{K}) \, dt = \frac{w'(\underline{K})}{\delta + r}.$$

Osservando che la funzione $e^{-(\delta + r)t} w'[K(t)]$ è sempre positiva, è facile dimostrare che se $\underline{q} < \Phi(\underline{K})$, allora $q(t)$ è – per un ben determinato t_1 – positiva in $[t_0, t_1[$ e diviene negativa in $]t_1, +\infty[$ (mentre non si annulla mai se $\underline{q} \geq \Phi(\underline{K})$), e che l'intervallo di tempo $(t_1 - t_0)$ non dipende da t_0 (sistema autonomo). Inoltre, se $\underline{q} > \Phi(\underline{K}), q(t) \to +\infty$ per $t \to +\infty$.

Quanto ora esposto può essere visualizzato mediante i grafici [A.3] e [A.4] e sintetizzato nello spazio delle fasi dalla Fig. 2 del paragrafo 3:

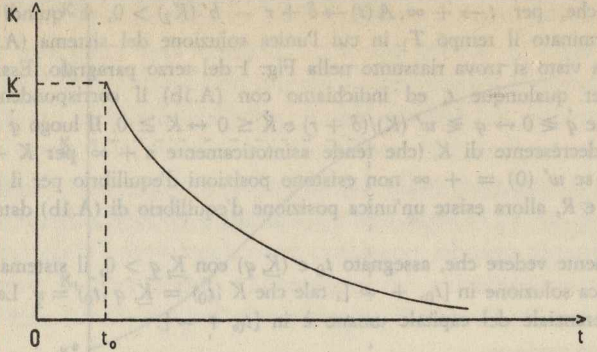

FIG. [A.3]

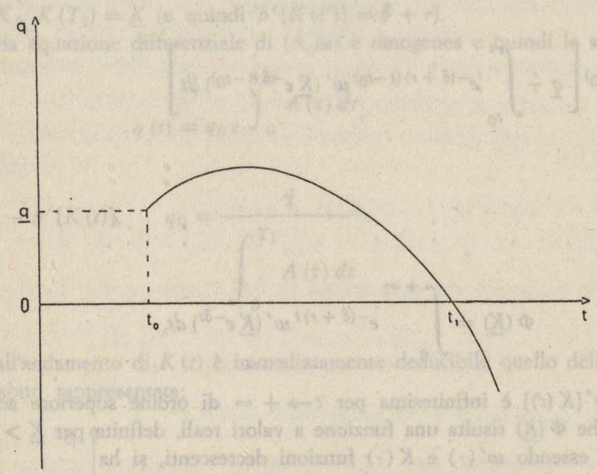

FIG. [A.4]

Esaminiamo infine il caso in cui $\underline{u}(t) = u \in \,]\,0, 1\,[$ per qualunque t, ed indichiamo con (A.1c) il relativo sistema. In particolare cerchiamo posizioni di equilibrio (K, q) per (A.1c) con $K > 0, q > 0$, ovvero soluzioni del sistema:

$$\begin{cases} \underline{u}\, h(K) - \delta K = 0 \\ q = \dfrac{w'(K)\,[h(K) - \delta K]}{\delta\,[h(K) - h'(K)\,K] + r\,h(K)} \end{cases} \tag{A.6}$$

Tale sistema, se compatibile, ammette un'unica soluzione $(\underline{K},\underline{q})$, con $0 < \underline{K} < K_2$, che fornisce l'unica posizione d'equilibrio di (A.1c); inoltre è $\underline{q} > 0$, come si può dedurre osservando che, dal teorema della media, per la decrescenza di $h'(K)$, segue che $h(K) - h(0) > h'(K) K > 0$. Osserviamo che il sistema (A.6) nelle ipotesi (2.3) – (2.4) è sicuramente compatibile se $h(0) > 0$ oppure se $\underline{u}\ h'(0) > \delta$ (ovvero se si può profittevolmente produrre capitale umano anche non avendone a disposizione oppure se l'incremento relativo iniziale del capitale stesso è maggiore del tasso di deprezzamento).

Per ottenere le soluzioni del nostro problema di ottimo, tenuto conto di (2.8 b), risulta utile vedere se esiste un controllo $u(t) = \underline{u}_1$, con $\underline{u}_1 \in]\ 0,\ 1\ [$, in corrispondenza del quale il punto di equilibrio $(\underline{K}_1, \underline{q}_1)$ di (A.1c) stia sulla curva di equazione $q = w(K)/h(K)$, con $\underline{K}_1 > 0$. Tale punto si ottiene come soluzione del sistema formato da (A.6) e $q = F(K)$, o di quello equivalente:

$$\begin{cases} \underline{u} = \dfrac{\delta K}{h(K)} \\[2ex] \dfrac{w'(K)\,h(K) - w(K)\,h'(K)}{h^2(K)} = \dfrac{q\,[(\delta + r) - h'(K)]}{h(K) - \delta K} = \dfrac{q\,(\delta + r) - w'(K)}{-\delta K} \\[2ex] q = \dfrac{w(K)}{h(K)} \end{cases} \tag{A.7}$$

Se $(\underline{K}_1, \underline{q}_1, \underline{u})$ è soluzione di (A.7), la seconda relazione mostra che le traiettorie di (A.1a) e (A.1b) passanti per $(\underline{K}_1, \underline{q}_1)$ ed il grafico della funzione $F(K) = w(K)/h(K)$ hanno tangente comune in $(\underline{K}_1, \underline{q}_1)$. Per rendersene conto, basta considerare i rapporti $\dot{q}/\dot{K}$ rispettivamente in (A.1a) e (A.1b).

A conclusione studiamo le pendenze delle soluzioni di (A.1a) e (A.1b) nei punti del grafico della funzione $q = F(K)$, in relazione alla pendenza di questa curva, nell'ipotesi che (A.7) ammetta l'unica soluzione $(\underline{K}_1, \underline{q}_1, \underline{u}_1)$. A tal fine consideriamo il sistema:

$$\begin{cases} \dfrac{\dot{q}}{\dot{K}} - F'(K) = 0 \\[2ex] q = F(K) \end{cases} \tag{A.8}$$

In relazione ad (A.1a) e (A.1b), tramite (A.8) si ottengono, rispettivamente, le equazioni:

$$B(K) = \frac{F(K)\,[\delta + r - h'(K)]}{h(K) - \delta K} - F'(K) = 0, \tag{A.9}$$

$$C(K) = \frac{F(K)\,(\delta + r) - w'(K)}{-\delta K} - F'(K) = 0. \tag{A.10}$$

Tenendo conto di (A.7), entrambe le equazioni hanno come unica soluzione $\underline{K}_1$ e quindi ciascuna delle due funzioni continue $B(K)$ e $C(K)$ ha segno costante in $]\,0, \underline{K}_1\,[$.

Ritornando ora al modello (3.1), in cui $h(K) = K^\beta$ e $w(K) = K^\alpha$, le equazioni $B(K) = 0$

e $C(K) = 0$ hanno pertanto l'unica soluzione $\underline{K}^*$. Inoltre è facile verificare che, per $K \rightarrow 0$, $B(K) \rightarrow -\infty$ e $C(K) \rightarrow +\infty$, e quindi in $]0, \underline{K}^*[$ risulta $B(K) < 0$ e $C(K) > 0$. Ciò significa che, nell'ipotesi (3.1), in ogni punto del grafico della funzione $q = F(K)$ con $K \in]0, \underline{K}^*[$, le traiettorie relative ai sistemi (A.1a) e (A.1b) hanno pendenze rispettivamente inferiore e superiore rispetto a quella del grafico della funzione $q = F(K)$ nel medesimo punto. Si può dedurre allora che le traiettorie di (A.1a) e (A.1b) che transitano nello spazio delle fasi per i punti $(\underline{K}, F(\underline{K}))$ con $0 < \underline{K} \leq \underline{K}^*$, sono, rispettivamente, tutte al di sopra od al di sotto del grafico della funzione $q = F(K)$ nella striscia $\{(q, K) : 0 < K < \underline{K}\}$.

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AN OPTIMAL TIME ALLOCATION MODEL WITH DIFFERENT TECHNOLOGIES

The model provides the solution for optimal time allocation between two activities (work and training) in a finite time horizon within a human capital framework. This model extends the formulations given by Ben-Porath (1967) and Sheshinski (1968), as it shows how the solution depends on marginal productivity of human capital and income. Moreover human capital shadow price displays characteristic patterns assuming that marginal productivities are different. This behavior reflects the change of the control over the entire programming time. Nonetheless "life cycles" are similar to those considered by Sheshinski.

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TRADE RESTRICTIONS, TERMS OF TRADE AND WELFARE UNDER VARIABLE RETURNS TO SCALE

by
CHI-CHUR CHAO * and EDEN S.H. YU **

1. *Introduction*

The welfare consequences of an exogenous shift in the terms of trade have been examined by several trade and development economists. Prebisch (1950) and Singer (1950) propose that the secular deterioration in the terms of trade facing the developing countries reduces income and welfare. Batra (1973) demonstrates that the losses in the terms of trade need not imply lower national income if there are factor market imperfections. Recently, Anam (1988) argues that a decline in the terms of trade may improve welfare in the presence of quota-induced rent seeking activities.

The present paper offers an alternative explanation as to why a deterioration in the terms of trade may paradoxically enhance welfare of a small open economy. In particular, we will consider an economy which is characterized by variable returns to scale in production. We will derive and contrast various welfare effects of a change in the terms of trade when this small economy pursues alternative trade policies, i.e., tariffs vs. quotas. The main novelty of this paper is the asymmetry between tariffs and quotas. In the presence of a quota, an improvement in the terms of trade continues to be beneficial to a small country. This constitutes an exception to the Bhagwati's (1971) generalized theory of distortions and welfare. However, if imports are restricted by tariffs, the welfare effect is indefinite in general. Thus, consistent with the theory of distortion and welfare, it is possible for an improvement in the terms of trade to be welfare-reducing.

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2. *The Setting*

We use the standard two-sector trade model incorporating variable returns to scale (VRS) developed by Batra (1968), Herberg and Kemp (1969), Panagariya (1980, 1981), Choi and Yu (1985, 1987), Parai (1985) and Beladi (1988). The economy under consideration is small so that it is a price-taker in world trade. On the production side, the two sectors produce two goods X_1 and X_2 using two factors of production: capital and labor. Assume the economies or diseconomies are output generated; they are external to the firms and internal to the industry.

The production functions are thus specified as follows:

$$x_i = g_i (X_i) F_i (c_i, l_i), \qquad i = 1, 2 \tag{1}$$

$$X_i = g_i (X_i) F_i (K_i, L_i), \qquad i = 1, 2 \tag{2}$$

where x_i is the output of a typical firm in industry i and c_i and l_i are capital and labor by the firm. X_i is the output of industry i and K_i and L_i are its total employment of capital and labor. The role of externality is described by g_i which is a positive function defined on $(0, \infty)$, and F_i is homogeneous of degree one.

Output elasticity of returns to scale of the ith industry (e_i) defined on $(-\infty, 1)$ may be written as

$$e_i = (dg_i/dX_i)(X_i/g_i), \qquad i = 1, 2. \tag{3}$$

Note that $e_i > 0$ for increasing-returns-to-scale (IRS) industry, $e_i = 0$ for constant-returns-to-scale industry (CRS) and $e_i < 0$ for decreasing-returns to-scale (DRS) industry.

Differentiating (2) and using the conditions of profit maximization and full employment, we obtain the following well-known result:

$$dX_1/dX_2 = -[(1 - e_2)/(1 - e_1)]\,p, \tag{4}$$

where p is the domestic price of X_2 in terms of X_1. Note that the marginal rate of transformation is shown to be negative. If $e_1 > (<)\ e_2$, the price line (p) is flatter (steeper) than the slope of the transformation curve.

The demand side of the economy is represented by an expenditure function defined by

$$E(p, u) = \min (D_1 + pD_2), \tag{5}$$

with respect to the demand for the two commodities, D_1 and D_2, subject to a strictly quasi-concave utility function $u(D_1, D_2) \geq u$.

For concreteness, let good 1 be the exportable and good 2 be the importable goods. Let

$$M = E_p(p, u) - X_2(p), \tag{6}$$

denote the importable good, where $E_p = \partial E(p, u)/\partial p = D_2$. The volume of import, M, is endogenously determined when the economy is initially distorted by tariffs, whereas M is exogenously fixed when the economy is initially distorted by import quotas.

The budget constraint is expressed by

$$E(p, u) = X_1 + pX_2 + (p - p^*) M, \tag{7}$$

where p^* is a world price which is assumed to be less than the domestic price ratio, p. The term $(p - p^*) M$ is government revenue from the tariffs or import quotas. The revenue is assumed to be redistributed back to the private sectors in a lump-sum fashion so that the revenue is spent in the same manner as other incomes.

The above model is amenable for examining the welfare implications of an exogenous deterioration in the terms of trade under tariffs or import quotas. Taking total differentiations (7) and utilizing (6), we obtain the change in welfare ($dW \equiv E_u du$) as

$$dW = E_u du = dX_1 + pdX_2 + (p - p^*) dM - Mdp^*, \tag{8}$$

where $E_u = \partial E/\partial u$. Note that under CRS, the first two terms on the RHS of (8) vanish since production equilibrium occurs when $dX_1 + pdX_2 = 0$. This standard result is, however, in need of revision under VRS. Using (4), (8) may be rewritten as

$$dW = sM[(e_2 - e_1)/(1 - e_1)]\,dp + (p - p^*) dM - Mdp^*, \tag{9}$$

where $s = (p/M)(dX_2/dp)$ is the substitution in production in response to a change in p. Note that assuming positive price-output response, $s > 0$.

We need to determine either dp in the case of import quotas or dM in the case of tariffs. To do so, we totally differentiate the equilibrium condition (6) as follows:

$$E_{pu}du = (e + s)(M/p)\,dp + dM, \tag{10}$$

where $E_{pu} = \partial E_p/\partial u$, and $e = -(p/M)(\partial E_p/\partial p)$ is the consumption substitution for a given utility. Note that since the expenditure function is homogeneous of degree one in goods prices, the marginal propensity to consume good 2 can be defined as $m = pE_{pu}/E_u$. Therefore, (10) may be rewritten as

$$(m/p)\, dW = (e + s)(M/p)\, dp + dM. \tag{11}$$

Note that $e > 0$ and $0 < m < 1$.

By using (9) and (11), we are ready to analyze the welfare effect of a deterioration in the terms of trade under tariffs and import quotas.

A. *Tariffs*

Let t be the rate of tariff, so that the domestic price ratio for producers and consumers is given by $p = (1 + t)\, p^*$. The welfare effect of a change in the terms of trade is then given by

$$dW = sM\,(1 + t)\,[(e_2 - e_1)/(1 - e_1)]\, dp^* + tp^*\, dM - Mdp^* \tag{12}$$

The first term on the RHS of (12) captures the divergent returns-to-scale effect on welfare which is positive when the importable sector has a larger elasticity of the returns to scale than the exportable sector. The second term indicates the terms of trade effect on imports and the third term is the direct welfare loss due to a deterioration in the terms of trade.

Prior to examining the welfare effect, we need first to obtain the domestic price elasticity of import demand under tariffs, which is defined by $a \equiv -\,(p/M)(dM/dp)$. By solving (11) and (12), we obtain that

$$a \equiv -\,(p/M)(dM/dp) = [e + s\alpha + m/(1 + t)]\, T, \tag{13}$$

where α is defined as $[1 - m\,(e_2 - e_1)/(1 - e_1)]$ and $T = [1 - mt/(1 + t)]^{-1}$ is the tariff multiplier. Note that $\alpha > 0$ since $[1 - m\,(e_2 - e_1)/(1 - e_1)] \geq [1 - m\,(1 - e_1)/(1 - e_1)]$. Then by substituting (13) into (12), we simplify (12) to

$$dW = sM\,(1 + t)[(e_2 - e_1)/(1 - e_1)]\, dp^* - M\,(1 + at)\, dp^*. \tag{14}$$

Let us consider several cases of analytical interest. Suppose the home industries operate under identical returns to scale, i.e., $e_1 = e_2$, with CRS as its special case ($e_1 = e_2 = 0$). Then (14) reduces to

$$dW = -M(1 + at)\,dp^*, \tag{15}$$

which indicates that a deterioration in the terms of trade, $dp^* > 0$, always reduces welfare. This result is consistent with the traditional wisdom.

Of particular interest is the situation in which the two industries operate with divergent variability in the returns to scale, i.e., $e_1 \neq e_2$. There are two distinct cases we will examine; one of them will provide a paradoxical result.

Consider first the case where $e_1 > e_2$; that is, the exportable sector has a larger elasticity of the returns to scale than the importable sector. A deterioration in the terms of trade raises the domestic relative price of importables. As a result, the domestic resources are induced to shift from the exportable (higher returns to scale) sector into the importable (lower returns to scale) sector. This production loss as reflected by the first term of (14), coupled with the direct welfare loss, necessarily reduces welfare.

Consider now the case where $e_2 > e_1$; that is, the importable sector has a larger elasticity of the returns to scale than the exportable sector. It is interesting to note that the terms of trade loss will generate a production gain, because the rise in the domestic relative price of the importables will cause resources to move from the exportable (lower returns to scale) sector into the importable (higher returns to scale) sector. The net welfare consequence of the terms of trade loss clearly depends on the relative strength of the two opposite effects. Specifically, if $(1 + at)/(s + st) < (e_2 - e_1)/(1 - e_1)$, the production gain due to the divergent returns to scale dominates the direct welfare loss of the terms of trade loss, thereby resulting in a higher welfare. This is likely to occur when s is larger and/or a is smaller: the larger the value of s and/or the smaller the value of a, the more the response of the home production in the importable sector. Thus, the following proposition can be stated:

Proposition 1: An exogenous deterioration in the terms of trade in the presence of a tariff may improve welfare, if the importable sector displays a larger elasticity of returns to scale than the exportable sector.

B. *Import Quotas*

Let us consider the welfare effect of a decline in the terms of trade under import quotas. If import quotas are imposed at a fixed level, then $dM = 0$. By using (9), the welfare effect is given by

$$dW = sM[(e_2 - e_1)/(1 - e_1)]\, dp - Mdp^*. \tag{16}$$

The first term on the RHS of (16) represents the returns-to-scale effect, and the second term is the direct welfare loss due to a terms of trade loss.

In order to determine dW, we need to determine dp, which can be obtained through (11) and (16) as

$$dp = - [m/(e + s\alpha)]\, dp^* < 0. \tag{17}$$

Eq. (17) states that an exogenous deterioration in the terms of trade reduces the domestic relative price of importables in the presence of a fixed import quota. This result can be explained in terms of the drop in the excess demand for importables as a result of the decrease in the quota revenues.

Given $dp/dp^* < 0$, the sign of dW crucially depends on the sign of $(e_2 - e_1)$. Consider the case where $e_1 = e_2$. Then (16) reduces to

$$dW = - Mdp^*, \tag{18}$$

which is the traditional result and states that welfare always decreases as a result of a decline in the terms of trade.

Next, consider the case where $e_1 \neq e_2$. The total welfare effect can be obtained by substituting (17) into (16) as

$$dW = - M\, [(e + s)/(e + s\alpha)]\, dp^*, \tag{19}$$

which is always nonpositive. It is thus interesting to note that, unlike the earlier case of a tariff, a deterioration in the terms of trade in the presence of a quota always reduces welfare. The only exception is the limiting case in which the exportable sector operates with sufficiently strong IRS, i.e. $e_1 \rightarrow 1$ (Panagariya, 1980, p. 508). Note that if $e_1 \rightarrow 1$, then $\alpha \rightarrow \infty$. It follows that $dW \rightarrow 0$. Thus, the following proposition is immediate:

Proposition 2: An exogenous deterioration in the terms of trade in the presence of a quota reduces welfare regardless of the sectoral returns to scale.

An explanation for this result is the following. In the presence of a quota, the returns to scale effect is not sufficiently large to offset the direct welfare loss due to the decline in the terms of trade. The stronger the returns to scale in the exportable sector, the smaller the welfare loss.

3. *Conclusions*

We have examined the welfare effect of an exogenous shift in the terms of trade for a small open economy. It is shown that a deterioration in the terms of trade in the presence of a tariff may improve welfare, if the importable sector displays a larger elasticity of returns to scale than the exportable sector. Thus, we have provided a possible alternative explanation as to why a decline in the terms of trade may paradoxically improve welfare of a small open economy.

Furthermore, we demonstrated an asymmetry between tariffs and quotas. Unlike the case of a tariff, a terms of trade loss cannot lead to a higher welfare in the presence of a quota regardless of the sectoral returns to scale. Since quotas rather than tariffs have become effective constraints on imports frequently used by developing countries, our results have important implications for the developing countries facing chronic deterioration in the terms of trade.

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RESTRIZIONI COMMERCIALI, TERMS OF TRADE E BENESSERE CON RENDIMENTI DI SCALA VARIABILI

Questo articolo esamina gli effetti sul benessere di un cambiamento esogeno dei terms of trade per una piccola economia aperta. Si stabilisce una asimmetria tra tariffe e contingentamenti. Si mostra che un deterioramento dei terms of trade in presenza di una tariffa può migliorare il benessere se il settore delle importazioni mostra una maggiore elasticità dei rendimenti di scala del settore delle esportazioni. Comunque, una perdita in terms of trade *non può* produrre un maggior benessere in presenza di un contingentamento.

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NON-NEUTRAL TECHNICAL CHANGE, ADJUSTMENT COSTS AND RATIONAL EXPECTATIONS: AN EMPIRICAL NOTE

by
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1. *Introduction*

The article of Pindyck and Rotemberg (1983) presents an interesting dynamic factor demand model taking into account adjustment costs for quasi-fixed factors under rational expectations. This model, which includes two quasi-fixed factors (capital and white-collar labour) and one flexible factor (blue-collar labour) fits well to annual US data for the period 1947-1969. Of course, the sample period considered is characterized by factor price and quantity movements, which were rather smooth compared to those we experienced in the 70's and 80's. Thus, it seems, at least to us, to be interesting to explore the explanatory power of the Pindyck-Rotemberg model with recent data. To this end, we estimated an extended version of the Pindyck-Rotemberg model, taking into account non-neutral technical change with quarterly data for five major German industries covering the period 1970-1984. Non-neutral technical change is included because the estimation of a static factor demand model (Kugler, Müller and Sheldon, 1988) as well as an ad-hoc dynamic model (Kugler, Müller and Sheldon, 1989) clearly rejected the hypothesis of neutral technical change for West Germany.

This paper is set up as follows: The next section presents the theoretical model. Thereafter, our empirical results are given in Section 3. The paper closes with a summary and some conclusions.

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2. *The Theoretical Model*

Let us assume that at time t the representative firm chooses the input level for the flexible factor blue-collar labour B_t and the quasi-fixed factor white-collar labour W_t and capital K_t. The nominal price of B_t is denoted by b_t, whereas the outlay for using one unit of W_t and K_t is given by w_t and k_t, respectively. Changes in the input level of blue-collar labour are costless, while white-collar labour and capital are subject to adjustment costs. One single output is produced with these inputs. Thus, technology can be represented by a restricted cost function for the flexible factor

$$C_t = f(b_t, W_t, K_t, Q_t, t). \tag{1}$$

This function gives the minimal expenditures on B_t to produce Q_t given its price and the input level of the quasi-fixed factors W_t and K_t. In addition, the time index t represents the effects of technical change. The function f is increasing and concave in b_t and decreasing and convex in W_t and K_t. Adjustment costs for white-collar labour and capital are represented by the convex function $c(W_t - W_{t-1}, K_t - (1-d) K_{t-1})$, where d is the depreciation rate for capital. The function gives adjustment costs in real terms. Thus, it has to be multiplied by the price of output P_t in order to get them in nominal terms.

Given these definitions, we assume that the firm maximizes its expected discounted value of profits. It was shown by Pindyck and Rotemberg (1983) that, as an implication, the expected discounted value of total costs is minimized. The minimand is given by

$$E_t \sum_{\tau=t}^{\infty} R_{t,\tau} [f(b_\tau, W_\tau, K_\tau, Q_\tau, \tau) + w_\tau W_\tau + k_\tau K_\tau + \\ + c(W_\tau - W_{\tau-1}, K_\tau - (1-d) K_{\tau-1}) P_\tau], \tag{2}$$

where $R_{t,\tau}$ is the discount factor and E_t stands for conditional expectation given the information available at period t.

Differentiating (2) with respect to b_t, W_t and K_t provides us with the following first order conditions:

$$\frac{\partial C_t}{\partial b_t} - B_t = 0,$$

$$\frac{\partial C_t}{\partial W_t} + w_t + \frac{\partial c(W_t - W_{t-1}, K_t - (1-d) K_{t-1})}{\partial W_t} P_t +$$

$$+ E_t\left[R_{t,t+1} \frac{\partial c\,(W_{t+1} - W_t, K_{t+1} - (1-d)\,K_t)}{\partial W_t} P_{t+1} \right] = 0,$$

$$\frac{\partial C_t}{\partial K_t} + k_t + \frac{\partial c\,(W_t - W_{t-1}, K_t - (1-d)\,K_{t-1})}{\partial K_t} P_t + \tag{3}$$

$$+ E_t\left[R_{t,t+1} \frac{\partial c\,(W_{t+1} - W_t, K_{t+1} - (1-d)\,K_t)}{\partial K_t} P_{t+1} \right] = 0.$$

The above condition with respect to the flexible factor follows from Shepard's Lemma and is static in nature. The dynamic first order conditions for the quasi-fixed factors W_t and K_t, the so-called Euler equations, can be interpreted as follows: The second equation, for instance, says that the decrease in variable or flexible cost of a one-unit increase in $W_t \left(\frac{\partial C_t}{\partial W_t}\right)$ is equal to the costs of using this additional unit (w_t), plus the adjustment cost at t of the increase in $W_t \left(\frac{\partial c_t}{\partial W_t} P_t\right)$ plus the expected discounted change of future adjustment costs $\left(E_t\left[R_t \frac{\partial c_{t+1}}{\partial W_t} P_{t+1}\right]\right)$.

These first order conditions are now analysed empirically [1]. In order to do this, we have to specify functional forms for $f(b_t, W_t, K_t, Q_t, t)$ and $c\,(W_t - W_{t-1}, K_t - (1-d)\,K_{t-1})$. We specify $f(b_t, W_t, K_t, Q_t, t)$ as a translog function which is homogeneous of degree one in b_t:

$$\ln(C_t) = \ln B_t + \ln b_t = \alpha_0 + \ln b_t + \alpha_1 \ln W_t + \alpha_2 \ln K_t +$$
$$+ \alpha_3 \ln Q_t + \alpha_4 t + \frac{1}{2}\gamma_{11} (\ln W_t)^2 + \gamma_{12} \ln W_t \ln K_t +$$
$$+ \gamma_{13} \ln W_t \ln Q_t + \gamma_{14} \ln W_t\, t + \frac{1}{2}\gamma_{22} (\ln K_t)^2 +$$
$$+ \gamma_{23} \ln K_t \ln Q_t + \gamma_{24} \ln K_t\, t + \frac{1}{2}\gamma_{33} (\ln Q_t)^2 +$$

[1] Of course, this approach does not allow to calculate factor demand functions depending on the time series process for the vector of prices. This would require an analytical solution of the stochastic control problem, which is in general an intractable task. However, there are numerical methods to solve this problem (Nadiri and Prucha, 1986).

$$+ \gamma_{34} \ln Q_t \, t + \frac{1}{2} \gamma_{44} t^2. \qquad (4)$$

By contrast to Pindyck and Rotemberg, who use only the linear time term $\alpha_4 t$, we allow for quadratic and cross product terms involving the time index. Thus, non-neutral and/or accelerating or decelerating technical progress is allowed for in our framework. The parameters α_4 and γ_{44} represent the total effect of technical change on flexible or variable costs. If γ_{44} is negative (positive), we have acceleration (deceleration) of technical progress. Otherwise, technical change is implemented at a constant rate α_4. The bias or non-neutrality of technical change is represented by the parameters γ_{14}, γ_{24}, and γ_{34}. For instance, γ_{14}, which is equal to $\frac{\partial \left(\frac{\partial C}{\partial W} \right)}{\partial t}$, gives the change over time in variable cost changes resulting from an additional input unit of W. Thus, if $\gamma_{14} > 0$ (< 0), we have W-saving (using) technical progress, otherwise ($\gamma_{14} = 0$) technical change is neutral. Of course, γ_{24} has the same interpretation for the second quasi-fixed factor K. Further insight can be obtained by imposing constant returns to scale (CRTS). It is easily shown by totally differentiating (4) with respect to W, K and Q that CRTS implies the following restrictions:

$$\begin{aligned} &\alpha_1 + \alpha_2 + \alpha_3 = 1, \\ &\gamma_{11} + \gamma_{12} + \gamma_{13} = 0, \\ &\gamma_{12} + \gamma_{22} + \gamma_{23} = 0, \\ &\gamma_{13} + \gamma_{23} + \gamma_{33} = 0, \\ &\gamma_{14} + \gamma_{24} + \gamma_{34} = 0. \end{aligned} \qquad (5)$$

The last equation shows that the bias of technical change for the two quasi-fixed factors and γ_{34} add up to zero. Thus, γ_{34} represents the bias of technical change for the flexible factor B.

For the adjustment cost function c, we adopt the following quadratic specification:

$$\frac{1}{2} \beta_{11} (W_t - W_{t-1})^2 + \frac{1}{2} \beta_{22} (K_t - (1 - d) K_{t-1})^2. \qquad (6)$$

Given these specifications, we obtain the following first order conditions. Firstly, homogeneity of degree one of C in b implies that the first condition of (3) always holds. Thus, testing this first order condition amounts to testing the input requirement function resulting from (4) after substracting $\ln b$ on both sides. Secondly, the Euler equations are written as:

$$\frac{C_t}{W_t}\left[\alpha_1 + \gamma_{11}\ln W_t + \gamma_{12}\ln K_t + \gamma_{13}\ln Q_t + \gamma_{14}t\right] + w_t + \\ + \beta_{11}\left[(W_t - W_{t-1})P_t - E_t[R_t(W_{t+1} - W_t)P_{t+1}]\right] = 0,$$

$$\frac{C_t}{K_t}\left[\alpha_2 + \gamma_{12}\ln W_t + \gamma_{22}\ln K_t + \gamma_{23}\ln Q_t + \gamma_{24}t\right] + k_t + \\ + \beta_{22}\left[(K_t - (1-d)K_{t-1})P_t - E_t[(1-d) \\ R_t(K_{t+1} - (1-d)K_t)P_{t+1}]\right] = 0. \qquad (7)$$

3. *Empirical Results*

For the estimation of the model, we replace the expected values by actual values plus an expectational error ε. This procedure yields, after some rearrangement, the following two equations:

$$w_t = -\frac{C_t}{W_t}\left[\alpha_1 + \gamma_{11}\ln W_t + \gamma_{12}\ln K_t + \gamma_{13}\ln Q_t + \gamma_{14}t\right] + \\ + \beta_{11}[R_t(W_{t+1} - W_t)P_{t+1} - (W_t - W_{t-1})P_t] + \varepsilon_{1,t+1}, \qquad (8)$$

$$k_t = -\frac{C_t}{K_t}\left[\alpha_2 + \gamma_{12}\ln W_t + \gamma_{22}\ln K_t + \gamma_{23}\ln Q_t + \gamma_{24}t\right] + \\ + \beta_{22}[R_t(1-d)(K_{t+1} - (1-d)K_t)P_{t+1} - (K_t - (1-d)K_{t-1})P_t] + \\ + \varepsilon_{2,t+1}. \qquad (9)$$

Under rational expectations, $E_t[\varepsilon_{1,t+1}] = E_t[\varepsilon_{2,t+1}] = 0$ holds. In addition, we will assume that the contemporaneous covariance matrix of ε_1 and ε_2 is Ω.

There is a symmetry restriction in the system given above. The coefficient of the term $\frac{C_t \ln W_t}{K_t}$ in the second equation is equal to the coefficient of the term $\frac{C_t \ln K_t}{W_t}$ in the first equation. Moreover, constant returns to scale (CRTS) result in two additional restrictions

$$(\gamma_{11} + \gamma_{12} + \gamma_{13} = 0, \gamma_{12} + \gamma_{22} + \gamma_{23} = 0),$$

which can be imposed on (8) and (9). The additional three CRTS restrictions

$$(\alpha_1 + \alpha_2 + \alpha_3 = 1, \gamma_{13} + \gamma_{23} + \gamma_{33} = 0, \gamma_{14} + \gamma_{24} + \gamma_{34} = 0),$$

can be used to calculate α_3, γ_{33} and γ_{34}. Thus estimation of (8) and (9) under CRTS allows to estimate all parameters of the cost function with the exception of α_4 and γ_{44}. This corresponds, of course, to the situation in a static three factor translog model resulting in two value share equations to be estimated.

The rational expectations assumption implies that the error terms ε_{1t+1} and ε_{2t+1} are uncorrelated with variables dated t and earlier. Therefore, only the adjustment cost variables have to be instrumented at the first stage of the estimation procedure. To this end, the variables W_t, W_{t-1}, K_t, K_{t-1}, C_t, Q_t, R_t, P_t and t were used as instruments. At the second stage, the two equations are estimated separately whereas the final stage takes into account contemporaneous correlation of the error terms and, if imposed, cross equation restrictions. This three-stage least squares approach is applied *a*) without restrictions, *b*) with the symmetry restriction and *c*) with symmetry and CRTS restrictions. These restrictions are tested with the corresponding asymptotic Wald χ^2 test.

Of course, we can augment our estimation system by the input requirement or flexible cost function (4). In principle, this procedure results in an efficiency gain and allows, in addition, to estimate the parameters α_4 and γ_{44}. However, the tremendously high intercorrelation of the right hand side variables of (4) in our sample of rather limited size resulted in severe numerical problems. Thus, this extended approach was not followed here.

Empirical implementation of the model outlined in the last section requires statistical information on the prices and quantities for output and inputs. We estimated our model using seasonally adjusted, quarterly data for five major industrial groupings (consumer goods, basic material, food and tobacco, investment goods, mining) in West German manufacturing for the years 1970-1984. Quarterly data were required to provide enough observations for estimation. However, with the exception of labour (blue and white-collar), only annual data were available for the FRG. We, thus, had to transform the annual figures into quarterly data. As for output, we used appropriate quarterly indicators in combination with an interpolation method developed by Chow and Lin (1971). In the case of capital, though, we were forced to resort to a simple cubic spline function to generate a quarterly series. Details on the data series and their sources are available from the authors.

The estimation results are reported in Table 1. The parameter estimates presented are restricted by the basic model assumption of symmetry. However, this restriction is rejected by the corresponding Wald test at the conventional 5% level in three out of five industries. The additional restrictions implied by constant returns to scale are rejected for all five cases. Thus, these tests point to misspecifications of our model. This conjecture is confirmed by the estimates obtained for the adjustment cost coefficients β_{11} and β_{22}. In two out of five industries at least one of these parameters is statistically significantly negative. These unsatisfactory findings seem to be surprising, as the application of a static translog price model with non-neutral technical change to both annual and quarterly data sets brought reasonable results (Kugler, Müller, Sheldon, 1988, 1989). The model used in these studies differs from the one currently applied in these respects. Firstly, adjustment costs under rational expectations are not considered. Secondly, capital is disaggregated into equipment and structures. Thirdly, the implicit treatment of energy and material inputs is different. For the static translog weak separability of capital and labour on the one hand, and energy and material on the other hand allows neglection of the latter in the analysis of the system of value shares for the former. However, in the current model we need a much stronger assumption in order to justify neglection of energy and material, namely that these inputs cannot be substituted for capital and labour. If energy and material are flexible and can be substituted for labour and capital, our restricted translog cost function (4) has to be augmented by corresponding energy and material price terms. This modification affects the Euler equation (7) even if weak separability holds: The C_t variable should be total flexible costs and not only flexible blue-collar labour costs, and the estimation model is therefore misspecified given that energy/material are flexible and substitutable for capital/labour.

TABLE 1

ESTIMATION RESULTS FOR DYNAMIC FACTOR DEMANDS, 1970-1984

	Consumer Goods	Raw Material & Production Goods	Food, Beverage & Tobacco	Producer Goods	Mining
Parameter: α_1	– 6,893 · 10^{-1} ***	9,829 · 10^{-1} *	– 4,032 · 10^{-1} ***	– 2,021 ***	9,025 · 10^{-1} ***
α_2	– 2,829 · 10^{-1}	– 7,528 · 10^{-1}	1,916 · 10^{-1}	3,217	6,725 ***
γ_{11}	– 1,342 · 10^{-1} ***	1,272 · 10^{-1} *	– 8,195 · 10^{-2} ***	– 2,735 · 10^{-1} ***	1,155 · 10^{-1} ***
γ_{12}	– 1,430 · 10^{-2}	– 1,343 · 10^{-1} ***	– 1.576 · 10^{-3}	9,921 · 10^{-2} ***	1,371 · 10^{-1} ***
γ_{13}	7,454 · 10^{-2} ***	4,525 · 10^{-2} ***	3,229 · 10^{-2} ***	9,524 · 10^{-2} ***	6,229 · 10^{-2} ***
γ_{14}	– 6,982 · 10^{-4} ***	– 4,555 · 10^{-4} ***	– 3,667 · 10^{-4} ***	– 1,214 · 10^{-3} ***	7,795 · 10^{-4} ***
γ_{22}	1,860 · 10^{-2}	6,171 · 10^{-2}	1,577 · 10^{-3}	– 3,053 · 10^{-1} ***	– 7,702 · 10^{-1} ***
γ_{23}	4,260 · 10^{-2} ***	1,413 · 10^{-3}	– 2,235 · 10^{-2}	1,540 · 10^{-2} **	5,422 · 10^{-2} ***
γ_{24}	– 7,569 · 10^{-5}	3,476 · 10^{-4} **	8,734 · 10^{-5}	1,426 · 10^{-3} **	5,123 · 10^{-4} ***
β_{11}	– 3,036 · 10^{2}	– 6,963 · 10^{3} **	5,312 · 10^{3} ***	1,698 · 10^{3} **	– 1,912 · 10^{4} *
β_{22}	– 3,134 · 10^{-7}	– 5,777 · 10^{-6} **	– 2,190 · 10 **	5,408 · 10^{-6}	1,765 · 10^{-4} ***
R^2 for the *W*-Equation	0,988	0,967	0,997	0,997	0,973
R^2 for the *K*-Equation	0,627	0,754	0,560	0,737	0,853
Wald Test for Symmetry	27,05 ***	2,43	1,00	65,84 ***	6,20 **
Wald Test for CRTS	76,46 ***	5,06 *	60,75 ***	74,42 ***	103,00 ***

* = 10%, ** = 5%, *** = 1%

This problem seems to be the obvious candidate for explaining the differing results, as the probable violation of the non-substitution assumption should strongly affect the empirical results, as in our sample period dramatic changes in energy and material prices took place. Therefore, we estimated a four-factor model containing energy and material inputs as flexible factor. Unfortunately, the results obtained, which are not reported here, suffer from the same problem of wrongly-signed adjustment cost coefficients. Thus, we have to look for another misspecification explaining our unsatisfactory results. The stochastic specification of the model may offer a fourth potential reason for the pattern of results obtained: the error terms of the estimated Euler equations only represent expectational errors. The specification of the production technology is deterministic. This is a questionable assumption for the time period considered, which is characterized by strong changes in supply conditions. By contrast, in a standard translog model, the error terms account, among other things, for random changes in technology. The consideration of a composite error term representing expectational errors as well as probably autocorrelated random changes in technology leads to a more complicated estimation problem, which is beyond the scope of this note. However, it may be a promising problem for future research.

5. *Summary and Conclusion*

In this paper, industrial factor demands for West Germany are analysed empirically for the period 1970-1984, using a model taking into account explicitly adjustment costs, rational expectations and non-neutrality of technical change. To this end, the model of Pindyck and Rotemberg (1983), which considers blue-collar labour as flexible and white-collar labour as well as capital as quasi-fixed factors, is extended to conditions of non-neutral technical change. Unfortunately, the estimation of this model results in parameter values which stand partly in strong contrast to the *a priori* restrictions derived from economic theory. The results obtained so far suggest that the disappointing results are to be attributed to the neglection of random changes in technology.

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PROGRESSO TECNICO NON NEUTRALE, COSTI DI AGGIUSTAMENTO E ASPETTATIVE RAZIONALI: NOTA EMPIRICA

In questo articolo, il modello dinamico di domanda di fattori di Pindyck e Rotemberg viene esteso a condizioni di progresso tecnico non neutrale e applicato ai dati dell'industria tedesca per il periodo 1970-1984. Purtroppo, dalla stima di questo modello derivano valori parametrici che sono in parte in netto contrasto con le restrizioni a priori della teoria economica. Quanto ottenuto sinora suggerisce che i risultati deludenti devono essere attribuiti al non aver tenuto conto di cambiamenti casuali nella tecnologia.

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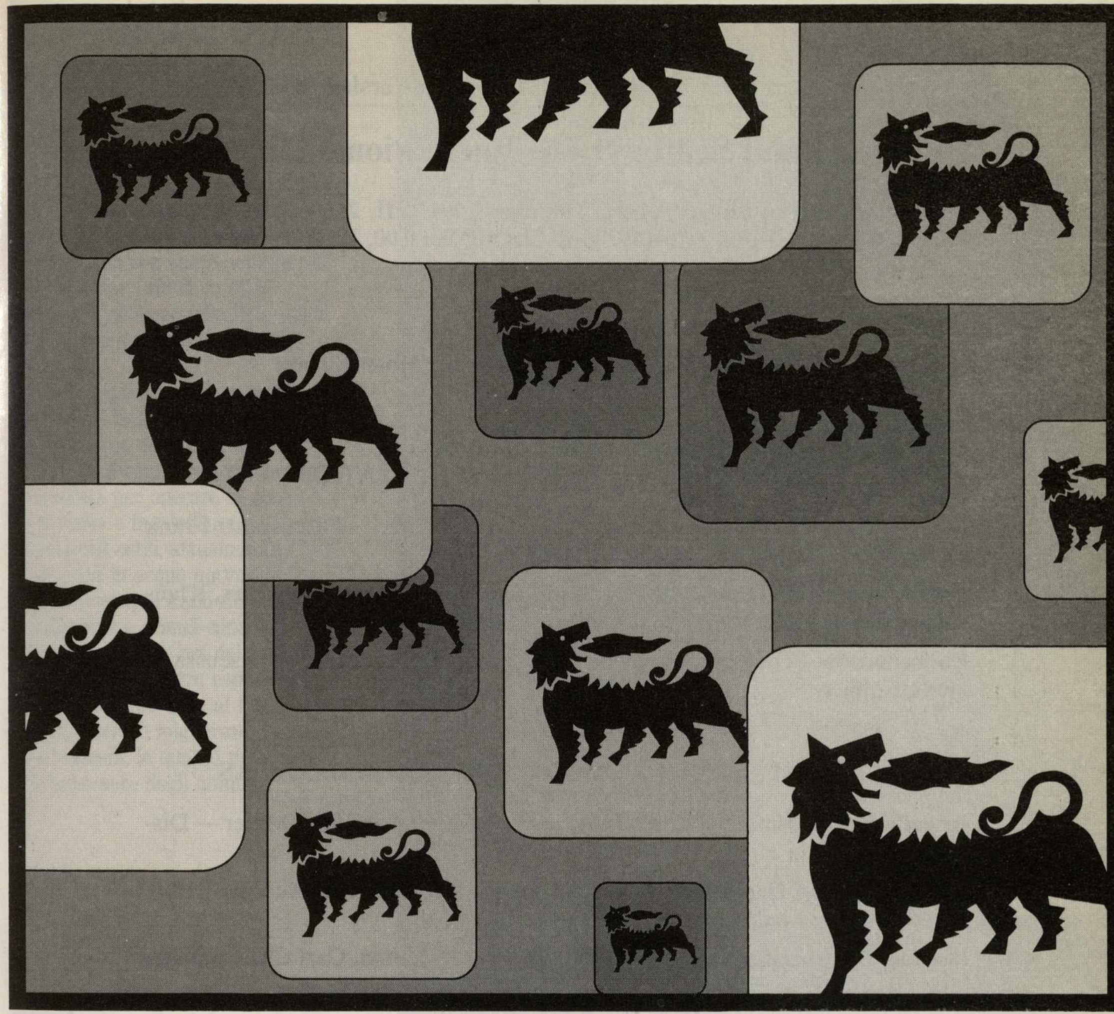

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Tutto ciò le consente di offrire servizi altamente specializzati quali le procedure d'incasso automatizzato RI.BA e R.I.D. e il Cash Management nonchè di porre a disposizione della clientela impianti automatici "self service" per lo svolgimento delle più frequenti operazioni di sportello.

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Direzione Centrale:
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piazza della Scala, 6
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BANCA COMMERCIALE ITALIANA

Società per Azioni - Sede in Milano
Registro Società n. 2774
Tribunale di Milano
Capitale Sociale L. 1.050.000.000.000
Riserva Legale L. 310.500.000.000
Banca di Interesse Nazionale

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