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SOTTO GLI AUSPICI DELLA
UNIVERSITÀ COMMERCIALE LUIGI BOCCONI
E DELLA UNIVERSITÀ DEGLI STUDI DI MILANO

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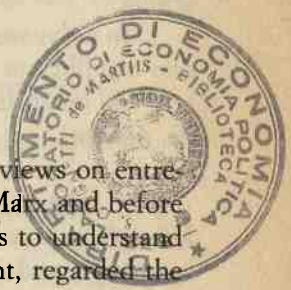
MARX AND KEYNES ON ENTREPRENEURSHIP

by
LAZAROS TH. HOUMANIDIS *



1. In order to understand the Marxian and Keynesian views on entrepreneurship one should start with Walras, who wrote after Marx and before Keynes and from a methodological point of view can help us to understand them better. Marx and Keynes each from his own standpoint, regarded the evolution of the capitalist system with pessimism.

Marx considers capitalism as inevitably doomed to an end because of its weaknesses due to the exploitation of the worker by the capitalist entrepreneur [1], while Keynes predicts a crisis in the system caused by secular stagnation [2].

The difference between them is partly explained by the course of the predicted crisis of the capitalist system. For Marx, capitalism is doomed because of the class struggle, that is because of the exploitation of man by man. The crisis will explode when the exploited will revolt against the exploiters during the final stage of the system of private ownership. For Keynes, capitalism will collapse because of the operation of the psychological law whereby a stage will be reached when saving will exceed spending following an increase in income. I shall discuss below the remedies proposed by Keynes to prevent this from happening.

2. In the Walrasian system the entrepreneur plays the role of a co-ordinator who concentrates the market of services, the market of goods and the market of capitals. The entrepreneur buys services and simultaneously offers his products for sale.

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* Emeritus Professor, University of Piraeus, President Greek Economic History Association. Paper presented before the 5th World Congress of Social Economics, York, 1988. I wish to thank Professor G.J.J. Botha for the editing of my paper as well as for his comments.

[1] J.R. Commons observes that for Proudhon the exploiter of the worker is the merchant-capitalist while for Marx it is the entrepreneur-capitalist (COMMONS, 1959, p. 143).

[2] HOUMANIDIS (1983, pp. 219-220).

In this manner he helps to provide services in the most effectual way, which, for the economy as a whole, constitutes the production function. He determines profits, salaries and the reward for services and, by the law of supply and demand, he establishes price on the basis of cost and scarcity. At this price pure profit is non-existent, while the profit-salary is absorbed into the cost of production. Thus, according to Walras, in a static economy – with constant technology, population, tastes etc. – dynamic profits are absent.

In a dynamic economy this will no longer be true when we move from one equilibrium position to another. Then the operation of various parameters will result in the emergence of a new equilibrium where pure profit will be present.

3. The contribution of the entrepreneur is not of a mere intermediary. His role is to combine the factors of production, to facilitate and promote inventions and innovations and, on the basis of the existing cost structure, to make the expansion of the market possible. For Walras a situation of competitive equilibrium is obtained from the interdependence of prices and the interaction of supply and demand, as follows:

$$\sum_{i=1}^{n+1} p_i \; s_i = \sum_{i=1}^{n+1} p_i \; d_i$$

Walras [3] regards money as being neutral, as something that merely helps in the exchange of goods and services. He conceives a prime material as a good of which the quantity on the market is Q_a. A part Q_a' will be used as a commodity, while another part Q_a'' will serve as money which, in its function as merchandise, will be priced p_u. Thus

$$(1) \qquad Q_a'' \; p_u = H_a$$

where H_a is the cash required by the public. This equation corresponds to a state of steady economic equilibrium and is equivalent to the case which Professor Anghel Rugina presents in the formula

$$(I) \qquad C_0 100\% + M_0 0\% + N_n \text{num } 100\% + M_n \text{anti–num } 0\%$$

where C_0 represents free competition, M_0 monopoly, M_n num money merchandise and M_n anti–num (credit money).

Walras argues that when credit money interferes in the circulation it

[3] WALRAS (1926, pp. 319-320, 352-353).

disturbs the equilibrium and causes a disequilibrium altering (1) as follows [4]:

$$(2) \qquad (Q_a'' + F)\, p_u = H_a$$

where F is credit money. If H_a changes following a disappearance of credit F from the equation, the value of money rises, (2) reduces to (1) and prices decrease. If, however, economic equilibrium is disturbed because of the effects of the 50% credit money, Walras equation (2) prevails and Rugina's formula becomes [5]

$$(II) \qquad C_0 50\% + M_0 50\% + M_n \text{ num } 50\% + M_n \text{ anti–num } 50\%$$

which represents a 50 per cent disequilibrium, or a Keynesian situation of underemployment equilibrium.

Walras did not allow the entrepreneur to play a proper role in his system, which was in accordance with his liberal social views, viz the maintenance of the price mechanism and replacement of the entrepreneur by the state. But the entrepreneur is more than the appropriation of the means of production by the state. The entrepreneur is someone with initiative who is conscious of the value of enterprise, its organization and the risks involved in an environment of uncertainty. This is not a role that the State can take over. Also, the State cannot always represent the interests of the community if it is not controlled by democratic social forces. Under a proper democracy the State is controlled by social forces, which prevent it from falling prey to the vested interests of individuals or group of individuals.

4. Karl Marx adopts two different approaches. In the first, the producer exchanges the products of his labour with those of another in accordance with their use-value and without the intervention of money – an exchange *C-C* – or without money acting as an intermediary measure of equivalent values. The case of the circuit *C-M-C* represents an initial sale and a final purchase and this is the model of a simple reproduction in which we have a steady equilibrium in accordance with (1) and (I) above.

However, when money becomes capital [6] – when it buys labour and means of production – then the circuit Money-Commodities-Money expands to include a surplus-value and becomes *M-C-M-M'*, which causes a disequilib-

[4] *id.*

[5] RUGINA (1987, p. 21).

[6] RUGINA (1975, No 3, pp. 359-367, No 4, p. 447); MARX (1956, vol. I, ch. IV, p. 145; vol. III, p. 322); SWEEZY (1956, p. 158 ff.).

rium and creates a conflict between the two key classes, i.e. workers and capitalists. This conflict results from the existence of a surplus value, which Marx regards as the essence of the capitalist system. It finds expression in Marx's extended circuit and also in Walras's equation (2) above, and in Rugina's equation of no 100% monnaie numéraire (M_n num).

The theory of surplus value has, of course, been severely criticized in the literature. Here we need not discuss it any further besides mentioning that in a dynamic economy surplus value supplies the means of reproduction of capital and labour and promotes economic growth in both capitalist and socialist societies. If, as Marxists claim, surplus value is absent from a socialist system it is not clear how economic growth is financed. They claim that during the transition from socialism to communism the surplus value – i.e. the source of exchange-value and of capital – will be distributed to the workers and will eventually disappear and all capital will be owned by the workers who would then enjoy the full product of their labour.

The question that arises is how realistic is the ideal of a true communist state? If it can eventually be attained, would the workers in the meantime be content to be exploited and also run the risk that the governing caste remains in power? The prediction that in a communist society all goods would be in abundant supply remains a mere utopia.

5. For Keynes, the entrepreneur is an indispensable factor of production. The decision whether or not to produce is influenced by the rate of interest, which the entrepreneur considers in relation to expected profits. If from this calculation an optimistic expectation arises, he will be inclined to invest; if not he may prefer to hoard. To that end Keynes proposed direct taxation and a public works policy with low rates of interest. For the neoclassical economists and their teacher, Alfred Marshall, this was sheer heresy.

Keynes was conscious of the virtues of the entrepreneur and of his particular characteristic of foresight – in this respect he was no doubt influenced by Marshall – but at the same time he accused the entrepreneur of holding cash balances which has the effect of reducing investment, i.e. that activity which breeds employment, increases the total income and the level of consumption.

Keynes sees the entrepreneur as the first actor within the psychological law and the corner-stone of the economic system; who can hope to survive only if the remedy that he proposes is adopted. For Keynes thrift is a virtue

only in time of economic boom as Lekachman showed sketching the benefits of high saving in a period like 1870-1914 [7].

The essence of the models of Marx, Walras and Keynes may be summarised as follows [8].

Marx

a. Only labour is productive.

b. A freely competitive market without frictions. Monopoly not seriously examined.

c. Capitalists enjoy surplus value because they own the means of production.

d. Profit results from surplus value.

e. Money is neutral and expresses the prices of commodities and services. Money is transformed into capital and buys labour in order to create surplus value.

f. Entrepreneurs are the parasites of society. They must be destroyed and replaced by the workers who will ensure that economic justice prevails.

g. Total income is equal to total wages plus surplus value.

Walras

a. The entrepreneur is the basic factor of production around whom orbit – like the planets around the sun – the markets of goods, capitals and services.

b. A freely competitive market without frictions. Complete laissez faire can be obtained by the nationalization of land in a manner that excludes monopoly and retains the laws of supply and demand.

c. The entrepreneur receives a reward of profit-wage, because under free competition the interaction of cost and scarsity (rareté or dernier besoin satisfait) does not allow the creation of pure profit.

d. Pure profit arises only during the transition from the equilibrium situation to another thanks to the exploitation of special opportunities and differential situations.

e. Money is neutral only if it is commodity-money-numéraire.

f. The entrepreneur being only a co-ordinator can be replaced by the State.

g. Under free competition income equals expenditure.

---

[7] LEKACHMAN (1966, pp. 94-95).

[8] HOUMANIDIS (1989, pp. 162-3).

Keynes

a. Both labour and capital are productive. Employment is measured by the wage-unit.

b. The State intervenes in freely competitive markets. Laissez faire is rejected, as it leads to unemployment, because the invisible hand necessary to it does not exist.

c. Bankers dominate both entrepreneurs and workers by supplying capital at a rate of interest that determines investment as a function of effective demand.

d. The expectations of entrepreneurs determine the level of activity as a function of the current role of employment, the rate of interest and the wage-unit.

e. Money is an active factor in the economic system. Its flow makes hoarding possible which gives rise to the gap between saving and investment.

f. The entrepreneur is the cause of not only economic progress but also of the stagnation of the economic system, when he stands to save more than he spends following an increment in his income.

g. Total income is equal to total expenditure and total saving to total investment (ex ante) at the full employment level. Expenditure depends upon the level of national income and the rate of interest impacts on the national income.

The Walrasian and Keynesian economic systems are metastatic for the following reasons:

a. We can say that pure profit arise only during the transition from the equilibrium situation to another (exploitation of opportunities, differential situations, changes in technology, population, etc.).

b. We shall let Keynes speak for himself: "The schedule of the marginal efficiency of capital is of fundamental importance because it is mainly through this factor (much more than through the rate of interest) that the expectation of the future influences the present. The mistake of regarding the marginal efficiency of capital primarily in terms of the current yield of capital equipment, which would be correct only in the static state where there is no changing future to influence the present, has had the result of breaking the theoretical link between to-day and to-morrow" [9].

7. Marx and Keynes hold similar views on the question of the deficiency in demand. This is the objective side of the question; the other, the

[9] KEYNES (1951, p. 145).

psychological side, comes into play between entrepreneur and worker. Their thesis on the deficiency in demand has been proved fallacious because during the 19th and 20th centuries both wages and profit have in general been rising.

Both Marx and Keynes recognize the concept of *homo oeconomicus*. Marx argues that the dominant factor of economic life – the entrepreneur – exploits the worker in order to accumulate. Keynes, for his part, maintains – although not sympathetically – the median mentality on the entrepreneur's role, who – like all individuals – has a liquidity preference.

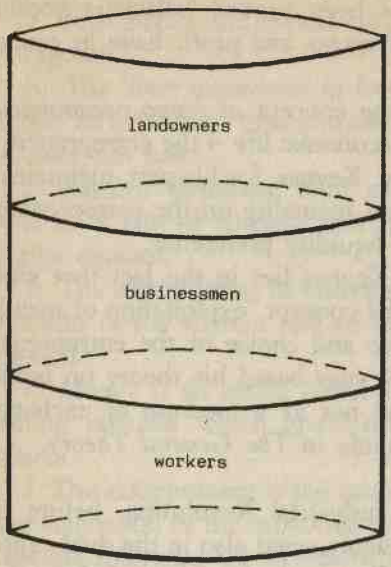
The difference between Marx and Keynes lies in the fact that while Marx's theoretical structure is based on the concept "exploitation of man by man", Keynes' is based on the preference and choice of the entrepreneur between hoarding and investing. Thus Keynes based his theory on money acting primarily as a store of value and not as a medium of exchange, although he retains the latter in his formula in *The General Theory*.

8. During the early years of the Industrial Revolution, before the development of capital markets, entrepreneurs acted also in the dual capacity of managers and suppliers of capital. That made them fairly independent of bankers. At those times they were not much affected by the rate of interest but fell victim to persistent increases in the rent of land. This was why classical economists did not clearly distinguish between profit and interest but had much to say about the monopoly of land.

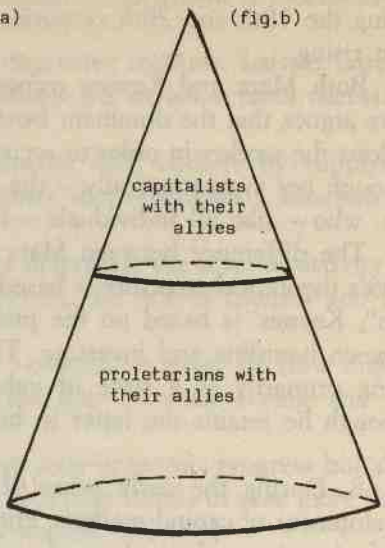
The classical economist did not clearly distinguish between these kinds of capitalists: the *entrepreneurs* (owners of capital), the *landowner-capitalists* (owners of the land), and the *workers* (owners of "muscular capital"). These three classes functioned simultaneously, each within the framework of its own cost of production. They represented an ideal and harmonized capitalist system. It is shown in Fig. (a) in the form of a cylinder signifying not only the free movement from one social class to the other but also their equality as regards to giving expression to the working of the basic law of self-interest.

The Marxian system is represented in Fig. (b) as a cone with the ruling class and its allies on top and the proletarians and others lower down. The neo-classical system, shown in Fig. (c) adds a conic section representing the banker-capitalists and monopolists (d). It is this section that I should like to see removed, as proposed in my "*Humanitarian Economics*" [10] and shown in Fig. (e) as a cylinder containing on top the collaborating intellectuals,

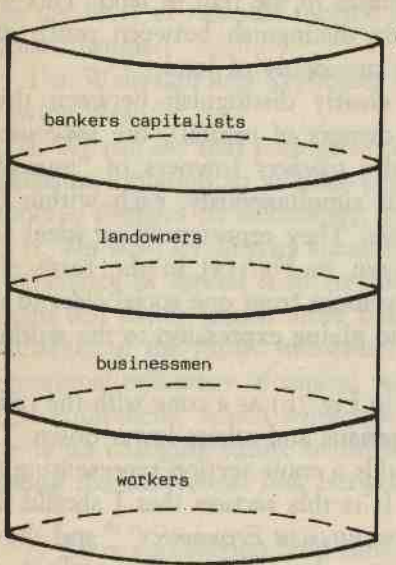
[10] HOUMANIDIS (1978).



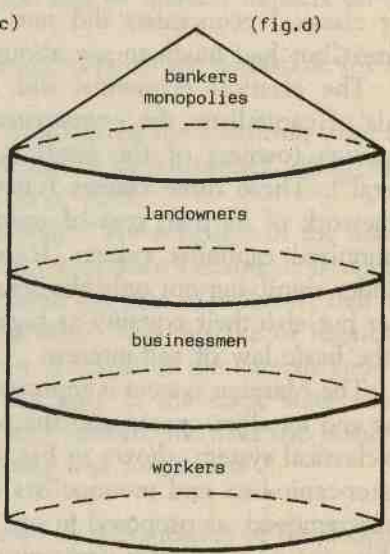
Social structure of Classical system



Social structure of Marxian system

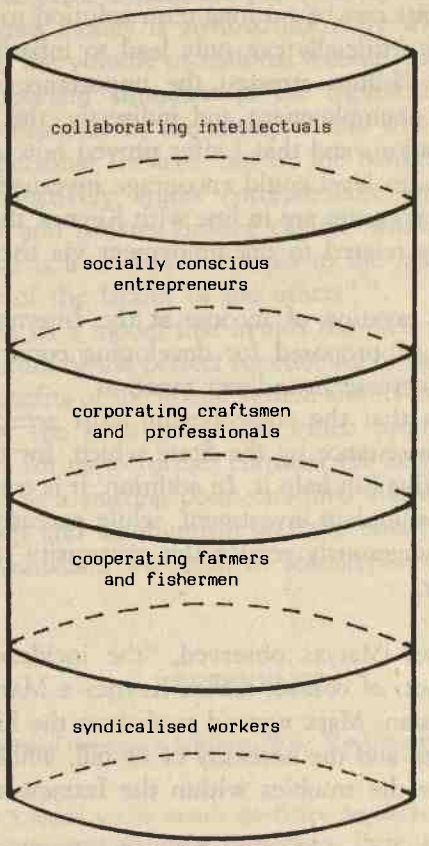


Social structure of Neoclassical system



Social structure of financial capitalism's system

followed lower down by the socially conscious entrepreneurs, co-operating craftsmen and professionals, the co-operating farmers and fishermen and at the bottom, the syndicalized workers. As regards the bankers and monopolists, I propose that they be either nationalized or subjected to the control of the social democratic forces.



Structure of humanitarian system
of Social Democracy

9. To return to Keynes. As we have said, Keynes sees the entrepreneur as both the stimulating factor of progress and the cause of the decline of the capitalist system because of his excessive thrift which gives rise to idle money. Keynes was an admirer of Silvio Gesell. As he puts it in a

well-known passage in *The General Theory*: "I believe that the future will learn more from the spirit of Gesell than that of Marx" [11] and, separating himself even more from the marxian position he used phrases about Marx's "Kapital" such as: "An obsolete economic book, not only scientifically erroneous but without interest or application in the modern world" [12].

The Keynesian solution to our economic problems has of course, been disputed by many economists – to whose ranks I myself also belong – because budget deficits can be no long-term solution to our problems, and to stimulate demand artificially can only lead to inflation.

It is true that Phillips stressed the importance of the relationship between wages and unemployment and indirectly, the possibility of a vicious circle of stagflation; and that Laffer proved how a decrease in direct taxation to an optimum level could encourage investment. However, both the Phillips and Laffer curves are in line with Keynes' theory because wages or prices are directly related to unemployment via the level of economic activity.

As regards the taxation of income at the International Congress of Economic History [13], I proposed for developing countries a reduction in income tax and an increase in indirect taxation.

The problem is that the entrepreneur must accept a fifth factor of production, namely assistance by the State which, for its part, should not destroy private initiative but help it. In addition, it is true that a decrease in direct taxation may stimulate investment, while excessive increase in indirect taxation may dangerously reduce the propensity to consume, and so threaten employment.

10. As Professor Matyas observed, "the incidence of similarity in certain issues does not, of course, makes Keynes a Marxist, as it does not make Marx a Keynesian. Marx wanted to deduce the historical, temporary character of capitalism and the necessity of its fall, while Keynes's aim was to find a remedy for the troubles within the framework of the capitalist system" [14].

Marx and Keynes agree on maintaining the double role of wages: as a cost of production to the entrepreneur, and as a source of demand for the goods produced by the enterprise. The controversy between Pigou and

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[11] KEYNES (op. cit., p. 355).
[12] *id.*
[13] HOUMANIDIS (1965, pp. 187 ff.).
[14] MATYAS (1983, p. 155).

Keynes concerned this split of the production process and its impact on consumption.

Keynes in attacking the neoclassical thesis, tries to salvage private enterprise [15]. On the one hand he advocates the increase of the marginal productivity of capital and on the other he proposes ways to increase the propensity to consume. For Keynes there is no fatal end to entrepreneurship. For Marx money is a medium of exchange and a passive factor of the price level, because price determines the quantity of money in circulation. According to Keynes money is an instrument by which we can raise economic activity and the volume of national income. He considers the rate of interest as an important stimulant of the capitalist system. To him the ruling class is not made up by the entrepreneurs who contribute to national income by their personal services, but by the bankers. From this point of view Keynes instinctively unites entrepreneurs and workers under the concept of labour and isolates finance capital, while Marx declared: "The industrial capitalist is a worker compared to the money-capitalist" adding: "but an exploiter of the labour of the others" [16].

Walras offers us a model that avoids the element of time in order to give us a clear picture of the perfect functioning of the economy. He wished to combine the benefits of the liberal system and its promotion of productivity, with those of the socialist system which promises greater economic justice. It remains for us to further consider the economic thought of these economists taking as a starting point our final aim of opening a third road between capitalism and communism and the possibility of combining the principle of individualism with that of sociality.

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[15] Keynes defines the validity of his proposal saying: "... avoiding the destruction of existing economic forms in their entirety and as condition of the successful functioning of individual initiative" (KEYNES, op. cit., p. 380).

[16] MARX (op. cit., vol. III, p. 387).

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MARX E KEYNES SULL'IMPRENDITORIALITÀ

Fra Marx e Keynes vi sono similarità per quanto riguarda la crisi del capitalismo, ma le loro teorie sono diverse.

Essi avevano idee analoghe sulla questione dell'inefficienza del capitalismo ma questa tesi si è mostrata falsa perché durante il 19° e il 20° secolo sia i salari sia i profitti sono generalmente aumentati. Entrambi questi autori riconoscono il concetto di *Homo oeconomicus* che per Marx, come imprenditore, sfrutta il lavoratore per accumulare capitale, mentre Keynes mantiene la visione corrente del ruolo dell'imprenditore, che – come tutti gli individui – ha una preferenza per la liquidità. Marx considera inevitabile la fine del capitalismo e Keynes cerca di proporre allo scopo di salvare il sistema la sua medicina dei lavori pubblici, del basso tasso di interesse in rapporto all'efficienza marginale del capitale e dell'imposizione diretta.

Walras ci ha offerto un modello statico che evita l'elemento del tempo per darci un chiaro quadro del perfetto funzionamento dell'economia, ma il suo sistema è astratto e meccanicistico.

L'autore cerca di presentare un sistema che combini il principio dell'individualismo con quello della socialità dal punto di vista del costo della dipendenza o effetto di dipendenza e del rapporto fra possibilità di produzione e risultato della produzione.

Egli accetta l'imprenditorialità come qualità che dà vita all'impresa e le forze collettive democratiche come controllo delle sue possibili attività antisociali.

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PROFITABILITY AND IMITATION IN THE DIFFUSION OF PROCESS INNOVATIONS

by
CRISTIANO ANTONELLI *

1. *Introduction*

The epidemic approach to the analysis of the diffusion of process innovations has recently been the object of a wave of criticism focusing attention on the limitations due to its static nature [1].

As diffusion proceeds a variety of factors change: the macroeconomic conditions, the relative costs of production factors, the prices and performance of capital goods incorporating the innovation as well as those of traditional capital goods. It is clear therefore that the profitability of adoption

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[1] As Metcalfe notes:

"Despite the obvious success of this (epidemic) approach, there are powerful reasons for believing it diverts attention away from important aspects of the diffusion process. There are two objections I wish to emphasize. The first relates to the static nature of the standard diffusion model – a given innovation is diffused within an unchanging adoption environment, although there are well documented reasons for expecting both innovation and environment to change as diffusion proceeds. Improvements to the innovation, general economic growth, changes in relative commodity and input prices, and other complementary or competing innovations, can all be expected to occur during diffusion". METCALFE (1981, p. 348).

See also Stoneman:

"However, over the past few years two further important developments in diffusion modelling have taken place. The first is the realisation that any observed diffusion phenomenon is not purely a reaction to demand forces but will also reflect supply phenomena. This indicates that diffusion can only be properly analysed in a model that takes account of both demand and supply forces" STONEMAN (1987, p. 52).

which is considered to be, together with the spreading of information, the leading factor in the diffusion of innovations, also changes over time [2].

Omission of this important factor in the standard epidemic model [3] has in recent years caused a general discontent with the epidemic approach. A whole family of supply-side oriented equilibrium models has been generated with the aim of supplanting the epidemic approach [4].

The basic assumption of the equilibrium models is that diffusion is the result of the rational behavior of fully informed but structurally heterogeneous potential adopters. Potential adopters are assumed to differ structurally in terms of size (Davies, 1979), production costs, competitive advantage (Reinganum, 1981), and vintage of existing capital stock (Stoneman, 1983). The innovation will spread, at each level of potential profitability of adoption of the capital good incorporating the technological change, only within the fraction of potential adopters for which the adoption is effectively profitable. As time proceeds potential profitability will increase because of the introduction of incremental technological change, due to the positive effects of learning by doing and competition brought on by imitation on the supply side (Stoneman, 1983) and learning by using on the demand side (Davies, 1979). Consequently new categories of potential adopters will find it effectively profitable to adopt the innovation and diffusion will proceed.

The equilibrium approach rests upon two strong hypotheses. First, the survival of obsolete production processes is considered to be the result of choice rather than ignorance. Uncertainty and information asymmetries are not considered as playing a role in the equilibrium approach. Economic agents are assumed to have full rationality (as opposed to bounded rationality) and unlimited knowledge even when new production processes are in-

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[2] As Mansfield observes, with respect to the innovations he considered: "One cannot tell with any accuracy how, and to what extent, the profitability varied in each of these cases. But, to illustrate the factors at work, note a few broad changes that occurred in the cases of three of the innovations. (a) The appearance of improved diesel locomotives in the thirties and forties increased the profitability of introducing them and hastened their acceptance. In addition, first costs declined, the relative prices of coal and oil changed, and the composition of the "holds out" varied. (b) The demand for toluene during the First World War undoubtedly accelerated the imitation process in the case of the by-product coke oven. (c) The Depression reduced the profitability of introducing centralised traffic control, whereas the wartime traffic boom increased its profitability" MANSFIELD (1961, p. 762).

[3] See Mansfield: "Variation over time in the profitability of introducing an innovation (due to improvements, the business cycle, etc.) is one potentially important factor that is omitted" MANSFIELD (1961, p. 762).

[4] See STONEMAN (1983) for an outstanding analysis of such a shift in the economic debate on the approaches to diffusion.

troduced in the market and information about their economic features and technological capacity is scarce and difficult to assess [5].

Second, while first adopters are sensitive to the absolute profitability of adoption, i.e. the increase in total factor productivity made possible by the innovation, the followers are more concerned about the profitability variations over time. With the passage of time firms adopt the innovation as the (growing) profitability of adoption matches the different substitution costs due to the different cost conditions of firms which are assumed to be structurally heterogeneous. In such a context it is clear that the engine of the diffusion process is now the growth of profitability of adoption. In the equilibrium approach in fact the profitability of adoption of capital goods incorporating technological innovations is bound to increase over time if diffusion is to proceed. Consequently, within the equilibrium approach, we would not expect incremental adoptions of an innovation exhibiting stable or decreasing profitability of adoption.

The fast changes in market conditions, the continuous rebates on the prices of familiar machines, the introduction of new machines based on unknown new technologies often requiring new skills further reduce the full rationality of customers who experience high levels of uncertainty and limited knowledge. In such a context, collective learning and imitation remain the basic source of information and the basis of decision making.

While it seems appropriate to pay adequate attention to the role of supply conditions in trying to understand the diffusion of process innovations, the assumptions of unlimited knowledge and unbound rationality of potential customers in a context of increasing profitability of adoption seem to warrant some further discussion.

2. *A Model of Diffusion with Imitation and Profitability*

2.1. *The role of profitability of adoption in diffusion.* – With perfect knowledge, homogeneous access to information about the relative profitability of the technological innovation and no adoption costs for the firms which adopt innovative processes, an innovated capital good will be introduced according to the level of purchasing costs. Diffusion then takes place over time because of the differences in production costs among firms. Following

[5] Still, it seems clear that such an assumption is hard to accept: the rate of introduction of an innovation in fact coincides with a world of evolving knowledge and a process of continuous expansion of the customers' choice set. Customers are thus forced to make decisions without a *known choice set* (see LOASBY, 1976).

the hypotheses of structural heterogeneity, firms are in fact expected to differ significantly with respect to size and wages. Large firms with higher wages are expected to adopt labor saving innovations earlier than smaller firms. Small firms will adopt new processes when the market price and the performance of innovated capital goods will decline so as to make it profitable to substitute labor. In conditions of perfect knowledge, homogeneous access to information and no adoption costs, diffusion, i.e. the time distribution of adoptions, will be determined only by the evolution of the hedonic price of innovated capital goods, as measured by the ratio between technical performance and prices with respect to that of traditional ones [6].

In a context of unlimited knowledge, the evolution of relative prices and performance of new capital goods is the result of a mix of supply factors which include the changes of the prices and performance of new machines, brought on by innovating firms and the strategies of the firms producing traditional capital goods. Such changes depend upon the structure of the supply industries, the shape of long-term production costs, the relationships between the firms active in the production of new capital goods and the firms producing the traditional machines, the location of producing firms, the differentiated access to production factors (skilled manpower in the case of textile machinery) at low cost and the opportunities which technological change offers to reduce production costs as an alternative to increase performance. Especially when firms producing innovated capital goods differ from firms producing traditional ones, there is keen competition based on quality *and* price reductions.

In a context of bounded rationality and limited knowledge, a growing amount of literature suggests that the profitability of adoption is not only influenced by the levels of purchasing costs and by the performance of innovated capital goods but also by the levels of *costs of searching* information about the innovation and the levels of *costs of adopting* the innovation, i.e. the cost of introducing a new capital good into the production process.

When we assume information asymmetries and limited knowledge influence the economic decision making of potential adopters, the bounded rationality limits the quantity of information potential adopters can process. It is costly to search for information about the performance of innovated capital goods which is necessary to assess their profitability. In turn the cost of searching is influenced by the availability of information which is itself a function of the stock of innovated capital goods already sold, as well

[6] For quite a long period of time in fact, especially for capital goods which do not incorporate radical innovations, coexistence and competition between innovated capital goods and traditional ones take place on the markets.

as of the advertising expenditures of producers. It is thus clear that potential adopters rely on the experience of previous adopters, i.e. imitation so that *collective learning* (Simon, 1982), *learning by observing* and more generally cognitive externalities, are major causes of the diffusion process.

Moreover empirical analysis of the factors influencing the decision of adopting an innovated capital good also reveals that *adoption costs* i.e. the costs of maintenance, training, purchasing spare parts for new capital goods have major effects on the profitability of adoption (David, 1985). Adoption costs for each potential adopter are influenced by strong real externality effects which add to the cognitive externalities. The growth of the stock of innovated capital goods leads to decreasing adoption costs for each additional adoption because of the growing availability of skilled manpower, technical assistance, maintenance, availability of components and spare parts [7]. The profitability of innovated capital goods for adopters is thus influenced by real external effects produced by the stock of adopters.

In sum, the growth of the stock of an innovated capital good generates real externalities and cognitive effects which traditionally are defined as *imitation effects* brought on by the swarming of information about the new machines, and help to increase the profitability of adoption.

It now seems clear that A) adoption depends on profitability; B) diffusion is generated by the process of increasing profitability, and C) increasing profitability of adoption itself depends on three factors:

i, the decline of market prices and the increase in the performance of innovated capital goods generated by the introduction of incremental innovations, by economies of scale, learning processes and competition among producers;

ii, the decline of search costs, which are necessary to evaluate the performance of innovated capital goods, is due to imitation and *cognitive externalities*, i.e. easier access to information spread by the growth of the stock of adopted capital goods incorporating technological innovations;

iii, the decline of adoption costs, which are different from purchasing costs, and are incurred when the innovated capital goods are introduced into the production process, is generated by *real externalities*, i.e. the lower costs of maintenance, skilled manpower and spare parts brought about by the growing stock of adopted capital goods incorporating technological innovations.

In sum, diffusion is the aggregate result of an active *decision* of adoption which, however, is made in conditions of limited knowledge and

[7] See also DAVID-BUNN (1988) for the notion of externality in diffusion.

bounded rationality. So far we can rely on the *epidemic approach* when focusing attention on the role of *imitation on the demand* side: because of cognitive heterogeneity, at any point of time during the diffusion process, only a fraction of total customers, proportional to the number of installed innovated capital goods, will be aware of what is available on the market of capital goods for given search costs and consequently adopt an innovated good. Following the *equilibrium approach*, however, we also expect that the changes in the purchasing costs of innovated capital goods, i.e. *supply forces* determining the evolution of market prices and performances, have an important role to play.

2.2. *A formalisation.* – From our discussion, it follows that the growth of the stock of innovated capital goods which can be considered as a proxy for collective learning and imitation should be added to, not substituted for, the role of supply forces, i.e. the change in purchasing costs.

To do so, we rely on a mixed model of diffusion derived from the traditional epidemic specification. Our hypothesis suggests that the diffusion of innovated capital goods is in fact the result of the interaction of A) the cognitive and real externalities which affect the profitability of adoption of innovated capital goods relative to that of traditional ones, brought about by the number of innovated machines already installed [8]; and B) the *evolution* over time of the purchasing costs and the performance of new machines compared to those of traditional ones.

Such an interaction can be formalised in the following differential equation:

$$\dot{Y} = \frac{b_1}{t} \cdot \frac{Y\,(N\text{-}Y)}{N} + \frac{b_2}{p}\dot{p}\,\frac{Y\,(N\text{-}Y)}{N} \tag{1}$$

where Y = adoption levels; N = ceiling number of potential adopters; t = time; p = levels of hedonic prices of innovated machines compared to the prices of traditional machines.

Equation (1) can be developed as follow:

$$\dot{Y} = \frac{(N - Y)\,Y}{N}\,m\,(t), \text{ for } m\,(t) = \frac{b_1}{t} + b_2\frac{\dot{p}}{p} \tag{2}$$

from which equation (3) can be derived:

[8] In this sense the epidemic spread of information coincides with a process of expansion of the potential customers' choice set. (See LOASBY, 1976).

$$(3) \qquad \frac{Y}{N - Y} = e^{\int m(t)\,dt + C_1}$$

The right hand side of equation (3) can be integrated, assuming p_o to be a positive quantity, for p differentiable with respect to time:

$$(4) \qquad \int m(t)\,dt = \int \left[\frac{b_1}{t} + b_2\frac{\dot{p}}{p}\right] dt = b_1 \int \frac{dt}{t} + b_2 \int \frac{\dot{p}}{p}\,dt =$$

$$= b_1 \log t + b_2 \int \frac{d \log p}{dt}\,dt + C_2 = b_1 \log t + b_2 \log p + C_2$$

Equation (4) can be further simplified into equation (5):

$$(5) \qquad Y = \frac{N}{\frac{1}{\gamma} + 1} = \frac{N}{e^{-(b_1 \log t + b_2 \log p + a)} + 1}$$

where $\gamma = e^{b_1 \log t + b_2 \log p + a}$ which leads to the following cumulative lognormal function [9]:

$$(6) \qquad Y = \frac{N}{e^{-a} e^{\log t^{-b_1}} e^{\log p^{-b_2}} + 1}$$

As is clearly shown by equation (1), the diffusion of the process innovation under consideration is assumed to be the result of the multiplicative interaction of time, and this expresses the classical "epidemic" process of imitation in conditions where diffusion is fueled by imitation, i.e. *externalities* generated by the stock held by adopters and by *supply forces* such as the changes in the hedonic prices of innovated machines due to the conduct of innovating firms, the effects of incremental technological change and the reaction of the producers of traditional machinery.

After logarithmic transformation equation (6) yields the following log-logistic equation:

$$(7) \qquad \log \frac{Y_{(t)}}{N - Y_{(t)}} = a + b_1 \log TIME + b_2 \log PRICE$$

which can easily be used to test the empirical evidence of the diffusion of innovated capital goods under the effect of the *imitation effect and the supply forces* measured by hedonic prices.

[9] Actually this curve is similar to but not identical to the cumulative lognormal.

Equation (7) constitutes a mixed model of diffusion which blends the traditional epidemic approach, where *TIME* is the only independent variable of the linearised transformation, with an appropriate adjustment being made for the evolution of the supply conditions of innovated capital goods dependent on changes in the supply of traditional capital goods and it is expressed in the second independent variable, *PRICE*, which is included in the linearised transformation.

With respect to the traditional specification of the epidemic approach, the mixed model we propose makes it possible for us to separate the specific role of imitation linked to the epidemic spreading of information from that of the economic decision making of potential adopters who gradually become aware of the advantages of the innovated capital goods and choose to adopt them according to their specific levels of risk aversion and switching costs on one hand and their relative profitability on the other [10].

From this point of view our mixed model seems to be able to take into account the effects of both the cognitive heterogeneity and information asymmetries which are traditionally built into the epidemic models, as well as the structural heterogeneity which is due to factors such as differences in size, vintage of existing capital stock, competitive advantage and production costs. While the epidemic contact gradually spreads the information among potential customers, the decision to actually adopt the process is influenced by the specific cost conditions which differ across firms [11].

3. *The Empirical Analysis*

3.1. *The Data.* – Shuttle-less looms were first introduced in Switzerland in the fifties. The technological innovation consisted in the increase in the working speed of the weaving process through a reduction in the weight of the shuttle and eventually through the substitution of the shuttle itself with new tools [12]. Along a clear technological natural trajectory a number of

[10] See LEKVALL-WAHLBIN (1973) and ANTONELLI (1989) for an initial discussion of the use of mixed models.

[11] It also seems clear that in our mixed model potential customers have an active role both in searching for information and in deciding whether to adopt or not. In the traditional epidemic model instead adoption was considered to be the parametric behavior of the customers who had received the information.

[12] The data on the evolution of physical productivity suggest that, with respect to the shuttle technology, ceteris paribus of market price and ceteris paribus of macroeconomic conditions, i.e. assuming constant rates of utilization and relative cost of factors, the shuttle-less

incremental innovations were introduced and a whole family of shuttle-less looms was generated [13]. Potential working speed increased from 220 knots of the projectile (introduced in 1970) to 250 with the rigid gripper (1975), 300 knots of the flexible gripper (1976), 600 knots of the air-jet and water-jet (1980).

In order to test equation (6) data on the diffusion of shuttle-less looms in the period 1976-1985 were collected for eight major countries as well as information about the evolution of the purchasing costs and the performance of both shuttle and shuttle-less looms.

Table 1 shows the data on the evolution of shuttle-less looms installed in a group of countries where the diffusion process had already reached about the same level of penetration in 1976, between 5% and 10% of the stock of shuttle looms: Japan, the U.S.A., France, W. Germany, Italy, Austria and Belgium; in the period 1976-1985, as well as the figure of the total number of looms installed in those countries at the end of 1976 [14].

Data on the evolution of the actual working speed of shuttle and shuttle-less looms (see Table 2) were collected with the help of the Associazione Cotoniera Italiana and a number of interviews with cotton weaving firms and these data should reflect the actual in-plant experience of production with looms of different vintage. Each vintage incorporates the incremental innovations introduced in the reference year but not the effects of learning by using.

Data on the evolution of nominal average market prices (see Table 2) were assessed by experts of the Associazione Cotoniera Italiana and by the firms interviewed and they should reflect the average nominal price of both shuttle and shuttle-less looms actually paid by cotton weaving firms, each year in normal conditions. In the opinion of a number of the experts interviewed the data apply to most European countries: France, Austria, Italy, West Germany, Belgium, as well as to Japan and to the U.S.A. All these countries are in fact active in the production of textile machinery, and

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technology can be considered highly capital intensive in Harrod terms. The capital-output ratio in fact changes because of the increase of capital productivity. The shuttle-less technology is slightly labor saving in Hicks terms because one team of three workers can control 42 new shuttle-less looms, irrespective of the vintage, instead of 36 shuttle looms. This suggests that attention should be focused on the evolution of the physical productivity and the prices of the new looms with respect to the performance and prices of the old looms, ignoring the changes in labor requirements.

[13] See NABSETH-RAY (1974), ROTHWELL (1980) and RAY (1984).

[14] One should consider that in the textile industry scrapping is not traditionally related to the purchase of new machines. Existing looms are kept and used according to fluctuations of capacity needs because of high levels of variability in demand.

TABLE 1

THE DIFFUSION OF SHUTTLE-LESS LOOMS

	Shuttle looms installed in	Shuttle-less looms installed in									
	1976	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
U.S.A.	280,319	21,229	23,625	38,856	46,711	38,681	44,822	45,950	52,030	57,420	61,760
JAPAN	117,967	10,284	11,427	11,434	12,164	14,498	15,255	18,420	22,550	25,750	30,060
SWITZERLAND	8,359	495	525	542	724	876	898	895	940	1,033	1,230
BELGIUM	18,100	390 *	541 *	751 *	1,069	1,352	1,710	2,240	4,750	3,600	4,300
FRANCE	37,699	3,500 *	4,053	5,000	6,000	7,200	9,230	10,000	9,770	10,360	10,580
W. GERMANY	40,898	1,200 *	1,694	1,800	3,600	5,100	6,000	9,135	9.720	10,510	12,200
ITALY	47,790	3,680	4,098	4,700	5,732	7,220	8,122	8,600	12,230	14,240	14,080
AUSTRIA	4,704	461	590	731	735	852	936	1,070	1,240	1,620	1,450

* Value estimated using figures of annual shipment given by ITMF.

SOURCE: ITMF (various years).

are relatively open to international competition in the textile machinery industry.

Data in Table 2 show that during the period 1976-1985 the hedonic prices of shuttle-less looms measured as a ratio of market price and working speed [15] decreased dramatically compared to those of shuttle looms. In 1985 by all standards, traditional looms were no longer competitive on the market.

3.2. *The test and the results.* – The econometric test of equation (7) should provide an estimate of the diffusion of shuttle-less looms as the result of an adoption process which is governed *jointly by*: A) the *epidemic effect* brought on by *the time* which it takes for information about the absolute advantages of the new weaving equipment to spread among firms which are assumed to be heterogeneous with respect to their ability to search for and process relevant information about new technological opportunities; B) the *supply forces* brought on by the evolution of prices and the performance of the innovated capital good with respect to the traditional one.

According to the specification of the model and the working hypotheses, we expect that the decline of hedonic prices will enhance the overall rates of diffusion encouraging adoption by potential customers who were, at the same time, made aware of the innovative processes by epidemic contacts with the new opportunities.

We expect the decline of hedonic prices to encourage adoption by potential customers especially in countries with high levels of structural heterogeneity stemming from the size of plants and firms, the vintage of existing capital stock, differences in production costs and competitive advantage. More specifically in fact we expect that in these countries firms with lower production costs, higher competitive advantage and younger vintage of capital stock will be more sensitive to the decline of hedonic prices. The fall in relative hedonic prices instead should have only limited effects in countries characterized by low levels of structural heterogeneity. In these countries in fact diffusion should be explained by cognitive heterogeneity alone.

Data collected for 9 countries were tested in equation (7.1):

$$(7.1) \qquad \log \frac{Y_{(t)}}{N - Y_{(t)}} = a + b_1 \log TIME + b_2 \log PRICE$$

$t = 1976, 1985$

[15] Shuttle-less looms have the same potential service-life as shuttle looms, i.e. an average of 15 years.

TABLE 2

EVOLUTION OF HEDONIC PRICES OF SHUTTLE-LESS LOOMS AND SHUTTLE LOOMS

Year	Price (*) / Working speed (**) of shuttle looms	Ratio of Price/Working speed of shuttle looms	Price (*) / Working speed (**) of shuttle-less looms	Ratio of Price/Working speed of shuttle-less looms	Relative profitability	Index number
1976	25,000/200 =	125	24,000/260 =	92.3	1 − 0.73 = 0.27	100
1977	30,000/210 =	142.8	30,000/275 =	109.1	1 − 0.76 = 0.24	90
1978	36,000/220 =	163.6	36,000/280 =	128.6	1 − 0.78 = 0.22	80
1979	35,000/220 =	159.1	38,000/300 =	126.6	1 − 0.79 = 0.21	78
1980	33,000/230 =	143.5	38,000/350 =	108.6	1 − 0.76 = 0.24	90
1981	34,000/240 =	141.6	40,000/385 =	103.9	1 − 0.73 = 0.27	100
1982	37,000/240 =	154.1	40,000/385 =	103.6	1 − 0.70 = 0.30	110
1983	37,000/240 =	154.1	44,000/440 =	100.0	1 − 0.65 = 0.35	130
1984	39,000/250 =	156.0	44,000/450 =	97.7	1 − 0.62 = 0.38	140
1985	40,000/255 =	156.9	45,000/470 =	95.7	1 − 0.61 = 0.39	145

SOURCE: The relative price is calculated as the complement to 1 of the share of the ratio price-working speed of shuttle-less looms with respect to the ratio price-working speed of shuttle looms:

$$\text{Relative price}_{(t)} = 1 - \frac{\dfrac{Price_{(t)}}{Working\ speed_{(t)}}\ \text{(shuttle-less loom)}}{\dfrac{Price_{(t)}}{Working\ speed_{(t)}}\ \text{(shuttle loom)}} \qquad t = 1976,\ 1985$$

(**) in knots per minute.

(*) in thousands of Italian lire.

where over a 10 year period: Y, the adoption level, is measured by the cumulative number of shuttle-less looms installed in each country at the year t; N is set equal to the total number of shuttle looms installed in each country in 1976; *PRICE*, the relative profitability, is measured by the index calculated in Table 2; *TIME*, the epidemic factor, is measured from 1976 which was the first year when observations were made of the diffusion process.

GLS and Ridge estimates of equation (7.1) have been made because of the unequal distribution of the error term over time detected by high levels of first order autocorrelation of residuals revealed by D.W. tests. The stability of the results of GLS estimates and RIDGE regressors (data of Table 3 are given with $k = 0.250$) confirms that the estimates shown are statistically reliable. The results of the estimates summarised in Table 3 provide a reliable account of the diffusion process of shuttle-less looms in the eight countries considered and show that in all countries the evolution of hedonic prices exerts a strong and significant influence on the rate of diffusion. The total variance explained is very high as is also the significance level of all the parameters.

As expected, in all countries the evolution of hedonic prices significantly enhanced the pace of the diffusion process which was fueled by the epidemic engine. *PRICE*, the proxy for *supply forces*, appears to be especially strong with respect to the *imitation effect* in Japan, Belgium and Italy where its parameter is three times larger than the one for time while it is quite weak in France. In the U.S.A., West Germany, Switzerland the supply effect appears to be as influential in the adoption process as imitation.

It is not casual that the decline of hedonic prices of innovated machines had significant effects in countries, such as Japan, Italy and Belgium characterised by a dualistic industrial structure of the cotton weaving industry. In these countries together with a few large firms which were presumably early adopters, the bulk of the industrial structure is made up of relatively homogeneous small firms. Structural heterogeneity is thus much more important than cognitive.

In order to value the comparison between the results of our mixed model and the standard epidemic model, the data in Table 2 tested the traditional log logistic equation (8):

$$\log \frac{Y_{(t)}}{N - Y_{(t)}} = a + b_1 \log TIME \qquad (8)$$

$t = 1976, 1985$

TABLE 3

RESULTS OF GLS AND RIDGE ESTIMATES OF EQUATION (7.1)

	GLS ESTIMATES						RIDGE ESTIMATES				
	a	b_1	b_2	R^2_A	F	$D\,W.$	a	b_1	b_2	SSE	MSE
U.S.A.	− 2.769	0.496	0.420	0.938	61.54	1.971	− 2.600	0.388	0.487	0.171	0.021
	(27.91)	(8.20)	(2.07)								
JAPAN	− 3.586	0.288	0.964	0.975	139.87	2.228	− 3.516	0.243	0.828	0.049	0.007
	(72.31)	(9.49)	(8.52)								
SWITZERLAND	− 2.994	0.370	0.457	0.899	35.77	1.264	− 2.874	0.294	0.472	0.159	0.019
	(28.79)	(5.84)	(2.15)								
BELGIUM	− 4.218	1.139	3.100	0.821	18.45	2.512	− 3.913	0.957	2.735	4.292	0.536
	(7.37)	(3.26)	(2.65)								
FRANCE	− 2.972	0.717	0.281	0.969	125.32	0.849	− 2.716	0.552	0.457	0.220	0.027
	(31.96)	(12.65)	(1.48)								
W. GERMANY	− 4.052	1.145	1.012	0.963	106.96	1.613	− 3.664	0.898	1.156	0.653	0.081
	(23.17)	(10.74)	(2.83)								
ITALY	− 2.951	0.590	1.140	0.976	166.03	1.712	− 2.776	0.481	1.065	0.173	0.021
	(34.00)	(11.15)	(6.43)								
AUSTRIA	− 2.509	0.526	0.798	0.954	84.81	2.355	− 2.343	0.423	0.784	0.184	0.023
	(24.86)	(8.56)	(3.88)								

Values of D.W. estimates refer to OLS estimates, t statistics in parentheses.

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TABLE 4

GLS ESTIMATES OF THE TRADITIONAL LOGISTIC MODEL

	a	b_1	R^2	F	$D.W.$
U.S.A.	− 2.867	0.561	0.906	86.88	1.373
	(27.20)	(9.32)			
JAPAN	− 3.745	0.397	0.722	20.80	0.526
	(25.86)	(4.56)			
SWITZERLAND	− 3.089	0.442	0.841	47.65	0.976
	(27.69)	(6.90)			
BELGIUM	− 4.862	1.624	0.665	17.87	1.529
	(7.26)	(4.23)			
FRANCE	− 3.031	0.761	0.960	219.31	0.777
	(33.82)	(14.81)			
W. GERMANY	− 4.262	1.303	0.927	115.55	0.953
	(20.17)	(10.75)			
ITALY	− 3.189	0.769	0.854	52.95	0.619
	(17.31)	(7.28)			
AUSTRIA	− 2.675	0.651	0.870	60.46	1.028
	(18.31)	(7.78)			

Values of D.W. refer to OLS estimates, t statistics in parentheses.

where all the variables are defined as in equation (7.1). Results are also given in Table 4.

The comparison makes it possible to focus attention upon the relationship between the parameter of the epidemic factor *TIME* estimated separately and its performance when estimated together with *PRICE*. It seems clear that the addition of *PRICE* provides better estimates of the global diffusion process. Moreover, it also seems clear that the parameter of *TIME* estimates the rate of the global process of diffusion rather than the rate of the epidemic effect. Estimates of equation (7.1) exhibit parameters for *TIME* which differ significantly from the estimates given by equation (8). In this respect equation (7.1) seems to provide a more accurate and specific estimate of the *epidemic effect*. In fact, the inclusion of the *supply effect* expressed by *PRICE*, actually increases it.

4. *Conclusions*

The traditional versions of the epidemic approach to the economic

analysis of the diffusion of new capital goods incorporating technological innovations narrowed the dynamic character of the adoption process to the spreading of information concerning the advantages of the innovation from early adopters to potential ones, i.e. among potential customers who were assumed to be heterogeneous in cognitive terms.

The new wave of equilibrium models has widened the scope of the analysis of the dynamic forces which generate the diffusion and has highlighted the role played by supply forces, the market behavior of firms supplying innovated capital goods including the introduction of incremental innovations and the changing profitability of adoption for potential customers who are assumed to be structurally heterogeneous. In doing so however the equilibrium approach has stressed the rational behavior of potential adopters and the attributes of unlimited knowledge and full rationality which seem difficult to accept in conditions where technology is changing rapidly and consequently the choice set of customers is incomplete and customers are structurally and cognitively different [16]. It seems to us that potential customers of innovated capital goods instead are characterised by limited knowledge and that their economic decision making is affected by bounded rationality. Collective learning in such conditions is a major source of information and therefore imitation remains the major engine of diffusion.

The epidemic approach is consistent with the recognition of these behavioral assumptions which are essential to understand the dynamics of diffusion. Consequently, it seems necessary to implement the epidemic approach, rather than disregard it, making adequate allowance for the role of the changing profitability of adoption.

The mixed model proposed in this paper seems to be able to take into account both the role of imitation and that of supply forces. As the results of the econometric estimates confirm, in the case considered, the sharp decline of the hedonic prices of shuttle-less looms in the late seventies clearly forced a number of informed potential customers to adopt the innovated capital good in a number of countries, characterized by the structural heterogeneity of potential adopters [17].

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[16] As Nelson and Winter note: "It is time consuming and costly for a firm to learn about and learn to use technology significantly different from that which is familiar. Further, firms will differ in their awareness, competence, and judgements in choosing to adopt or not to adopt new techniques" NELSON-WINTER (1982, p. 237).

[17] More generally the evolution of hedonic prices seems to be the most relevant aspect of supply forces in the case of the diffusion of a well established innovation such as shuttle-less looms. Technological expectations engendered by the continuous introduction of incremental

In conclusion, the diffusion of process innovations seems to be the result of two distinct forces: *the epidemic process of imitation* which accounts for the process by which potential customers search for information and become aware of the new capital goods available on the market and the *supply effect* by which heterogeneous customers, depending on the actual level of relative profitability of adoption at any time, decide whether to adopt a new process after considering their specific cost conditions.

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PROFITTO E IMITAZIONE NELLA DIFFUSIONE DELLE INNOVAZIONI DI PROCESSO

I recenti sviluppi della microeconomia "comportamentista" suggeriscono di apprezzare le ipotesi di razionalità limitata e apprendimento costruite nell'approccio epidemico all'analisi della diffusione delle innovazioni di processo, senza tuttavia trascurare gli effetti della dinamica dei fattori di offerta come l'evoluzione dei prezzi e delle prestazioni del macchinario in cui è incorporata l'innovazione tecnologica, valorizzati dai modelli di equilibrio.

A partire da queste ipotesi è stato elaborato un modello misto di diffusione delle innovazioni in cui la crescita nel tempo dello stock di macchinario innovato è contemporaneamente influenzata dall'imitazione espressa dal livello delle adozioni, come nei modelli epidemici, e dalla profittabilità di adozione, espressa dal livello dei prezzi edonici del macchinario innovato, come nei modelli di equilibrio.

La verifica empirica nel caso della diffusione internazionale di una significativa innovazione di processo introdotta nell'industria cotoniera nel periodo 1976-1985 come i telai senza navetta conferma la rilevanza di entrambi i fattori e la valenza esplicativa del modello misto proposto.

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DUALISM, TRADE THEORY, AND THE INTERPRETATION OF INDUSTRIAL STRUCTURE

by
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I.

The selection of appropriate policies for economic growth in the American South has been a source of much discussion. The issue often depends upon the interpretation of industrial development as the modern period is entered, that is, during the quarter century after World War II. The South as a whole has long been viewed as relatively more labor abundant than the rest of the nation. According to the Heckscher-Ohlin (H-O) Theorem, then, one would expect specialization in those industries which are relatively labor-intensive.

There is a body of evidence, however, that questions such Southern specialization. Some of the South's industrial development since the Civil War and more recently has been in capital-intensive, high-wage sectors. Various explanations have been offered for this. Economic activity following the Civil War was subject to a great deal of external manipulation, and some areas even exhibit the classic dual economy, with a labor-intensive sector coexisting with a highly capital-intensive sector. In a sense, then, the region may be characterized as being haunted by the ghost of exploitation and manipulation. If one accepts the presumption that the region's industrial

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structure is the result of "unnatural" distortions, then policy prescriptions for economic development will call for not only the continuing elimination of the distortions themselves but the promotion by government of labor-intensive industries as well.

It is, however, possible that the region's unbalanced industrial structure would have evolved anyway in the absence of the distortions, in that the natural (i.e., neoclassical) market forces would have by themselves produced the region's pattern of development. If such is the case, policies designed to undo the distorted structure may not be productive, since they will be attempting to overcome not only the distortions but much more powerful underlying forces as well. This present paper reexamines the South's post-World War II industrial concentration in light of some extensions of the H-O model (assuming that a pattern of specialization is indicative of a trade pattern).

We find that the observed patterns of industrial concentration are usually consistent with relative factor endowments. This interpretation requires that natural resources be taken into account along with the mobility and trade dependency of the capital stock. That is, capital is treated as a mobile resource that responds to differences in factor-price ratios (e.g., local real wage divided by national real interest rate) which in turn reflect the underlying basis for trade. (The failure of trade, and of factor migration, to produce factor-price equalization is noted and is attributed to aggregation errors, factor market distortions, adjustment lags, and failures of production conditions to adhere to incomplete specialization and neoclassical factor substitution).

Specifically, this study investigates the degree of spatial concentration of manufacturing activity within the Southern states and the factor intensities of those industries, and tests the structure and changes in structure for conformity to spatial patterns predicted by the H-O theory of interregional trade. No attempt is made to verify H-O in comparison with any other theory (dual economy, Ricardian, specific factor, location, unequal exchange, and so on). The study simply examines whether there is to be a presumption that the Southern industrial structure is a distorted contrivance by special interests.

Cross-sectional measures of spatial concentration are developed from the *Census of Manufactures* data in the form of adjusted location quotients and distributions of manufacturing value-added for the South Atlantic, East South Central and West South Central regions and their component states. In addition, the operationalization of various concepts of factor intensity, including natural resource intensiveness, is developed. These measures of

factor-intensity include capital-labor ratios, value-added per employee, human capital per production worker, and cost-of-materials per employee.

The concentration measures and factor-intensity measures are tested using simple correlation analysis for conformity to the prediction that the individual census regions and states of the South tend to be specialized in those industry groups which employ relatively labor-intensive methods of production. In addition, the change in the structure of each region and state is tested for conformity to the theory.

The results of the analysis indicate that not every region and state have industrial structures which conform to this simple hypothesis. As the degree of spatial delineation becomes finer, differences emerge in the power of the Heckscher-Ohlin theory to explain the structure of Southern manufacturing and to predict changes in that structure. The inclusion of natural resources into the analysis suggests that those capital-intensive industries heavily concentrated in the South are also natural-resource-intensive.

II.

A well known study that illustrates the large literature examining the applicability of H-O in explaining the pattern of industrial activity in the South was by Moroney and Walker (1966). Employing a two-factor model, they examined the relation between location quotients and capital-labor ratios. The structure of Southern manufacturing was found not to conform to labor-intensive lines; however, changes in the structure evolved along labor-intensive lines. (Lewis' (1971) results were mixed but generally in support of Moroney and Walker's results. McFadyen (1973, 1974) found that some areas of the South had manufacturing structures drawn along H-O lines, while other Southern subregions failed to exhibit this. Klassen (1973), Moroney (1967, 1970), and Moroney and Toeves (1977) have presented results indicating both a strong natural resource and labor orientation in the structure of Southern manufacturing industry).

A region's industrial activity tends to be concentrated in those lines which make intensive use of the relatively abundant immobile [1] factors of production, provided that:

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[1] Immobility of a primary resource means that transport costs approach infinity. Partial immobility means that transport costs may induce movement of other resources (primary or intermediate) to the site of the resource in question (primary or intermediate). The number of immobile resources is clearly dependent on the time horizon.

(*a*) it is possible to classify the production of different commodities as being intensive in certain factors;

(*b*) unit costs are not subject to external economies of scale;

(*c*) the same technology is available in all regions under consideration;

(*d*) a high degree of competition exists in all aspects of interregional commerce; and

(*e*) structural barriers to full employment are not significant.

(Specifying factors of production as interregionally immobile obviously requires caution since there exist many degrees of mobility, and differences in factor endowments generate factor migration as well as trade).

Moroney and Walker interpreted the relative cheapness of Southern labor to imply relative abundance and derived two hypotheses to be tested with *Census of Manufactures* data for 1949 and 1957 [2]:

1. Industries having relatively high capital-labor ratios are less concentrated in the South than are industries having relatively low capital-labor ratios.

2. Recent industrial development in the South has been concentrated in relatively labor-intensive industries.

The first hypothesis failed to be verified for either 1949 or 1957; the second, as tested for the interval 1949-1957, was substantiated [3].

Some dual-economy growth models provide the basis for an alternative theoretical interpretation of the relationship between factor endowments and geographic specialization. The implied hypothesis about the capital intensity of industrial activity is identical to the Moroney-Walker findings, if the dual-economy region (or nation) tends toward a bias in exports toward primary and unfinished secondary products and has a capital-intensive, apparently fixed-coefficient, foreign-owned export sector which exists side by side with a labor-intensive subsistence sector. The trade may be characterized by complete specialization (no import-competing industries) and hence an absence of international factor-price-equalization. (This state of affairs may be a direct outgrowth of the historical mobility of capital between

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[2] MORONEY and WALKER (1966, pp. 580-81, 584). When the location coefficient is greater than 1, the concentration of an industry is greater than the national average for the industry in question. (Capital, an abstract fund of resources which can be released from present consumption, is measured here as material capital which exists in connection with specific lines of activity).

[3] MORONEY (1967, 1970) improved the results by extending the number of factors of production. Concerning the integration of transport costs with the factor endowments analysis, see JOHNSON'S (1981) monograph and its bibliography.

capital-rich and labor-rich (and/or natural-resource-rich) economic systems) [4].

In short, insofar as the evolution of the Southern economic structure in the pre-World War II years corresponds to such dual-economy assumptions, the Moroney-Walker findings are, in fact, theoretically derivable hypotheses. Dual-economy models often contain an explicit natural resource factor of production and posit as an assumption the capital-mobility associated with the exploitation of this natural resource, and these models provide a way to explain the factor-intensity paradox.

Such a factor-intensity paradox may be a failure of H-O assumptions, but not necessarily. A many-product, many-factor H-O situation may involve an export that uses a scarce factor intensively (Vanek, 1968), and a labor-rich economy may be labor poor in terms of the specific human capital required for a specific industry (Gift and Marxsen, 1984). These extensions of H-O weaken the factor-intensity hypothesis, but improve its explanatory power. Patterns of specialization in post-World War II Southern manufacturing illustrate this.

III.

The analysis requires employment data for a specified date collected for a specific commodity group, in our case, for the years 1958 and 1967 by two-digit SIC, on the regional and national level. Adopting as notation,

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[4] A dual economy of the type that is germane to this paper often emerges whenever foreign (extraregional) capital is used to develop an export sector in a primary or unfinished-secondary product in a society that is organized around traditional agriculture. If the industry so developed is of an extractive nature or involves chemical distillation, then this sector will be much more capital-intensive than the subsistence sector. In any case, the pattern of reinvestment of savings is such that prosperity in the export sector does not lead to substantial development of other industry lines within the local economy. Furthermore, there is a weakness of both forward and backward linkage effects, since the development of the export sector is characteristically such that the final products are manufactured outside the local economy and the industry's fixed equipment is imported. The local economy is deprived of any large accelerator effects from new investment in the export sector, and, in the case of a highly capital-intensive export, receives no large injections into the income stream to generate multiplier effects.

There is sometimes a tendency for the tertiary sector to be suppressed, except whenever its development pertains directly to the needs of the export sector, as is the case, for example, with transportation facilities connecting mines and plantations with seaports. This infrastructure suppression, which is a cleavage between the export and subsistence sectors, further weakens multiplier effects.

X_{ij} = the number of ith regional employees in the jth industry,
X_i = total regional employment where $X_{ij} \leq X_i$ due to inclusion of all nonagricultural employment,
N_j = total national employment in j^{th} industry,
N = total national nonagricultural employment,
the location quotient is then defined as

$$Q_{ij} = \frac{X_{ij}}{X_i} \cdot \frac{N}{N_j}$$

It is assumed that if X_{ij}/X_i is greater than N_j/N, then the ith region is relatively specialized in the jth industry, implying net exportation of the commodity. Further, if X_{ij}/X_i is less than N_j/N, then the ith region is a net importer of the commodity group. And further, if X_{ij}/X_i is equal to N_j/N, then the region is self-sufficient. Thus, the location quotient can range between zero to infinity.

The location quotient outlined above can be criticized on several points. First, productivity differences are assumed away; and secondly, differences in consumer preferences and incomes are ignored. Both are warranted, but this does not destroy the usefulness of the location quotient as a first measure of relative specialization.

To adjust for possible differences in regional productivities, the above location quotient can be further refined. Basically, this is a problem of weighting the above quotients by a value-added (or another indicator of productivity) index.

We define:
V_{ij} = the value-added per employee in the ith region and j^{th} industry.
V_j = the national value-added per worker in the jth industry.
Then the adjusted location quotient is defined as

$$\frac{\frac{X_{ij}}{X_i}}{\frac{N_j}{N}} \cdot \frac{V_{ij}}{V_j}$$

Thus, a greater than national value-added per worker increases the location quotient while a lower than national value-added per worker lowers the location quotient, removing the effects of any existing productivity differences as reflected by the value-added index. Relative to the nation, all three southern regions are classified as labor-abundant; relative to the South,

the West South Central region is considered as capital-abundant. Thus:

Null Hypothesis I. There exists no linear relation between the location quotients and the various measures of factor intensities.

Alternative Hypothesis I. There exists a linear relation between the location quotients and the various measures of factor intensities.

$$HI_1 : r = 0; \qquad HI_2 : r \neq 0.$$

Null Hypothesis II. There exists no linear relation between the 1958-67 percentage changes in location quotients and the various measures of factor intensities.

Alternative Hypothesis II. There exists a linear relation between the 1958-67 percentage changes in location quotients and the various measures of factor intensities.

$$HII_1 : r = 0; \qquad HII_2 : r \neq 0.$$

Null Hypothesis III. There exists no linear relation between the distribution of manufacturing value-added and the various measures of factor intensities.

Alternative Hypothesis III. There exists a linear relation between the distribution of manufacturing value-added and the various measures of factor intensities.

$$HIII_1 : r = 0; \qquad HIII_2 : r \neq 0.$$

The simple correlation coefficient, ρ, is estimated by means of simple linear regression of the constructed location quotients and each of the measures of factor intensity. In addition, the correlation coefficients between the various factor intensity measures will be reported.

The rejection of the null hypothesis in favor of the alternative hypothesis is an α error (type I error) which is minimized by setting the level of significance at $\alpha = .10$. Appropriate 't' values for this level vary as to observation size.

The following results are reported on two levels of aggregation by spatial regions consisting of the three southern census regions and the sixteen individual states.

The following measures were used to measure the industrial factor intensities:

1. Regional capital-labor estimates for each of two-digit SIC's.
2. Regional fixed-capital-labor ratios.

3. State capital-labor ratios from the regional estimates (1) and (2) above.

4. National capital-labor ratios (and fixed-capital-labor ratios).

In addition to the above four measures, each of which represents (assuming full capacity) the number of dollars of capital per worker required to produce a unit of product, the following measures were used to obtain an insight into "factor intensity":

5. Value-added per worker; this represents the dollars of value-added produced by one employee.

6. Average human capital per production worker estimates which are adjusted for sex, race, and "quality" of nonwhite education.

7. Skill indexes by two-digit SIC.

8. Quasi-rents-payroll ratios.

9. Cost of materials per employee.

The calculations are found in Tables 1 through 4.

High and significant correlation between national and regional capital-labor and fixed-capital-labor ratios and the 1958 industry location quotients was found where industrial structure was dominated by SIC categories 28 (chemicals), 30 (rubber and plastics), 33 (primary metals), and 37 (transportation equipment) in the case of Maryland; SIC 28 (chemicals) and 33 (primary metals) in the case of West Virginia; SIC 26 (paper and allied products), 28 (chemicals), 29 (petroleum) in the case of Louisiana; and SIC 28 (chemicals), 29 (petroleum) and 34 (fabricated metals) in the case of Texas. The coefficients are positive, thus superficially contrary to H-O; but they are positive precisely in those cases where new industrial development along the lines of labor intensive processes was most prevalent. Furthermore, it is in these same cases that changes in concentration have coincided with real capital intensity following human capital.

It is apparent that although natural resources have played a major role in attracting manufacturing, not every region of the South has an industrial structure in which natural-resource-intensive industries are highly concentrated. Whereas the West South Central region does show a positive and strong correlation between materials costs and the location quotients, the correlations between these variables for the South Atlantic and East South Central regions show an opposite relationship. That is, while the most heavily concentrated industries in the West South Central region (chemicals, petroleum, stone and clay, and paper) do tend to be resource-intensive and capital-intensive, the remaining two subregions of the South show a negative relationship between the cost of materials measure and the location quotients. The development of the South has followed diversified lines, and

conclusions drawn from aggregative analysis do not necessarily apply to the subregions. Analysis on the basis of multicounty districts within states would show still more diversity.

It is only when the development of the South Atlantic and East South Central regions over the 1958-1967 period is examined that natural resources appear to exert an influence on their industrial structures. While the correlations between the percentage changes in the locations quotients and cost of materials are not strong, they are positive. In the West South Central region, the industries with the largest percentage declines in location quotients tended to be those with low ratios of materials costs to labor costs.

It is possible that, in the case of the West South Central region, the paradoxical high and positive correlations between the capital-labor ratios and the location quotients reflect the attraction of natural resources, since resource oriented industries tend to require large investments in capital equipment. The strong and positive correlations between the capital-labor ratios and cost of materials to payroll ratios support this explanation.

When the South Atlantic region's structure is examined in this light, it is found that those industries which have had relatively large percentage increases (or small percentage declines) in their location quotients are relatively low in materials intensity, as indicated by the negative and significant correlation coefficient. That is, relatively labor-intensive SIC groups have shown the largest percentage increases in location quotients. The East South Central region yields results similar to those of the South Atlantic, in that the H-O predictions are born out by the negative and significant correlations between the location quotients and the capital-labor ratios.

The negative correlations between the location quotients and the cost of materials, together with the strong positive correlation between capital intensity and resource intensity, show the strong influence of natural resources in certain parts of the South. These results are consistent with the hypothesis that the patterns of specialization in post-World War II Southern manufacturing were determined primarily by factor supply conditions. An appropriate response to the vagueness of the results may be to attribute them to imperfectly stated concepts of factor endowment and unproven assumptions about relative factor endowments.

Clearly, less developed areas, richly endowed with natural resources, may exhibit development paths along capital-intensive lines rather than labor-intensive or human-capital intensive lines. It follows that a few capital-intensive sectors characterized by small labor requirements could persist even with low wage rates and high unemployment.

Such tendencies are evident in the application of a five-factor model, constructed as follows.

Notation

Q = output
K = nonhuman capital
H = human capital
L = labor
M = materials
E = energy

Production Function

$$Q_i^s = f_i(K, H, L, M, E) \qquad i = \text{SIC}_{20\text{-}39}$$

$$Q_i^n = g_i(K, H, L, M, E) \qquad s = \text{southern region}$$

$$\sum_{i=20}^{39} Q_i^s = Q_*^s; \quad \sum_{i=20}^{39} Q_i^n = Q_*^n \qquad n = \text{nonsouthern region}$$

Factor Endowments:

$$\sum_{i=20}^{39} K_i^s = K_*^s; \quad \sum_{i=20}^{39} K_i^n = K_*^n$$

$$\sum_{i=20}^{39} H_i^s = H_*^s; \quad \sum_{i=20}^{39} H_i^n = H_*^n$$

$$\sum_{i=20}^{39} L_i^s = L_*^s; \quad \sum_{i=20}^{39} L_i^n = L_*^n$$

$$\sum_{i=20}^{39} M_i^s = M_*^s; \quad \sum_{i=20}^{39} M_i^n = M_*^n$$

$$\sum_{i=20}^{39} E_i^s = E_*^s; \quad \sum_{i=20}^{39} E_i^n = E_*^n$$

Assumptions on Relative Factor Endowments

1. $K^s_*/L^s_* >/< K^n_*/L^n_*$

2. $H^s_*/L^s_* >/< H^n_*/L^n_*$

3. $M^s_*/L^s_* >/< M^n_*/L^n_*$

4. $E^s_*/L^s_* >/< E^n_*/L^n_*$

Equations Fitted

I. $LQ = \alpha + \beta_1 (KL) + \beta_2 (HCL) + \beta_3 (MCL) + \beta_4 (ECL) + \mu_1$

II. $LQ = \alpha^* + \beta^*_1 (KL) + \beta^*_2 (HCL) + \beta^*_3 (MCL) + \mu_2$

Variables

LQ = Location quotients
KL = Quasi-rent/wage-bill
HCL = Payroll less wages/wage-bill
MCL = Cost of materials/wage-bill
ECL = Energy costs/wage-bill

The estimated coefficients for the aggregated five-factor model indicate that capital intensity was positively related to the level of industrial concentration, which is at variance with the expectation of a negative influence. The South appears to show a 1972 industrial structure drawn along capital-intensive lines. (See Tables 5, 6 and 7). The coefficient for the human capital variable has the expected negative sign, indicating concentration in those industries employing relatively low levels of human capital. Neither the materials cost index nor the energy cost index appears statistically significant, and we may not reject the hypothesis that these coefficients are statistically different from zero.

The same pattern is obtained in the estimated coefficients for both the South Atlantic and East South Central regions. Both show a significant positive association of capital intensity and concentration. In addition, both subregions reveal negative associations of concentration and human capital

TABLE 1

LOCATION AND CAPITAL INTENSITY: SIMPLE CORRELATION COEFFICIENTS, UNITED STATES USED AS COMPARISON BASE [1]

Region	Hypothesized Relationship	1958 Location Quotient and Regional Capital-Labor Ratio	1958 Location Quotient and Regional Fixed-Capital-Labor Ratio	1958 Location Quotient and Value-Added Per Employee	1958 Location Quotient and National Capital-Labor Ratio
South Atlantic	(–)	.155	–.136	.339	.169
East South Central	(–)	.139	–.178	.432 ***	.126
West South Central	(–)	.897 ****	.945 ***	.414 *	.854 ****
Region	Hypothesized Relationship	1958 Location Quotient and National Fixed-Capital-Labor Ratio	Percent Change in Location Quotient and Regional Capital-Labor Ratio		Percent Change in Location Quotient and Regional Fixed Capital-Labor Ratio
South Atlantic	(–)	–.142	–.287		–.240
East South Central	(–)	–.188	–.021		.064
West South Central	(–)	–.967 ****	–.142		–.159
Region	Hypothesized Relationship	Percent Change in Location Quotient and Value-Added Per Employee	Percent Change in Location Quotient and National Capital-Labor Ratio		Percent Change in Location Quotient and National Fixed-Capital-Labor Ratio
South Atlantic	(–)	–.382 *	–.302		–.277
East South Central	(–)	–.251	–.010		.071
West South Central	(–)	–.214	–.124		–.139

**** Significant at .001 level; *** significant at .01 level; ** significant at .05 level; * significant at .1 level.

[1] A priori sign is determined by ranking the manufacturing wage rate within each region. Regions are evaluated relative to entire United States.

TABLE 2

LOCATION AND CAPITAL INTENSITY: SIMPLE CORRELATION COEFFICIENTS, SOUTHERN CENSUS-REGIONS AGGREGATE USED AS COMPARISON BASE [1]

1. (Region)	2	3	4	5	6	7	8	9	10	11	12	13
South Atlantic	(–)	–.168	–.164	–.282	–.037	–.376	–.395 *	–.427 *	.528 **	–.129	.069	–.162
East South Central	(–)	–.356	.344	–.247	–.321	.159	.159	–.097	.234	–.240	.253	–.162
West South Central	(+)	.958 ****	.948 ****	.403 *	–.089	–.146	–.173	.222	.403	.001	.671 ***	.502 *

1. (Region)	2	14	15	16	17	18	19	20	21	22	23
South Atlantic	(–)	–.176	–.116	–.350	–.186	–.140	–.389	.173	–.173	–.437 *	–.056
East South Central	(–)	–.184	–.407	–.583 **	–.449 *	–.111	–.005	.189	–.378	.194	–.192
West South Central	(+)	.503 *	.493 *	–.054	.245	203	–.134	.550 *	.714 ***	–.197	.863 ****

1: Region. – 2: Hypothesized Relationship. – 3: 1958 Location Quotient and Regional Capital-Labor Ratio – 4: 1958 Location Quotient and Regional Fixed-Capital-Labor Ratio. – 5: 1958 Location Quotient and Value-Added Per Employee. – 6: 1958 Location Quotient and Human Capital per Production Worker. – 7: Percent Change in Location Quotient and Regional Capital-Labor Ratio. – 8: Percent Change in Location Quotient and Regional Fixed-Capital-Labor Ratio. – 9: Percent Change in Location Quotient and Value-Added Per Employee. – 10: Percent Change in Location Quotient and Human Capital Per Production Worker. – 11: Distribution of Manufacturing Value-Added and Human Capital Per Production Worker. – 12: Distribution of Manufacturing Value Added and Value-Added Per Employee. – 13: Percent Change in Manufacturing Value-Added Distribution and Regional Capital-Labor Ratio. – 14: Percent Change in Manufacturing Value-Added Distribution and Regional Fixed-Capital-Labor Ratio. – 15: Percent Change in Manufacturing Value-Added and Human Capital Per Production Worker. – 16: 1958 Location Quotient and Skill Index. – 17: 1958 Location Quotient and Elasticity of Substitution – 18: 1958 Location Quotient and Quasi-Rent Payroll Ratio. – 19: Percent Change in Location Quotient and Quasi-Rent Payroll Ratio. – 20: Distribution of Manufacturing Value-Added and Quasi-Rent Payroll Ratio. – 21: 1958 Location Quotient and Cost of Materials Per Employee. – 22: Percent Change in Location Quotient and Cost of Materials. – 23: Distribution of Manufacturing Value-Added and Cost of Materials.

**** Significant at .001 level; *** significant at .01 level; ** significant at .05 level; * significant at .1 level.

[1] A priori sign is determined by ranking the manufacturing wage rate within each region. Regions are evaluated relative to the three Southern regions' average.

TABLE 3

LOCATION AND CAPITAL INTENSITY: SIMPLE CORRELATION COEFFICIENTS, SOUTHERN STATES[1]

1 (State)	2	3	4	5	6	7	8	9	10
Delaware	(+)	−.062	−.057	.012	.258	−.474 *	−.179	.427	−.580 **
Maryland	(+)	.476 **	.421 *	−.409	.521 **	−.207	−.113	.368	−.090
Virginia	(−)	.824 ***	−.022	−.195	.688 ***	−.251	−.367	.595	−.080
West Virginia	(+)	.392	.649 ***	−.264	.610 ***	−.338	−.270	.339	−.273
North Carolina	(−)	−.063	−.079	−.200	−.323	−.063	−.079	.125	−.009
South Carolina	(−)	.083	.027	−.043	−.151	−.318	.049	.055	−.217
Georgia	(−)	.213	.449 **	.846 ****	−.337	.161	.394 *	.822 ****	−.253
Florida	(−)	−.015	−.188	−.165	.352 *	−.327	−.201	.045	−.552 **
Kentucky	(+)	.851 ****	−.023	−.210	.633 ***	−.132	.022	.083	−.317
Tennessee	(−)	−.090	.098	−.058	−.044	−.491	−.231	.496 **	−.426 *
Alabama	(+)	−.120	−.109	−.510 **	.113	−.129	−.125	.130	−.111
Mississippi	(−)	−.251	−.111	−.547 **	−.320	.072	.000	.067	.087
Arkansas	(−)	.005	.027	−.231	−.166	−.410 *	−.435 *	.259	−.139
Louisiana	(+)	.864 ***	.849 ***	−.164	.275	−.152	−.165	.549	−.237
Oklahoma	(+)	.932 ****	.915 ****	−.253	.575 **	−.394	−.395	.121	−.418 *
Texas	(+)	.957 ****	.937 ****	−.251	.375	.216	.187	.240	−.113

1 (State)	2	11	12	13	14	15	16	17	18
Delaware	(+)	.056	−.095	−.061	.404	−.482 *	−.198	.436	−.541 **
Maryland	(+)	.565 **	.409 *	−.566 **	.555 *	−.070	−.089	.417 *	.171
Virginia	(−)	.514	.353	−.338	.519	−.202	−.198	.628	−.033
West Virginia	(+)	.318	.755 ****	−.195	.739 ****	.809 ****	.374	−.306	.079
North Carolina	(−)	.068	.005	−.165	−.183	−.030	−.144	.264	.142
South Carolina	(−)	.218	.166	−.013	−.025	.304	−.144	.137	−.158
Georgia	(−)	−.025	.053	.264	−.101	−.046	−.027	.071	.081
Florida	(−)	−.037	−.095	−.011	.518 **	−.270	−.092	.039	−.273
Kentucky	(+)	.503 **	.277	−.203	.698 ***	−.175	.054	.336	−.290
Tennessee	(−)	.176	.474 **	−.225	.294	−.409 *	−.182	.434 *	.198
Alabama	(+)	−.050	−.043	−.442 *	.209	−.035	−.051	.380	.036
Mississippi	(−)	.008	.100	−.459 *	−.117	.368	.051	.044	.597 ***
Arkansas	(−)	−.086	−.063	.031	.044	−.344	−.394	.231	−.077
Louisiana	(+)	.460	.465	−.121	.444	−.122	−.135	.546	−.198
Oklahoma	(+)	.414 *	.378	−.102	.303	−.213	−.235	.295	−.094
Texas	(+)	.480 **	.471 **	.008	.690 ***	.270	.232	.323	.033

1: State. – 2: Hypothesized Relationship. – 3: 1958 Location Quotient and Capital-Labor Ratio. – 4: 1958 Location Quotient and Fixed-Capital-Labor Ratio – 5: 1958 Location Quotient and Human Capital Per Production Worker. – 6: 1958 Location Quotient and Value Added Per Employee. – 7: Percent Change in Location Quotient and Capital-Labor Ratio. – 8: Percent Change in Location Quotient and Fixed-Capital-Labor Ratio. – 9: Percent Change in Location Quotient and Human Capital Per Production Worker. – 10: Percent Change Location Quotient and Value-Added Per Employee. – 11: Distribution of Manufacturing Value-Added and Capital-Labor Ratio. – 12: Distribution of Manufacturing Value-Added and Fixed-Capital-Labor Ratio – 13: Distribution of Manufacturing Value-Added and Human Capital Per Production Worker. – 14: Distribution of Manufacturing Value-Added and Value Added Per Employee. – 15: Percent Change in Manufacturing Value-Added and Capital-Labor Ratio. – 16: Percent Change in Manufacturing Value-Added Distribution and Fixed-Capital-Labor Ratio. – 17: Percent Change in Manufacturing Value-Added Distribution and Human Capital Per Production Worker. – 18: Percent Change in Manufacturing Value-Added Distribution and Value-Added Per Employee.

**** Significant at .001 level; *** significant at .01 level; ** significant at .05 level; * significant at .1 level.

[1] A priori sign is determined by ranking the manufacturing wage rate within each region. States are evaluated relative to the South's average.

TABLE 4

REGIONAL INDUSTRY LOCATION QUOTIENTS BY REGION AND 2 DIGIT SIC 1958 AND 1967

SIC	South Atlantic			East South Central			West South Central		
	Location Quotient		% Change	Location Quotient		% Change	Location Quotient		% Change
	1967	1958		1967	1958		1967	1958	
20 Food & Kindred Products	.77	.74	.04	1.01	.97	.03	.94	.26	2.54
21 Tobacco Manufacturers	5.02	5.33	−.06	3.46	3.55	−.02	.05	.08	−.38
22 Textile Mill Products	3.96	3.70	.07	1.13	1.47	−.23	.16	.24	−.32
23 Apparel & Related Products	1.06	.81	.31	1.88	1.21	.55	.60	.71	−.16
24 Lumber & Wood Products	1.00	1.03	−.02	1.85	1.52	.22	.98	1.48	−.34
25 Furniture & Fixtures	1.62	1.43	.14	1.58	1.10	.44	.61	1.00	−.39
26 Paper & Allied Products	1.11	1.05	.05	1.34	1.09	.23	.79	1.38	−.43
27 Printing & Publishing	.59	.56	.05	.55	.54	.02	.51	.87	−.41
28 Chemicals & Allied Products	1.15	1.16	−.01	1.74	1.48	.17	1.47	2.45	−.40
29 Petroleum & Coal Products	.23	.25	−.06	.51	.36	.40	5.17	7.70	−.33
30 Rubber & Plastics Products	.50	.34	.48	1.21	1.09	.11	.51	.70	−.27
31 Leather & Leather Products	.42	.30	.41	1.43	.99	.43	.36	.38	−.05
32 Stone, Clay, & Glass Products	.95	.84	.13	1.04	.93	.12	.89	1.54	−.42
33 Primary Metal Industries	.47	.57	−.17	1.06	1.15	−.08	.53	.80	−.34
34 Fabricated Metal Products	.42	.40	.05	.82	.71	.14	.62	.86	−.27
35 Machinery, except Electrical	.29	.22	.29	.61	.38	.58	.47	.84	−.44
36 Electrical Machinery	.49	.37	.32	.94	.80	.18	.38	.29	.29
37 Transportation Equipment	.52	.47	.11	.44	.37	.19	.68	1.01	−.32
38 Instruments & Related Products	.26	.12	1.20	.18	.15	.18	.33	.51	−.36
39 Miscellaneous Manufacturing	.42	.43	−.02	.73	.30	1.42	.31	.42	−.27

TABLE 5

FIVE-FACTOR MODEL, REGRESSION RESULTS

Coefficient	South		South Atlantic		East South Central		West South Central	
	A	B	A	B	A	B	A	B
β_1	.512	.508	.859	.531	.119	.528	.067	.123
	(3.9)	(4.1)	(3.9)	(2.52)	(4.53)	(4.60)	(.528)	(1.23)
β_2	−3.14	−3.14	−4.35	−4.30	−.629	−3.01	−1.069	−1.27
	(−3.80)	(−3.9)	(−3.60)	(−3.04)	(−4.76)	(−4.90)	(−1.63)	(−2.19)
β_3	−.043	−4.74	−.227	−.294	−.107	−.300	.844	.957
	(−.52)	(−.63)	(−1.2)	(−1.37)	(−2.47)	(−3.49)	(4.50)	(9.14)
β_4	−.014		−.595		−.114		−.111	
	(−.126)		(−2.6)		(−.573)		(.732)	
α	1.49	1.49	2.42	2.59	.286	1.64	.693	.689
	(3.80)	(3.90)	(3.40)	(3.17)	(5.65)	(5.9)	(2.84)	(2.877)
Adjusted R^2	.53	.56	.50	.32	.65	.66	.89	.87
F	6.49	9.2	5.87	4.03	9.90	13.66	30.05	41.16
n	20	20	20	20	20	20	19	19

Equation A: $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \mu_1$
Equation B: $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \mu_2$
X_1 := quasi-rent/wage-bill.
X_2 := payroll less wages/wage-bill.
X_3 := materials cost/wage-bill.
X_4 := energy cost/wage-bill.
Y = location quotient.

TABLE 6

FIVE-FACTOR MODEL, TEST OF COEFFICIENT EQUALITY, EQUATION A (CHOW TEST)

	S:SA	S:ESC	S:WSC	SA:ESC	SA:WSC	ESC:WSC
$\hat{\beta}_1^i : \hat{\beta}_1^j$	Reject Null	Reject Null	Reject Null	Reject Null	Reject Null	Reject Null
$\hat{\beta}_2^i : \hat{\beta}_2^j$	Do Not Reject Null	Reject Null	Reject Null	Reject Null	Reject Null	Do not Reject Null
$\hat{\beta}_3^i : \hat{\beta}_3^j$	Do Not Reject Null	Reject Null	Reject Null	Reject Null	Reject Null	Reject Null
$\hat{\beta}_4^i . \hat{\beta}_4^j$	Do Not Reject Null	Do Not Reject Null	Do Not Reject Null	Do Not Reject Null	Do Not Reject Null	Do Not Reject Null

Equation: $LQ = \alpha + \hat{\beta}_1(KL) + \hat{\beta}_2(HCL) + \hat{\beta}_3(MCL) + \hat{\beta}_4(ECL)$

TABLE 7

FIVE-FACTOR MODEL, TEST OF COEFFICIENT EQUALITY, EQUATION B (CHOW TEST)

	S:SA	S:ESC	S:WSC	SA:ESC	SA:WSC	ESC:WSC
$\hat{\beta}_1^i : \hat{\beta}_1^j$	Do Not Reject Null	Do Not Reject Null	Reject Null	Do Not Reject Null	Reject Null	Reject Null
$\hat{\beta}_2^i : \hat{\beta}_2^j$	Do Not Reject Null	Do Not Reject Null	Reject Null	Reject Null	Reject Null	Do Not Reject Null
$\hat{\beta}_3^i : \hat{\beta}_3^j$	Do Not Reject Null	Reject Null	Reject Null	Do Not Reject Null	Reject Null	Reject Null

Equation: $LQ = \alpha + \hat{\beta}_1(KL) + \hat{\beta}_2(HCL) + \hat{\beta}_3(MCL)$

SOURCES: U.S. Bureau of the Census, *U.S. Census of Manufacturing: 1958, Volume III Area Statistics* (Washington: U.S. Government Printing Office, 1961); U.S Bureau of the Census, *Census of Manufactures, 1967, Volume I, Summary and Subject Statistics* (Washington: U.S. Government Printing Office, 1971).



utilization. The materials and energy indices show a slight negative influence on location. In the case of the West South Central region, however, the materials-intensity measure exerts a positive influence.

IV.

The results here suggest that post-war Southern development was largely in keeping with the weak H-O predictions from the extended model. None of this, however, means that H-O tells the whole story. Valid historical examples abound of important imperfections in competition that clearly contradict the H-O assumptions. Numerous subsidies distort factor prices in any case. The point here is simply that the Southern pattern has probably been partly mindless and impersonal, and partly planned and contrived. Aggregative statistical analysis will not be of much help in telling what this balance has been in specific localities. But the distinction is important. Local development planning to undo economic imbalance will proceed very differently in each case. Did the "market" cause it, or did "carpet bagger politics" cause it? A dual-economy structure can be the outgrowth of any historical process that produces the coexistence of capital-intensive exports and labor-intensive subsistence farming in a country (region) that has at least the superficial appearance of being labor rich and capital poor.

The American South has been viewed as a labor-abundant region [5] whose best development strategies lie in the promotion of labor-intensive industries. Average wages are lower than elsewhere, and the ratio of capital to the number of workers overall in the South is lower than elsewhere. Thus, by either the price definition or the physical-factor definition, labor is abundant.

This suggests a number of effects with the existence of free interregional trade and factor mobility:

1. Average relative wages would tend to rise over time as free trade tended to equalize factor prices.
2. Labor would leave the South.
3. Investment would be attracted to the South, and to labor-intensive industries specifically.
4. The South would increase the degree of specialization in labor-intensive industries, and, so long as wages remained lower than elsewhere,

[5] For a clarification of the sense in which the South has been labor-rich or labor-poor, see WRIGHT (1986).

more labor-intensive production techniques would be employed in Southern plants than in the same industries elsewhere.

5. The South would be a net importer of capital-intensive goods and a net exporter of labor-intensive goods.

6. The role of economic policy would be to eliminate frictions which impeded the free flow of goods and factors.

7. If policies were employed to assist development, industrial-development incentives would focus on attracting labor-intensive industries, since these would be "with the wind".

Much economic planning in the South has been along lines consistent with these seven effects. In spite of this environment, many of the expected effects have failed to materialize. First, factor-price differentials have remained large. Second, the South has some of its highest concentrations (relative to the nation) of industries in those where wages are high and capital is used intensively.

Why is behavior so different from what was predicted? Results from the classic 2-by-2-by-2 model of factors and trade generally become much weaker when there are more dimensions, especially when there are more than two factors in production. Starting with Vanek's pioneering paper, there is now a substantial literature which shows the effects of a many-factor world on trade and specialization. The standard two-factor results are not guaranteed in an otherwise well behaved world when there are more than two factors. For instance, the relative shortage of an essential factor of production which is not generally transportable may force peculiar patterns of specialization, i.e., intensive use of a scarce factor. Furthermore, even if there are "adequate" quantities of all essential factors, complementarities in production may cause intensive employment of a relatively scarce factor. The South's apparent abundance of labor may come partly from the method of aggregation. This, along with the failure of average wage rates to equalize, could be the result of differences in the mix of labor types in the South and elsewhere.

Relative factor prices for large aggregates are not a satisfactory guide for local planning. Aggregation may even conceal crucial scarcities or missing factors when specific resources are included in the abstract aggregates of labor and capital, including the social overhead. The appropriateness of new industrial development is affected by the structure of employment which it provides, and communities differ greatly from one another as to their endowments of the various types of labor. Furthermore, industries are not equal in their negative externalities, which compounds the problem of matching industrial development with local resources.

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DUALISMO, TEORIA DELLO SCAMBIO E INTERPRETAZIONE DELLA STRUTTURA INDUSTRIALE

Questo articolo esamina lo sviluppo industriale degli stati meridionali degli U.S.A. alla luce del teorema Heckscher-Ohlin concentrando l'attenzione su un paradosso che riguarda l'intensità dei fattori. Si esaminano interpretazioni alternative del paradosso e ne vengono discussi gli aspetti istituzionali.

Il sud nel complesso è da tempo considerato piú ricco di lavoro del resto del

paese. Secondo il teorema di Heckscher-Ohlin ci dovremmo quindi attendere la specializzazione nelle industrie a maggiore intensità di lavoro. Vi è tuttavia un'ampia evidenza contraria. Parte dello sviluppo industriale del sud sin dai tempi della Guerra Civile e anche piú recentemente si è verificato in settori ad alta intensità di capitale e con elevati salari.

Questo fenomeno è stato spiegato in vari modi. In particolare, ponendo in rilievo che dopo la Guerra Civile l'attività economica è stata soggetta a molti interventi esterni. È tuttavia possibile che questa evoluzione della struttura industriale si sarebbe verificata anche in assenza di distorsioni, per effetto della concorrenza del mercato. Questo articolo riesamina la concentrazione industriale nel sud nel secondo dopoguerra alla luce di alcune estensioni del modello Heckscher-Ohlin. Si conclude che i comportamenti osservati nella concentrazione industriale sono generalmente considerati con le dotazioni relative dei fattori.

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THE EVALUATION OF THE U.S. MANUFACTURING SECTOR USING MULTIFACTOR INPUTS OF CAPITAL, LABOR, ENERGY AND REAL CASH BALANCES

by
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Introduction

From the standpoint of production and output, money or real cash balances and energy are essential inputs for firms. The idea of the inclusion of money into the production function has a well founded base. Specifically, Levhari and Patinkin (1968), Johnson (1969), Nadiri (1969) and Bailey (1971) have argued that money, in the form of real balances, should be included as an input factor in the production process. Similarly, Berndt and Wood (1975), Hudson and Jorgenson (1974), Griffin and Gregory (1976) and Nguyen and Andrews (1986) have argued that the inclusion of the energy input in the production function is valid. In particular, Jorgenson (1984) clearly develops the underlying reason for the inclusion of the energy input within the aggregate production function. In this study, he states that "the key to understanding the role of energy in advancing U.S. productivity is to analyze the growth of productivity in individual industrial sectors". Further, Moghimzadeh and Kymn (1986) followed the lead of Jorgenson and investigated the role of energy in the aggregate production function, by using a disaggregated energy component: an electric energy component and a non-electric energy component. Their interest focused on the estimated cost shares, and the own and cross-price elasticities of demand for the factors of production of manufacturing output.

From an empirical standpoint, testing the role of money or real cash balances in the production process has been undertaken in various studies.

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Nadiri (1969), Sinai and Stokes (1972), Khan and Kouri (1975), Prais (1975), Niccoli (1975) and Subrahmanyan (1980) addressed the issue of real cash balances within the Cobb-Douglas production framework. Later, Apostolakis (1983) and Kyer (1987) address the issue of real cash balances using the flexible translog production function form. This study differs from these cited in that our interest lies in the investigation and evaluation of the inclusion of the two factor inputs, energy and money or real cash balances in the U.S. Manufacturing sector. Specifically we are interested in the interaction that goes on between the factors of production of capital, labor, energy and money. This choice of factor inputs was largely influenced by the earlier work of Griffin and Gregory (1976) and Berndt and Wood (1975). In particular, Berndt and Wood (1975) empirically rejected the weak separability assumption for the materials input. In addition we have chosen to assume that the materials input is separable, given the evidence present in the literature, as well as that one can view the materials input as being an intermediate input, dependent upon the inclusion of real cash balances (or money) within the production process. Further, we have incorporated the test for constant returns to scale for the production function as well as the aggregate and individual tests for input separability.

The primary source of the data, regarding capital, energy and labor, used in this study was Nguyen and Andrews (1986). This database is composed of the Divisia aggregation of both the input quantities and their respective prices. Throughout this study references made to capital, labor and energy imply the respective Divisia quantity indexes of these inputs. The authors compiled the data regarding the money input from the Federal Trade Commission publication, *Quarterly Financial Report for Manufacturing, Mining and Trade*. In addition, the price or opportunity cost of money is defined as the nominal rate of interest on 4-6 month commercial paper. References made to money represent the Divisia quantity index of real cash balances in the U.S. Manufacturing sector.

The Model and Hypotheses

The objective of this paper is to investigate the possible validity of the inclusion of the inputs energy and money into the production function of the U.S. Manufacturing sector. Given that our production function is of the following form

$$Q = F(X_k, X_l, X_e, X_m, T) \tag{1}$$

where Q = gross manufacturing output, X_k = a capital input index,

X_l = a labor input index, X_e = an energy input index, X_m = a money input index, and T = a time index employed to measure technical change. We are assuming that the respective functional form of (1) to be the flexible translog specification. Further, considering that the factor inputs are aggregated using the Divisia indexing process, one cannot justify that the underlying production function exhibits constant returns to scale unless one empirically tests such an assumption. Therefore, we have decided to test the assumption of constant returns to scale, specifically by following the proposed methodology of Chan and Mountain (1983).

Using the translog approximation to the logarithm of Q results in (1) being written as

$$\ln Q = A_o + B_T{}^*T + \Sigma A_i \ln X_i + 1/2 \sum_i \sum_j A_{ij} \ln X_i \ln X_j + \\ + \sum_i t_{iT} \ln K_i T + 1/2\, t_{TT}{}^* T^2 \qquad (2)$$

where $A_{ij} = A_{ji}$ due to Young's theorem. Keeping in mind that we do *not* initially assume costant returns to scale implies that we are assuming that Q is homogenous of degree theta, θ, an unknown constant value. This implies that with respect to the parameters of (2) that $\sum_i A_i = \theta$, $\sum_i A_{ij} = 0$ for all j and $\sum_i t_{iT} = 0$. Thus (1) displays constant returns to scale when $\theta = 1$, if $\theta > 1$ increasing returns to scale and if $\theta < 1$ decreasing returns to scale. The modified first order conditions with respect to the production of Q at minimum cost and incorporating the effect of θ are

$$S_i = p_i X_i / \sum_i p_i X_i = F_i X_i / \sum_i F_i X_i = F_i X_i / \theta F = 1/\theta\, (\partial \ln Q / \partial \ln X_i) \qquad (3)$$

This implies directly that the factor share equations resulting from (2) can be written as

$$S_i = 1/\theta\, (A_i + \Sigma A_{ij} \ln X_i + t_{iT}{}^* T) \text{ for } i = k,\ l,\ e,\ m \qquad (4)$$

Letting $A_i^* = A_i/\theta$, $A_{ij}^* = A_{ij}/\theta$ and $t_{iT}^* = t_{iT}/\theta$ for all $i, j = k, l, e, m$, then (2) and (4) can be rewritten in the following form [1]

$$\ln Q = A_o + B_T{}^* T + 0\, (\sum_i A_i^* \ln X_i + 1/2 \sum_i \sum_j A_{ij}^* \ln X_i \ln X_j + \\ + \sum_i t_{iT}^* \ln X_i T) + 1/2\, t_{TT} T \qquad (5)$$

and

$$S_i = A_i^* + \Sigma A_{ij}^* \ln X_j + t_{iT}^* T \text{ for } i = k,\ l,\ e,\ m \qquad (6)$$

[1] For the full theoretical development, see CHAN and MOUNTAIN (1983).

Given the previously defined parameter restrictions with respect to the assumption of varying returns to scale, one of the derived cost share equations can be eliminated. In this study we have chosen to eliminate the share equation representing the labor input. Therefore, the model for estimation to test the assumption of constant returns to scale will consist of the system of equations composed of (5) and three of the four share equations of (6). The parameter estimates for the system were obtained by employing a nonlinear iterative procedure for Zellner's Seemingly Unrelated Estimation technique. All coefficient values reported where estimated using software which does not employ a maximum likelihood estimation procedure, but rather an objective function minimization procedure [2]. However, this does not limit one's capabilities to test the hypotheses of constant returns to scale, Hicks' neutrality, technical progress or local and global separability. Gallant and Jorgenson (1979) have shown that the objective function minimization procedure can yield a test statistic, T^0, which is an analog of the log-likelihood ratio test and is distributed asymptotically as a chi-square distribution with $(r\text{-}s)$ degrees of freedom [3]. To use this test statistic, at a given alpha level of significance, the null hypothesis, H_0, is rejected if the calculated T^0 test statistic exceeds the critical chi-square, X^2, with $(r\text{-}s)$ degrees of freedom. Therefore, given this criteria we will use the respective T^0 statistic to test the hypotheses of constant returns to scale, Hicks' neutrality, technical progress and local and global separability.

Empirical Results

The reported empirical estimates in Table 1 are the result of estimating (5) and three of the four share equations of (6). Model 1 is the full, unrestricted model which assumes varying returns to scale and non-Hicks

[2] We are referring to SAS/ETS.

[3] To calculate the T^0 test statistic, the following was used.

Let n = the number of observations in the sample; S = the value of the objective function that results from the iterative minimization procedure for the model associated with the alternative hypothesis; S^* = the value of the objective function that results from the iterative minimization procedure for the model associated with the null hypothesis; $(r\text{-}s)$ = the difference in the number of parameter restrictions between the model of the null hypothesis and the model of the alternative hypothesis.

Then $T^0 = n^*S^* - n^*S$. T^0 is distributed asymptotically as a chi-square distribution with $(r\text{-}s)$ degrees of freedom, (i.e., $X^2(r\text{-}s)$). Therefore if $T^0 > X^2(r\text{-}s)$ at some prescribed alpha level, then the null hypothesis, H_0, is rejected. Similarly, if $T^0 < X^2(r\text{-}s)$ at some prescribed alpha level, then H_0 cannot be rejected.

neutrality. Model 2 represents the situation of assuming that varying returns to scale and Hicks neutrality exist. In this case we are testing the feasibility of the restrictions that $t^*_{iT} = t_{TT} = 0$ for all i. If the hypothesis represented by Model 2 cannot be rejected, the Model 2 will be assumed to represent the alternative hypothesis under which Model 3 and 4 will be tested.

In testing the hypothesis of the existence of Hicks neutrality, under the assumption of varying returns to scale, the calculated T^0 test statistic is 2.54 and the critical X^2 value at alpha levels of 5% and 10% are 9.49 and 7.78 respectively. Hence, we cannot reject the null hypothesis and so Model 2 becomes the alternative hypothesis in testing Models 3 and 4.

In Model 3 we are assuming that there exist varying returns to scale and that technical progress does not exist. In testing this specific hypothesis the calculated T^0 value is 0.91 and at 1 degree of freedom the critical X^2 value at alpha levels of 5% and 10% are 3.84 and 2.71. Again, the null hypothesis cannot be rejected which implies that we can assume that our model does not experience technical progress.

Model 4 represents the case of testing the specific hypothesis that the production function specification will be experiencing constant returns to scale, (i.e., $\theta = 1$). In this case the calculated T^0 value is 0.67 and at one degree of freedom the critical X^2 values are 3.84 and 2.71 at alpha significance levels of 5% and 10%. This leads to the conclusion not to reject the hypothesis of constant returns to scale and we can state statistically that the assumption of constant returns to scale is valid for the purposes of our model. In addition, this results in Model 4 becoming the alternative hypothesis in the testing of the conditions of input separability, as well as the model of choice in the estimating of the Allen partial elasticities of substitution and the own and cross price elasticities of demand.

Turning to Table 2, we present the empirical results associated with testing both local and global separability of the translog aggregation of energy and money from that of capital and labor. In both cases Model 4 is used as the alternative hypothesis and the T^0 test statistic was employed. Model 5 assumes that local or weak separability exists between the factor inputs energy and money and the factor inputs capital and labor. Under this assumption, two additional parameters were constrained in the model to zero and the resulting T^0 value of 0.37 was calculated. For alpha levels of 5% and 10% at two degrees of freedom, the critical X^2 are 4.61 and 5.99. Hence we cannot reject the null hypothesis of weak local separability of the aggregate factor inputs energy and money from capital and labor. Similarily in evaluating the case of strong or global separability between energy and money and capital and labor, the calculated T^0 value is 3.29. Again at both

TABLE 1

PARAMETER ESTIMATES FOR TESTING THE HYPOTHESES OF HICKS' NEUTRALITY, TECHNICAL PROGRESS AND CRTS

	Model 1	Model 2	Model 3	Model 4
A_0	0.0726	− 0.2870	− 1.0256	1.8883
	(0.10)	(− 0.54)	(− 4.97)	(30.60)
A_k	0.5281	0.3992	0.3723	0.3634
	(5.86)	(8.73)	(8.77)	(8.33)
A_m	0.007	− 0.0033	− 0.0024	− 0.0089
	(0.06)	(− 0.59)	(− 0.43)	(− 1.34)
A_e	0.0259	0.2558	0.2532	0.2673
	(0.30)	(5.94)	(5.89)	(6.21)
A_{kk}	0.1109	− 0.0245	− 0.0216	− 0.0307
	(3.10)	(1.19)	(− 1.08)	(− 1.54)
A_{mm}	− 0.0006	− 0.0019	− 0.0015	− 0.0032
	(− 0.39)	(− 2.15)	(− 1.73)	(− 2.97)
A_{ee}	− 0.0435	0.0191	0.0214	0.0255
	(− 1.54)	(0.90)	(1.03)	(1.17)
A_{km}	− 0.0067	− 0.0051	− 0.0039	− 0.0052
	(− 2.17)	(− 2.41)	(− 2.16)	(− 2.06)
A_{ke}	0.0636	0.0934	0.0882	0.0910
	(3.25)	(6.20)	(6.27)	(5.85)
A_{me}	0.0025	0.0011	0.0005	0.0001
	(0.59)	(0.42)	(0.20)	(0.03)
T_k	− 0.0030			
	(− 3.06)			
T_m	0.00003			
	(0.25)			
T_e	0.0017			
	(2.42)			
B_T	0.0184	0.0037		0.0137
	(2.52)	(1.41)		(14.87)
T^2	− 0.0009			
	(− 2.43)			
Theta	1.3562	1.5176	1.6915	1
	(8.83)	(3.37)	(14.12)	
S^*n	81.88	84.42	85.33	85.09
d.f.		4	5	5

S^*n = the value of the objective function after the minimization procedure.

Asymptotic *t*-values are in parentheses, however the asymptotic *t*-value associated with the coefficient *theta* tests the following null hypothesis:

H_0: theta = 1 vs. H_a: theta ≠ 1.

TABLE 2

PARAMETER ESTIMATES FOR TESTING WEAK AND STRONG SEPARABILITY OF CAPITAL AND LABOR FROM ENERGY AND MONEY

	Model 4*	Model 5**	Model 6***
A_0	1.8883	2.4855	1.5768
	(30.60)	(5.67)	(13.84)
A_k	0.3634	0.5705	0.2346
	(8.33)	(3.31)	(6.52)
A_m	− 0.0089	− 0.0373	− 0.0182
	(− 1.34)	(− 2.63)	(− 5.53)
A_e	0.2673	0.0911	0.0669
	(6.21)	(3.24)	(16.32)
A_{kk}	− 0.0307	0.0519	− 0.0219
	(− 1.54)	(2.93)	(− 2.32)
A_{mm}	− 0.0032	− 0.0012	− 0.0019
	(− 2.97)	(− 1.16)	(− 2.37)
A_{ee}	0.0255	0.0055	
	(1.17)	(0.41)	
A_{km}	− 0.0052	0.0018	0.0077
	(− 2.06)	(1.45)	(13.12)
A_{ke}	0.0910		
	(5.85)		
A_{me}	0.0001		
	(0.03)		
B_T	0.0137	0.0245	0.0175
	(14.87)	(12.34)	(16.65)
Theta	1		
R_3		− 0.2055	
		(− 10.10)	
R_4		0.0127	
		(0.71)	
S^*n	85.09	85.46	88.38
d.f.		2	3

S^*n = the value of the objective function after minimization.

Asymptotic *t*-values are in parentheses.

* Model 4 represents the case of a scale factor of one, and is the alternative hypothesis to test models 5 and 6 against.

** Model 5 represents the case of testing the weak local (aggregate) separability of Money and Energy from Capital and Labor.

*** Model 6 represents the case of testing the global (aggregate) separability of Money and Energy from Capital and Labor.

TABLE 3

PARAMETER ESTIMATES FOR TESTING THE GLOBAL SEPARABILITY OF THE FACTOR INPUTS FOR THE TRANSLOG PRODUCTION FUNCTION SPECIFICATION

$Q = F(X_k, X_l, X_e, X_m, T)$

	Model 4[1]	Model 7[2]	Model 8[3]	Model 9[4]	Model 10[5]
A_0	1.89	1.35	1.56	2.20	2.17
	(30.60)	(9.25)	(33.91)	(33.91)	(13.93)
A_k	0.36	0.19	0.29	0.32	0.18
	(8.33)	(26.48)	(9.02)	(14.06)	(6.01)
A_m	− 0.01	0.02	0.003	0.01	0.007
	(− 1.34)	(3.99)	(9.04)	(10.52)	(1.46)
A_e	0.27	0.01	0.25	0.19	0.17
	(6.21)	(0.36)	(7.24)	(14.39)	(5.89)
A_{kk}	− 0.03		− 0.03		
	(− 1.54)		(− 1.97)		
A_{mm}	− 0.003	− 0.004		− 0.00004	− 0.004
	(− 2.97)	(− 3.15)		(− 2.68)	(− 4.50)
A_{ee}	0.03	0.000005	0.04	− 0.00002	0.02
	(1.17)	(0.18)	(2.21)	(− 0.57)	(2.39)
A_{km}	− 0.005				
	(− 2.06)				
A_{ke}	0.09	− 0.0006	0.06		
	(5.85)	(− 0.51)	(5.78)		
A_{me}	0.0001			0.003	0.002
	(0.03)			(7.94)	(3.27)
B_T	0.01	0.02	0.003	0.008	0.02
	(14.87)	(17.72)	(1.52)	(3.39)	(15.15)
Theta	1	1	1	1	1
n^*S	85.09	88.17	88.02	88.04	88.14
d.f.		3	3	3	3

n^*S = the value of the objective function after minimization.

The asymptotic *t*-values are in parentheses.

1. Model 4 represents the case of a constant returns to scale factor of one and is the alternative hypothesis for testing Models 7, 8, 9 and 10.

2. Model 7 represents the case of testing the separability of the input money from the other inputs capital, labor and energy.

3. Model 8 represents the case of testing the separability of the input capital from the other inputs labor, energy and money.

4. Model 9 represents the case of testing the separability of the input labor from the other inputs capital, energy and money.

5. Model 10 represents the case of testing the separability of the input energy from the other inputs capital, labor and money.

the 5% and 10% alpha significance levels, with 3 degrees of freedom, the null hypothesis with respect to the strong or global separability of the aggregated factor inputs cannot be rejected. Hence, the question of both the local and global separability of the aggregation of the factor inputs energy and money from capital and labor is accepted by a substantial margin.

Having accepted the previous hypotheses with respect to the local and global aggregate separability of the factor inputs, we next turn to the issue of testing the global separability of the inputs individually. These results are presented in Table 3 and once again Model 4 will be used as the alternative hypothesis. In Models 7, 8, 9, and 10 there exist three degrees of freedom and the critical X^2 value at 3 degrees of freedom at the alpha significance levels of 5% and 10% are 6.25 and 7.81 respectively. Model 7 represents the case of testing the separability of the input money from the subset of inputs composed of capital, labor and energy. In this case the calculated T^0 value is 3.08 and the null hypothesis with respect to the global separability of money cannot be rejected. For Model 8, the calculated T^0 is 2.93. Therefore the null hypothesis addressing the issue of the global separability of the capital input from the subset of inputs composed of labor, energy and money cannot be rejected. In Models 9 and 10, we address the question of the separability of the factor inputs labor and energy respectively. For Model 9 the calculated T^0 value is 2.95 and for Model 10 the calculated T^0 value is 3.05. Hence, we cannot reject the null hypothesis in both cases at either the 5% or 10% significance levels.

Elasticity Estimates

The results presented in Table 4*A* are the Allen partial elasticities of substitution (AES), s_{ij}, and the own and cross price elasticities of demand, N_{ij}, along a gross isoquant. All estimated elasticity values are based upon the parameter estimates resulting from the assumptions that the production function possesses constant returns to scale, as well as Hicks' neutrality and the respective factor shares of the four input factors. The elasticity estimates were obtained using the following computations (for explicited development see Berndt and Christensen, 1973):

$$s_{ij} = \frac{A_{ij} + S_i S_j}{S_{ij}} \quad \text{for all } i \text{ and } j \text{ and } i = j$$

$$s_{ii} = \frac{A_{ii} + S_i^2 - S_i}{S_i^2} \quad \text{for all } i$$

and

$$N_{ij} = S_j * s_{ij} \text{ for all } i \text{ and } j$$

TABLE 4A

ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION FOR THE U.S. MANUFACTURING SECTOR, 1958-1981 – AVERAGES AND SELECTED YEARS

	Average AES	1960	1965	1970	1975	1981
s_{kk}	– 5.58	– 5.73	– 5.83	– 6.49	– 5.65	– 5.34
s_{ll}	– 0.026	– 0.04	– 0.01	– 0.004	– 0.04	– 0.07
s_{ee}	– 9.85	– 10.80	– 11.01	– 11.09	– 7.82	– 6.80
s_{mm}	– 301.52	– 253.68	– 218.06	– 146.46	– 318.43	– 418.06
s_{kl}	0.51	0.51	0.51	0.47	0.49	0.49
s_{ke}	9.74	10.87	11.38	12.45	7.11	5.97
s_{km}	– 5.11	– 4.65	– 4.07	– 2.98	– 5.67	– 6.84
s_{le}	– 1.41	– 1.90	– 1.74	– 1.75	– 0.74	– 0.52
s_{lm}	2.66	2.44	2.27	1.91	2.80	3.28
s_{em}	4.62	4.84	4.54	3.60	3.86	3.99

where S_i represents the cost share of the ith factor input and A_{ij} represents the estimated coefficient values associated with Model 4.

In Table 4A the average Allen partial elasticity estimates, AES, for the time period 1958-81 are reported, as well as the estimated elasticity values for selected years. Initially the results show that both on average and for the selected years the own AES values are negative, as one would expect. In addition, from the respective signs of the AES estimates one can begin to get some idea of the way that the factor inputs interact within the production process. The observed average AES values of 0.51 for capital and labor and 9.47 for capital and energy imply that capital can be viewed as a substitute with labor and energy. Whereas, the observed average AES value of – 5.11 for capital and money implies that these two factor inputs can be viewed as complements in the production process. With respect to the labor input and the inputs of energy and money, the observed average AES values are – 1.41 and 2.66. Here one would conclude that labor and energy are complements while labor and money could be viewed as substitutes. Similarly, the observed average AES value of 4.62 for energy and money would lead one to the conclusion that these two inputs are substitutes in the production process [4].

[4] The derived respective sign of the AES between the factor inputs energy and money were not what one would expect given a priori economic reasoning. We strongly believed that energy and money would turn out to be complements within the production process. Therefore,

Turning to Table 4*B*, the own and cross price elasticities of demand are presented and as one would expect, the own price elasticites are all negative. With respect to the relative magnitudes of the own price elasticities, the labor input appears to be highly inelastic, both on average and over time. Observing the own price elasticities of capital and energy, these factor inputs are somewhat inelastic, with energy being the more inelastic. Lastly, the observed own price elasticity of the money input appears to be relatively more elastic than all other factor inputs, both on average and over time.

From the standpoint of the cross price elasticities of demand, both on average and over time, capital and labor and capital and energy appear to be relatively inelastic, with capital and energy being somewhat less inelastic than capital and labor. However, moving to the other respective cross price elasticities, those associated with capital and money, labor and money, energy and money and labor and energy all appear to be highly inelastic. In particular, this observed high inelasticity between capital and money, labor and money and energy and money provides the empirical support to our belief that money is an essential input into the production function for the U.S. Manufacturing sector. Similarly, the observed high inelasticity of labor and energy and money and energy and the observed relative inelasticity of

TABLE 4*B*

OWN AND CROSS PRICE ELASTICITIES OF DEMAND FOR THE U.S. MANUFACTURING SECTOR, 1958-1981 – AVERAGES AND SELECTED YEARS

	Average Value	1960	1965	1970	1975	1981
N_{kk}	– 0.96	– 0.97	– 0.98	– 1.00	– 0.97	– 0.96
N_{ll}	– 0.02	– 0.008	– 0.005	– 0.003	– 0.03	– 0.05
N_{ee}	– 0.63	– 0.60	– 0.59	– 0.59	– 0.70	– 0.71
N_{mm}	– 1.40	– 1.36	– 1.32	– 1.22	– 1.43	– 1.53
N_{kl}	0.38	0.39	0.39	0.37	0.36	0.36
N_{ke}	0.61	0.61	0.61	0.66	0.63	0.63
N_{km}	– 0.02	– 0.02	– 0.03	– 0.03	– 0.03	– 0.03
N_{le}	– 0.08	– 0.09	– 0.04	– 0.09	– 0.07	– 0.06
N_{lm}	0.01	0.01	0.01	0.02	0.02	0.01
N_{em}	0.02	0.03	0.03	0.03	0.02	0.01

future research will involve a disaggregation of the energy component to see if the effect of electric energy and non-electric can account for an opposite AES sign.

capital and energy provides additional empirical support for the inclusion of energy as an essential input in the production process.

Summary and Conclusions

The results of this study are significant in that we have shown that the assumption of constant returns to scale is a statistically valid assumption. Similarly, we have provided some insight into the issue of the separability of the factor inputs energy and money within a multifactor framework. That is, we have shown that the aggregation of energy and money are both locally and globally separable from the aggregation of capital and labor. In addition, we have validated the global separability of the individual inputs energy and money from the respective set of multifactor inputs. Thus we can conclude, with a high degree of statistical certainty, that the input factors of energy and money are separable within a multifactor production function framework. From the standpoint of the empirical AES and price elasticity estimates, the conclusion that capital and energy are substitutes and that capital and money are complements are what one would expect given a priori economic reasoning. Similarly, the conclusion that labor and energy are complements is again substantiated via economic reasoning, in that a rise in the price of energy will lead to a fall in the demand for labor. In addition, the same a priori reasoning can be used to support the conclusion that labor and money are substitutes within the production process. The empirical conclusion that energy and money are substitutes cannot be readily explained using economic reasoning. This has resulted in the arriving at the belief that further study may be warranted. That is, to investigate the possible implications of a disaggregated energy component: one composed of an electric energy component and a non-electric energy component. Such a study could possibly show that the effect of substitutability is overshadowing the complementarity with respect to the input factor money.

However, the empirical findings of the relative highly inelastic cross price elasticities between capital and money, labor and money and energy and money leads us to conclude that one can view money as an essential input into the production process of the U.S. Manufacturing sector. In addition, the relative highly inelastic cross price elasticity between labor and energy and energy and money and the relative inelastic cross price elasticity between capital and energy imply that energy can also be viewed as an essential input into the production process of the U.S. Manufacturing sector.

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VALUTAZIONE DEL SETTORE MANIFATTURIERO DEGLI STATI UNITI CON L'USO DI INPUT DI CAPITALE, LAVORO, ENERGIA E LIQUIDITÀ IN TERMINI REALI

Dal punto di vista della produzione, la moneta (o i saldi liquidi in termini reali) e l'energia sono input essenziali per le imprese manifatturiere. Nella letteratura questi due input sono stati analizzati separatamente, mai congiuntamente, assumendo una specificazione translog flessibile per la funzione di produzione. L'obiettivo di questo articolo è quindi di analizzare la validità dell'inclusione della moneta e dell'energia come output nella funzione di produzione del settore manifatturiero degli Stati Uniti per il periodo 1958-1981 e verificare la rispettiva separabilità di questi input entro uno schema con molti fattori. Inoltre, considerando che sia gli input sia l'output sono aggregati usando il processo di indicizzazione di Divisia, non si può giustificare che la sottostante funzione di produzione abbia rendimenti costanti di scala. Perciò l'assunzione dei rendimenti costanti di scala viene verificata empiricamente.

Questo studio ha dato alcuni importanti risultati. Primo, i rendimenti costanti di scala sono una assunzione statisticamente valida. Secondo, quanto al problema della separabilità, gli input individuali energia e moneta si sono manifestati globalmente separabili e quando aggregati essi sono sia localmente sia globalmente separabili dall'aggregazione capitale e lavoro. Perciò, è statisticamente valido concludere che la moneta e l'energia sono input essenziali nel processo di produzione.

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GOVERNMENT SPENDING AND LABOUR SUPPLY: AN EXPOSITORY NOTE

by
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1. – In analysing the effects of fiscal policy on labour supply account must be taken not only of the increase in taxation but also of the way in which the Government uses the revenue deriving from the higher tax rates. One of the few studies that have expressly considered the simultaneous effects of the taxes and expenditure on the individual supply of labour is the one by Scitovsky (1951) which concluded: "The imposition or raising of income tax accompanied by free public services, always tends to diminish people's willingness to work". The validity of this result is, however, as shown by Winston (1965), limited by Scitovsky's rather restrictive hypothesis that public goods and private goods are perfect substitutes. Following Winston's criticism to Scitovsky, Lindbeck (1982), in a recent paper, considered the effects on labour supply of tax changes coupled with different kinds of public spending.

In this note we reexamine these problems by considering the general case in which perfect substitutability is not imposed and the individual utility function is not separable with respect to public goods. It is shown that the effects of fiscal policy on the labour supply depend on the degree of substitutability between consumption and government expenditure on goods and services on the one hand and leisure time and government expenditure on the other hand.

2. – Let us consider an individual who maximises a utility function that includes private goods X, leisure time, L, and the government's expenditure on good and services, G;

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$$U = U(X,L,G) \tag{1}$$

subject to:

$$L = T - N \tag{2}$$

and

$$W(1 - a)N + A = PX \tag{3}$$

where T is the maximum amount of time available and N the time devoted to work.

Eq. (3) is the budget constraint where W is the gross wage rate, determined exogenously, a is the income tax rate, which for simplicity is assumed to be proportional, A is the unearned income including transfers from the government sector, and P is the exogenous market price of the composite private good X.

From the first order conditions, obtained by maximising equation (1) with respect to X and N, subject to (2) and (3) one gets:

$$\frac{U_X}{U_L} = \frac{P}{W(1 - a)} \tag{4}$$

$$W(1 - a)N + A - PX = 0 \tag{5}$$

Equations (4) and (5) can be solved to obtain the demand for private consumer goods and the labour supply (demand for leisure time).

In order to look at the effects on the labour supply of a tax increase coupled with a government expenditure increase on good and services, let us consider a balanced budget marginal change, i.e.:

$$dG = \frac{WN}{P_G} d\,a \tag{6}$$

where P_G is the price of goods supplied by the government, which for the sake of simplicity is assumed to be equal to P. If we totally differentiate the system (4)-(5) and use (6), we get:

$$\frac{dN}{da} = -\frac{\frac{P^2}{W(1 - a)^2}}{\Gamma} - \frac{WN}{\Gamma}\left[\left(\frac{U_{XX}}{U_L} - \frac{U_X}{U_L^2}U_{LX}\right) - \frac{P}{P_G}\left(\frac{U_{XG}}{U_L} - \frac{U_X}{U_L^2}U_{LG}\right)\right] \tag{7}$$

where the terms in round brackets show the derivatives of the marginal rate of substitution between leisure time and private goods with respect to X and G and where

$$\Gamma = -\frac{\partial\left(\frac{U_X}{U_L}\right)}{\partial L} P - \frac{\partial\left(\frac{U_X}{U_L}\right)}{\partial X} W(1 - a) > 0$$

from the second-order conditions.

If public goods and private goods are perfect substitutes, i.e.: $U_{XX} = U_{XG}$ and $U_{LX} = U_{LG}$we obtain a result similar to Scitovsky's, as the term in square brackets in (7) cancel out and the labour supply is reduced because of the negative substitution effect. More generally, the overall effect on the labour supply will depend on the values assumed by the term in square brackets in (7). The hypothesis that leisure time is not an inferior good means that the first term inside the square brackets is negative. Consequently if the second term in the square brackets is positive then the income effect of a change in the supply of public goods works in the same direction as the income effect generated by a change in taxation. (If on the other hand, this term takes on negative values it opposes, and may be more than offsets, the income effect of the change in taxation).

The income effect associated with a change in the supply of public goods is given by the change in the marginal rate of substitution between private goods and leisure time, due to a change in the supply of the public goods themselves. Consequently it will have a positive sign if an increase in the supply of public goods leads to an increase in the ratio of the marginal utility of the private good to the marginal utility of the leisure time, while it will be negative in the opposite case. The first case will occur if, in the individual utility function, the public good shows an elasticity of substitution with respect to the private good lower than the elasticity of substitution between leisure and the public good. The marginal utility of the leisure time will decrease with respect to that of the private good in the opposite case.

To sum up: in assessing the effects of tax changes combined with changes of the same amount in government expenditure four cases must be considered. Firstly, the one analysed by Scitovsky in which government expenditure and private goods are perfect substitutes. At the other extreme the case in which government expenditure does not modify the marginal rate of substitution between leisure time and consumption leads to results identical to those that are obtained when only the tax change is considered.

More generally, apart from these two particular cases, one must take into account the different degrees to which consumption and leisure time, on the one hand, and government expenditure on the other can be substituted for each other. When the public good is, in the individual utility function, substitute for leisure time more than for private good, then to the income effect deriving from a tax change one must add, in opposing the substitution effect, the income effect deriving from the increase in public good. If, on the other hand, the public good is a "substitute" for the private good more than for the leisure time, the income effect deriving from the change in the quantity of public goods, acts in the same way as the substitution effect, with the result that the effect of fiscal policy on the labour supply will tend to be negative.

3. – The conclusions obtained in the previous section are illustrated in Figure 1. U is the individual's initial point of equilibrium. Following a rise in income tax the new point of equilibrium will be V. In this case the substitution effect H_1H_3 is greater than the income effect equal to H_2H_3. Let us examine the effect deriving from the change in government spending coupled with the tax change. If government spending does not modify the shape of the indifference curve (i.e. the marginal rate of substitution at each point) then the point of equilibrium will remain at V.

More generally, as government spending modifies the marginal rate of

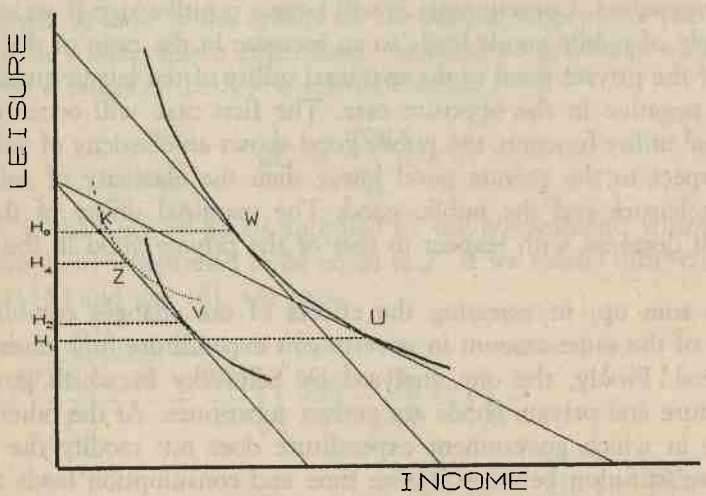

FIGURE 1

substitution between leisure time and consumption it gives rise to a change in the shape of the indifference curve.

In particular, if the goods offered by the government are substitutes for consumption more than for leisure time one finds, compared with V, a positive income effect, equal e.g. to H_2H_4. In this case the new point of equilibrium is at Z, with a greater reduction of the labour supply than at V. At most, if government spending perfectly substitutes for private goods, such an income effect would exactly offset the income effect deriving from the tax increase, and the new point of equilibrium would be at K.

Finally, if government spending substitutes leisure time more than the private good there would be an income effect that would be added to that deriving from the tax increase and the equilibrium of the individual would show a labour supply greater than H_2.

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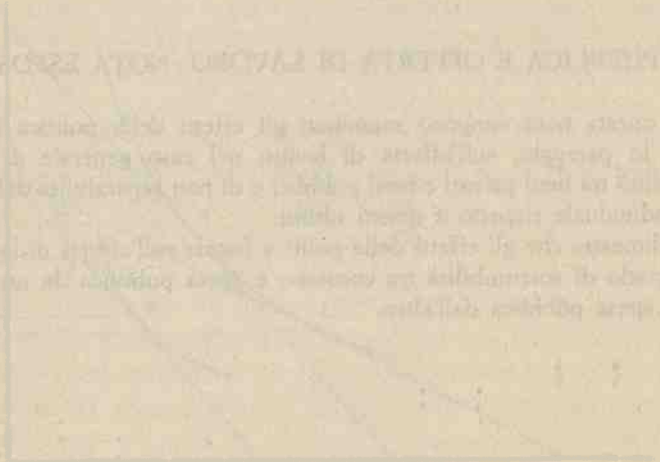
SPESA PUBBLICA E OFFERTA DI LAVORO: NOTA ESPOSITIVA

In questa nota vengono esaminati gli effetti della politica fiscale, con il bilancio in pareggio, sull'offerta di lavoro nel caso generale di non perfetta sostituibilità tra beni privati e beni pubblici e di non separabilità della funzione di utilità individuale rispetto a questi ultimi.

Si dimostra che gli effetti della politica fiscale sull'offerta di lavoro dipendono dal grado di sostituibilità tra consumo e spesa pubblica da un lato e tempo libero e spesa pubblica dall'altro.



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THE BEHAVIOUR OF FOREIGN EXCHANGE RATES: THE TURKISH EXPERIENCE

by
VEDAT AKGIRAY *, KURSAT AYDOGAN ** and G. GEOFFREY BOOTH ***

1. *Introduction*

Empirical research on the statistical behaviour of foreign exchange rates and other speculative price series has long been an important application area of financial economics. The widespread interest in such research is largely due to the fact that probabilistic characterizations of financial series are useful not only in understanding the operations of markets but also they have implications for theoretical models and their empirical testing. In the particular case of foreign exchange rates, several probability models have been used successfully to explain their statistical behaviour over time, and inferences have been made about the efficiency of currency markets and the structural models of exchange rate determination. Recent studies in this area include Boothe and Glassman (1987), So (1987), Akgiray, Booth, and Seifert (1988), and Akgiray and Booth (1988b). The common finding in all related work is that daily exchange rate changes follow leptokurtic and often skewed distributions, and they are best described by some non-normal family of distributions. Other studies such as Milhoj (1987), Bollerslev (1987), and Hseih (1988) suggest that these distributional phenomena may be the result of exchange rates being characterized by a conditional heteroscedastic autoregressive process. Of these studies, only Akgiray, Booth, and Seifert (1988) examine the properties of black market exchange rates.

This paper extends the extant literature by providing a comprehensive analysis of the statistical properties of black and official exchange rates of

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the Turkish lira (TL) for the U.S. dollar and the German mark. The United States and West Germany are two of the major trading partners of Turkey, and they are also important in terms of bilateral capital flows such as debt and workers' remittances. The fits of four statistical distributions, which have been widely used to model speculative price changes, are investigated and compared. These are the normal distribution, the stable distribution with characteristic exponent less than two, the compound normal distribution (also known as the mixture of normal distributions), and the mixed diffusion-jump process model. A conditional heteroscedastic autoregressive process is also estimated and its fit is compared with the above four models. Two important results are found: (1) Daily exchange rate changes do not exhibit any apparent time-series properties that can be used for modeling purposes, and (2) empirical distributions are best described by the compound normal distribution model. These findings about the TL exchange rates appear to be different from those about other currencies' exchange rates, especially the exchange rates between the currencies of the major industrial nations. The differences may be attributed to the unique characteristics of the Turkish economy in world markets.

The rest of the paper is organized as follows. The next section describes the data and presents several descriptive statistics about the empirical distributions. The third section includes the estimates of the five probability models, following a brief description of each model. The statistical fits of the models are then compared in the fourth section of the paper. The final section offers some conclusions and suggestions for future research.

2. *Data Description*

The data used in this study consist of daily prices of the TL in U.S. dollars and German marks, and covers the period between September 4, 1985 and August 31, 1987. Both the official and the black market bid and ask prices are readily available, and they are obtained from *Dunya Journal.* Choice of the starting date is due to the lack of reliable data prior to September 1985.

The official price is the price set by the Central Bank of Turkey. This is done in the following way. To manage the country's balance of payments, the Central Bank determines a desired real exchange rate between the Turkish lira and a basket of the currencies of Turkey's major trading partners. The nominal rate for this basket is determined from inflation forecasts. This rate is frequently altered to reflect changes in inflation and real rate adjust-

ments, if necessary. The official rate for a particular currency is calculated using the composite rate and the European market cross rates among the basket currencies.

The market for foreign exchange in Turkey is headquartered in Istanbul and has a network of dealers and brokers in the country's major cities. The major dealers meet in an unorganized exchange to auction various currencies. Almost all transactions are spot. The black market price reported by *Dunya Journal* is that offered by some major dealer (usually anonymous) on a given day. Several other papers also publish the same data (different dealers), and any discrepancies among reported prices are almost always negligible.

To obtain a unique price series for each market, the bid and ask prices are averaged. The series of exchange rate changes are then obtained as the logarithm of the ratio of two successive prices. This method of calculation establishes consistency with the literature and helps avoid possible numerical problems. The final sample sizes are 523 observations of official rate changes and 514 black market rate changes, the difference being due to the unavailability of black market prices on ten days during the two-year period. The black market rate is hereafter referred to as the free rate, since during the two-year period there were no government sanctions against participating in this market.

Monday-to-Monday exchange rates of the dollar and the mark, (that is, value of the TL in dollars and marks), and the corresponding weekly exchange rate changes for the two-year period are plotted in Figure 1. The official and the free market rates have moved very closely during this period, with the free rate being higher throughout. As expected, however, the free market rate has fluctuated with more variability than the official rate. None of the exchange rate change series seems to show any apparent nonstationarities: all seem to wander around a costant mean and with constant variance. Similar behaviour is seen when daily rates are plotted (not shown).

The simple correlation coefficients between the series of daily and weekly exchange rate changes are reported in Table 1. For both currencies, contemporaneous correlations between the official and free daily changes are not as strong as may be expected. Higher correlations, however, are observed between the weekly series. On the other hand, the correlation between the official rate and the lagged free rate is higher than the contemporaneous correlation for both currencies and also for both daily and weekly data. As pointed out by Akgiray, Aydogan, Booth, and Hatem (1989), all of these phenomena may be related to the speed of information dissemination in the free markets and the speed at which the official rate is

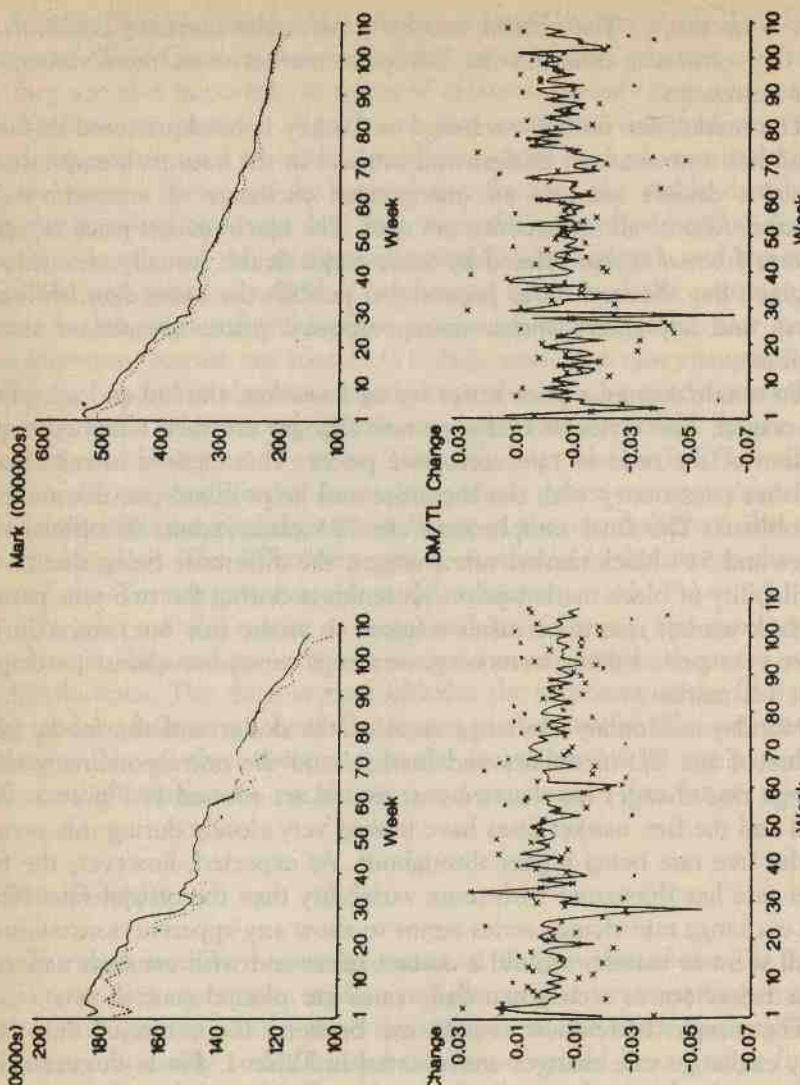


FIGURE 1. Plots of Exchange Rate Series

Note: The dotted lines and the symbol "x" correspond to the free market rates.

TABLE 1a

CORRELATIONS BETWEEN DAILY SERIES

	DO	*DF*	DF_{-1}	*MO*	*MF*	MF_{-1}
DO	1.000	0.078	0.145	−0.316	−0.029	−0.107
DF		1.000	0.020	−0.035	−0.011	0.092
DF_{-1}			1.000	−0.080	0.025	−0.035
MO				1.000	0.095	0.221
MF					1.000	0.021
MF_{-1}						1.000

TABLE 1b

CORRELATIONS BETWEEN WEEKLY SERIES

	DO	*DF*	DF_{-1}	*MO*	*MF*	MF_{-1}
DO	1.000	0.562	0.273	−0.212	−0.203	0.116
DF		1.000	0.006	−0.223	0.367	0.183
DF_{-1}			1.000	−0.069	−0.184	0.362
MO				1.000	0.541	0.028
MF					1.000	0.144
MF_{-1}						1.000

Note: *D* denotes dollar, *M* mark, *O* official rate, and *F* denotes the free rate.

adjusted accordingly. It is clear that, although the official and the free exchange rates have moved more or less together over time and some causal relationship may exist between the two, the official and the free exchange rate changes are not close substitutes statistically. They are to be analyzed separately.

2.1 *Distributional Statistics.* – Table 2 presents several sample statistics describing the empirical distributions of daily exchange rate changes. These include the sample mean, variance, skewness, kurtosis, range, median, interquartile range (IQR), maximum, minimum, Kolmogorov-Smirnov D-statistic to test for normality, and the sample log-likelihood function value when a normal distribution is fit to data. All of these statistics (except

TABLE 2

SAMPLE STATISTICS ON DAILY EXCHANGE RATE CHANGES

	Dollar		Mark	
	Official	Free	Official	Free
Sample size	523	514	523	514
Mean (00s)	−.1025	−.1051	−.1857	−.1927
t (mean = 0)	− 5.68	− 3.73	− 7.23	− 6.67
Variance (000s)	.0169	.0407	.0345	.0430
Skewness	− 3.286	−.1758	− 3.726	−.6187
Kurtosis	46.125	5.722	37.955	7.479
Range	.0733	.0535	.0832	.0634
Median (00s)	−.0672	0	−.1083	−.1043
IQR	.0038	.0054	.0053	.0057
Maximum	.0223	.0248	.0160	.0291
Minimum	−.0509	−.0287	−.0672	−.0343
D-statistic	.0894	.1045	.1108	.1061
Log-likelihood	2130.4	1869.5	1945.1	1855.3

the normal likelihood function values) are calculated using the univariate procedure of the SAS package.

The moments of all four samples indicate that the empirical distributions have heavy tails and sharp peaks at the center compared to the normal distribution. The Kolmogorov-Smirnov test leads to the rejection of normality in every sample. The Kiefer-Salmon (1983) test for normal kurtosis (zero excess kurtosis) also rejects the normality hypothesis in all cases, and the same test for normal skewness (zero) rejects the hypothesis for the official rate samples. Clearly, exchange rate changes cannot be represented as normal random variables, and probability models that allow for leptokurtosis are called for. Visual inspections of the sample histograms (not shown) also confirm this conclusion.

When the official rates are compared to the free rates, some interesting differences are observed. The free exchange rate change samples consistently have higher sample variance, higher left skewness, higher kurtosis, smaller range, higher maximum, higher minimum, and higher mean. Differences between sample medians are mixed. Most of these observed differences may be partially explained by the way the Central Bank sets the

official rates. For example, frequent devaluations of the TL can account for the left skewness and unusually high levels of kurtosis.

2.2 *Time Series Statistics.* – The purpose of estimating the time series properties of the series is to discover whether the observations are statistically independent. If the series are found to be dependent, then the dependence structure can be used for time series modelling. This is usually accomplished through the estimation and analysis of sample autocorrelation functions. Table 3 contains several test statistics regarding the time series properties of the exchange rate change series. These tests are conducted not only for the original series but also for the squared series (series formed by squaring the original observations) and the absolute series. The reasons for studying all three series are explained in detail by Akgiray (1989). Briefly, a complete test for independence should look at not only the first-order properties of a series but also its second-order (and, ideally, other higher order) properties.

The first test result reported in Table 3 for the original series is the runs-up test (similar results are obtained by a runs-down test). This is a distribution-free test for independence, which may be more reliable than serial tests when the empirical distribution is not normal or when dependence is suspected. For large samples, the test statistic is asymptotically chi-square distributed with 6 degrees of freedom. According to this criteria, the null hypothesis of independence (that is, strict white noise) cannot be rejected in any one of the four samples (official and free rates for the dollar and the mark). The low values of the statistics relative to their critical levels are to be noted as well.

Also included in Table 3 are statistics to test the hypothesis of strict white noise both in the time domain (Fisher's kappa and Bartlett's Kolmogorov-Smirnov type statistic) and in the frequency domain (Ljung-Box portmanteau test statistic, also known as the Q-statistic). These statistics are calculated using the SPECTRA and ARIMA procedures of SAS, respectively. Descriptions and uses of these tests can be found in Priestley (1981). Strictly speaking, Fisher's and Bartlett's tests are both tests of the hypothesis of normal (strict) white noise. Consequently, when there are significant departure from normality or when the sample size is not sufficiently large, they may be biased towards rejecting the null hypothesis of independence. The same shortcoming applies to the Ljung-Box (LB) test, and the following results must be interpreted accordingly.

Based on Fisher's kappa statistic, the independence hypothesis cannot be rejected at the 5-percent probability level in any sample: the statistic is always smaller than its critical value. The results with Barlett's test are

mixed. At the 5-percent level, the hypothesis may be rejected in all four of the absolute series, in the squared series for the German mark, and in the original series for the official mark rate. As mentioned above, however, these rejections are to be interpreted with caution.

TABLE 3

TIME SERIES STATISTICS

	Dollar		Mark	
	Official	Free	Official	Free
A. Ordinary series:				
Runs-up test	3.5	3.6	1.7	2.8
Fisher's kappa	5.2842	7.5610	5.651	6.7807
Bartlett's test	.0565	.0563	.0748	.0565
LB (6)	13.47	10.64	5.93	8.20
LB (12)	22.96	18.22	9.07	15.39
LB (24)	34.07	24.91	17.19	32.46
B. Squared series:				
Fisher's kappa	2.1719	2.7506	5.5408	7.3017
Barlett's test	.0247	.0181	.0882	.0801
LB (6)	2.46	23.35	0.71	20.56
LB (12)	3.57	26.54	3.82	32.79
LB (24)	4.75	41.89	8.75	38.48
C. Absolute series:				
Fisher's kappa	5.5411	6.1668	5.8081	6.1998
Barlett's test	.0846	.0704	.0725	.0637
LB (6)	26.22	17.02	15.19	12.00
LB (12)	46.81	19.37	26.50	21.96
LB (24)	58.82	32.42	39.24	38.17

Notes:

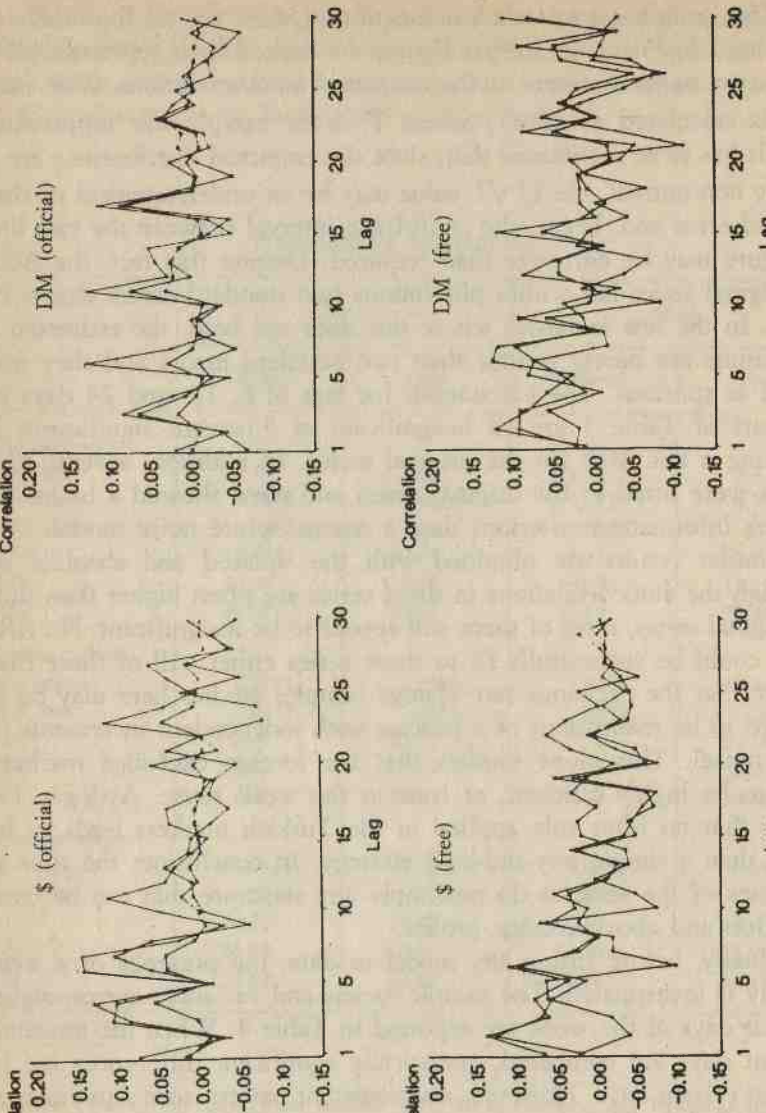
- The critical value of the runs-up test statistic is 12.592 at 5-percent and 10.645 at 10-percent significance level.
- The critical values of LB (6), LB (12), and LB (24): 12.592, 21.026, 36.415 at 5-percent significance level, and 16.812, 26.217, 42.980 at 1-percent significance level, respectively.
- The critical values of Fisher's kappa statistic: 9.12 at 5-percent significance level and 10.72 at 1-percent significance level.
- The critical values of Bartlett's test statistic: 0.061 at 5-percent significance level and 0.073 at 1-percent level (approximately).

The sample autocorrelation functions (ACF) for all four daily series are plotted in Figure 2. In this figure, the dashed lines represent plus and minus two standard errors of the estimated autocorrelations. One standard error is calculated as $1/\sqrt{T}$, where T is the sample size (approximately 520). It has to be mentioned that, since the empirical distributions are significantly non-normal, the $1/\sqrt{T}$ value may be an understatement of the true standard error and, hence, the confidence interval between the two lines in the figure may be narrower than required. Despite this fact, the ACFs of the original series fall within plus/minus two standard errors almost everywhere. In the few instances where this does not hold, the estimated autocorrelations are barely greater than two standard errors and they may be treated as spurious. The LB statistic for lags of 6, 12, and 24 days in the first part of Table 3 are all insignificant at 5-percent significance level, indicating a flat ACF for the original series. In addition, several ARIMA models were fitted to the original series and none showed a better fit (by Akaike's information criterion) than a normal white noise model.

Similar results are obtained with the squared and absolute series. Although the autocorrelations in these series are often higher than those in the original series, most of them still appear to be insignificant. No ARIMA model could be successfully fit to these series either. All of these findings indicate that the exchange rate change samples studies here may be safely assumed to be realizations of a process with independent increments (strict white noise). This alone implies that the foreign exchange markets are likely to be highly efficient, at least in the weak sense. Aydogan (1988) reports that no filter rule applied in the Turkish markets leads to higher profits than a simple buy-and-hold strategy. In conclusion, the time series properties of the samples do not imply any structure that can be used for prediction and above-average profits.

Finally, before fitting any model to data, the presence of a weekday anomaly is investigated. The sample means and variances corresponding to different days of the week are reported in Table 4. When the moments on different days are compared, statistically significant differences are found between certain days. However, no consistent pattern seems to emerge as a market anomaly. For example, a phenomenon such as the Monday effect does not seem to apply in these markets. Intraday differences in the distributional moments are more apparent in the free rates than in the official rates. On the other hand, official rate changes have higher variances (and higher absolute mean in the case of the dollar) on Fridays than on other days of

FIGURE 2. Autocorrelation Functions



Note: * for original series, + for absolute series, and x for squared series.

TABLE 4

SAMPLE MEANS AND VARIANCES BY WEEKDAY

Weekday	Dollar		Mark	
	Official	Free	Official	Free
Monday	−.0806	−.0061	−.1867	−.0510
	.0168	.0439	0.391	.0455
Tuesday	−.0848	−.1878	−.2178	−.2310
	.0116	.0336	.0265	.0287
Wednesday	−.0913	−.0534	−.1373	−.2422
	.0095	.0259	.0171	.0347
Thursday	−.0815	−.3017	−.2154	−.3172
	.0095	.0505	.0244	.0587
Friday	−.1734	.0298	−.1707	−.1196
	.0369	.0430	.0653	.0440

Note: The first row contains the sample means and the second row the sample variances, both in 00s.

the week: this may be the only exception to the above statement of no anomaly.

3. *Statistical Models and Analysis*

In this section, four probability models are fit to samples of daily exchange rate changes: the infinite-variance stable distribution, the mixed diffusion-jump model, the compound normal distribution, and the generalized autoregressive conditional heteroscedastic process model. The theoretical foundations of all of these models are consistent with the data characteristics reported in the previous section. The fits of the models are then compared to choose the most descriptive model for TL exchange rates. As a benchmark, the simple normal distribution is also included in this comparison. As these models are well-known in the statistics and finance literatures, only brief descriptions are given.

3.1 *Stable Laws.* – Stable laws have been introduced into the economics literature by Mandelbrot (1963) and Fama (1965), and they have often been used to explain the empirical distributions of various speculative price changes. The statistical and economic appeal of stable laws lie in their basic defining properties: (a) Only stable laws can be the limiting distributions of sums of independent identically distributed random variables, and (b) the distributions of the sums of stable random variables are also stable. Since the change in any speculative price over a given length of time can be viewed as the sum of many independent and (approximately) identically distributed random effects, it should be subject to a stable distribution (at least, asymptotically). The normal distribution is the most widely used stable distribution.

A stable distribution is defined in terms of four parameters: location parameter ($-\infty < \delta < \infty$), scale parameter ($c > 0$), measure of skewness ($-1 \leq \beta \leq 1$), and the index ($0 < \alpha \leq 2$), also known as the characteristic exponent. The cases $\beta > 0$, $\beta < 0$, and $\beta = 0$ correspond to left skewness, right skewness, and symmetry about δ, respectively. The index α is interpreted as a shape parameter: distribution tails are "thicker" the lower the value of α. Moments of order $k \geq \alpha$ do not exist. The case $\alpha = 2$ is the normal distribution with finite moments of all orders. Consequently, the choice between a normal distribution and a non-normal stable distribution is based on whether $\alpha < 2$. Detailed descriptions of stable laws may be found in Feller (1971).

The lack of closed-form expressions for general stable distribution functions is a major difficulty in designing maximum likelihood estimation procedures. Among several alternative estimation methods, the regression--type method developed by Koutrouvelis (1980) seems to rank best with respect to its statistical properties and it is adopted here. This method gives unbiased and consistent estimates of all four parameters without any restrictions on the parameter space. The full stable law analysis in this paper consists of two steps. In the first step, the fit of stable distributions is investigated by checking whether the stability property is satisfied in the samples. This involves estimating the four parameters from samples of sums of one, two, and four daily observations. If the observations are stable random variables, then the estimates of the index α from samples of different sum sizes must be statistically identical. The second step consists of the analysis of empirical tail shapes independently from the central observations. The tail-shape analysis supplements the first step analysis, and it is based on the idea that stable laws are most easily distinguishable from finite-variance distributions in their extreme tails. The procedure is developed by

TABLE 5

STABLE LAW ANALYSIS

Parameter	Dollar		Mark	
	Official	Free	Official	Free
Index	1.725	1.457	1.675	1.520
	1.641	1.774	1.624	1.763
	1.660	1.797	1.654	1.765
Skewness	.397	.481	.582	.542
	.131	.279	.380	.885
	.036	.811	.233	1.000
Scale (00s)	.199	.296	.272	.313
	.291	.540	.399	.549
	.404	.730	.560	.837
Location (00s)	−.107	−.072	−.189	−.251
	−.197	−.231	−.374	−.442
	−.381	−.551	−.715	−.906
Tail-shape (γ)	.3902	−.1212	.4073	.1654
$(\gamma + 2(se))^{-1}$	1.503	18.94	1.458	2.517
$(\gamma - 2(se))^{-1}$	8.696	−3.39	7.770	−15.1

Note: In the upper part of the table, the first row contains the estimates from samples of one daily observations, the second row from samples of sums of two daily observations, and the third row from samples of sums of four daily observations.

DuMouchel (1983), and it gives a tail-shape parameter γ. If the underlying distribution is indeed stable, then $\gamma > 0$ and $1/\gamma \approx \alpha$. The parameter γ is estimated using the upper and lower 10-percent of the order statistics. Detailed explanation of this general approach may be found in Akgiray and Booth (1988a).

The parameter estimates are reported in Table 5. The upper part of the table contains the regression-type estimates of the four stable distribution parameters for sums of one, two, and four daily exchange rate changes. The estimates of the tail-shape parameter γ along with confidence bounds around $1/\gamma$ are given in the lower part. Important differences are found between the official and the free rate samples. For the official rates, the

estimates of the index α do not show any upward tendency towards 2 as the sum size increases from one to four daily observations. In other words, the stability property is not violated. On the other hand, the index values for the free rate changes tend to increase and may be approaching 2, a condition that implies the rejection of infinite-variance stable laws in favor of some finite-variance distribution. The tail-shape analysis confirms these findings. For the official rates, the empirical tails are found to be consistent with stable tails: for both currencies, $(\gamma + 2\,(se))^{-1} < \alpha < (\gamma - 2\,(se))^{-1}$. Similar consistency is not found in the free rate distribution tails.

Therefore, it appears that the distributions of official exchange rate changes may be modeled as stable distributions with index values less 2, and that the distributions of free rates appear to have finite variances. This difference between the official and the free rates as it regards their relative compatibilities with stable laws may be explained as follows. If the official exchange rate is adjusted at discrete time intervals rather than continuously as new information becomes relevant, then a given change in the rate will reflect cumulative impact of information arrivals since the last rate adjustment. Consequently, the moments of the empirical distributions will be dominated by only a few observations, and they will appear to 'wander erratically' over time. Indeed, the high levels of leptokurtosis are mere reflections of this phenomenon. A natural way of modeling these types of uncertainty is the stable distribution, and this seems to be the case here.

3.2 *Mixed Diffusion-Jump Processes.* – These probability models have been first suggested for stock prices by Press (1967) and then studied in detail by Merton (1982). They have been shown to adequately describe the time paths of stock prices (Akgiray and Booth, 1986) and also those of several foreign exchange rates (Akgiray and Booth, 1988b). Mixed diffusion-jump processes are constructed by the superposition of a diffusion process and an independent compound jump process. The prototype of these processes is obtained by letting the diffusion process be a Brownian motion and the jump process be compound Poisson. The implied time path is a mixture of continuously varying price (governed by the Poisson process). The result is a fairly general independent increment process with finite moments.

The mixed process is described in terms of five parameters: the mean (μ_d) and the variance (σ_d^2) of the Brownian motion component, the jump intensity (λ) of the Poisson process (denoting the expected number of jumps per unit time), the mean $(\mu_j)$and the variance (σ_j^2) of the jumps, which are assumed to be normally distributed. The resulting density function can

TABLE 6

MIXED DIFFUSION-JUMP PROCESS ESTIMATES

Parameter	Dollar		Mark	
	Official	Free	Official	Free
μ_d (00s)	−.0935 (.0178)	.0118 (.0562)	−.1667 (.0355)	−.1276 (.0252)
μ_j (00s)	−.2792 (.0397)	−.1102 (.0103)	−.1.8106 (.6944)	−.3237 (.1760)
λ	.0325 (.0124)	1.1473 (.4661)	.0692 (.0159)	.1843 (.0615)
σ_d^2 (000s)	.0114 (.0013)	.0138 (.0068)	.0327 (.0059)	.0283 (.0021)
σ_j^2 (000s)	.0773 (.0058)	.0692 (.0206)	.0751 (.0130)	.0543 (.0039)
log-likelihood	2191.9	1886.9	1981.3	1915.6

be expressed in closed form and hence maximum likelihood estimation is available. The particular numerical maximization algorithm used here is described in detail by Akgiray and Booth (1986). Inference about the fit of these processes is also straightforward. When the restriction $\lambda = 0$ is imposed, the resulting distribution is normal with mean μ_d and variance σ_d^2. Consequently, letting L_m and L_n denote the maxima of the log-likelihood function for the unrestricted mixed process and that for the restricted normal process, respectively, the statistic $-2(L_n - L_m)$ is asymptotically chi-square with three degrees of freedom.

The maximum likelihood estimates of the five parameters and the log-likelihood function values at these points are reported in Table 6. Most importantly, the estimates of the jump intensity λ and the jump size variance σ_j^2 are significantly different from zero, indicating the presence of statistically significant random jumps in the exchange rate series. To assess the overall fit of the model, chi-square test statistics (based on the log-likelihood values in Table 6 and those for the normal distribution in Table 2) are calculated as explained above, and they are all found to be significant.

The conclusion is that the mixed diffusion-jump process is more descriptive than a pure diffusion process for all four series.

When the parameters estimates for the official rate series are compared with those for the free rate series, interesting differences are observed. For both currencies, the official rates have lower jump intensities but higher jump means (in absolute terms) and higher jump variances. This is consistent with the finding of higher leptokurtosis in the official rate samples and also with the better fit of stable distributions to these samples. The practical interpretation is that the official rates are adjusted less 'smoothly' (larger and more variable discontinuities in their time paths) than the free market rates. This phenomena can again be related to the way the authorities set the official exchange rate on a daily basis.

3.3 The Compound Normal Distribution. – In this approach, an observed exchange rate change is modeled as a drawing from one of K distinct normal distributions. At any point in time, the probability of coming from the kth normal distribution with mean μ_k and variance σ_k^2 is equal to p_k, where $p_1 + ... + p_K = 1$. Hence, the probability density function for a compound normal random variable is the linear combination of the density functions of the component normal variates, with weights $p_1, ..., p_K$. As discussed in Kon (1984) and Akgiray and Booth (1987), several economic scenarios may lead to a compound normal distribution of price changes. The model is particularly applicable when there are changes in the economic environment generating the exchange rates, and the timing and nature of these changes cannot be identified deterministically. Such changes are described by the differences in the parameters of the K normal distributions. In general, these models are capable of explaining all the empirical characteristics of the exchange rate series.

A compound normal distribution has $3K - 1$ distinct parameters, and they are efficiently estimated by the EM (Expectation-Maximization) algorithm, which is maximum-likelihood based and specifically designed for general mixture densities. The estimation procedure is carried out in two dimensions: (1) Estimate the parameters for given K, and (2) determine the optimal value for K. Since a compound normal distribution with $M - 1$ normals is nested within the parameter space of another with M normals, chi-square tests based on the likelihood ratios are readily available and their successive application yields the optimal value of K for a given sample. The case $K = 1$ is the single normal distribution.

The results for all four series are reported in Table 7. Based on the

TABLE 7

COMPOUND NORMAL DISTRIBUTION ESTIMATES

Parameter	Dollar		Mark	
	Official	Free	Official	Free
p_1	.009	.472	.009	.789
	(.005)	(.053)	(.007)	(.062)
μ_1 (00s)	−.932	−.025	−3.282	−.113
	(.048)	(.006)	(.166)	(.021)
σ_1 (00s)	2.541	.217	2.308	.398
	(.919)	(.045)	(.269)	(.085)
p_2	.289	.528	.336	.211
	(.011)	(.001)	(.008)	(.082)
μ_2 (00s)	−.156	−.176	−.281	−.491
	(.012)	−(.032)	(0.82)	(0.99)
σ_2 (00s)	.475	.846	.651	1.152
	(.082)	(.192)	(.155)	(.348)
p_3	.702		.655	
	(.001)		(.011)	
μ_3 (00s)	−.069		−.095	
	(.027)		(.031)	
σ_3 (00s)	.234		.301	
	(.100)		(.039)	
log-likelihood	2245.2	1927.4	2072.4	1916.5

likelihood ratio tests, mixtures of two normal distributions ($K = 2$) is best for the free rate samples. The addition of a third normal distribution is needed for the official rate samples. The reason for this difference between the free and the official rates is not clear. Mixtures of four or more normals, however, do not provide significantly more explanation for either series. Most of the parameter estimates are statistically significant. In all cases, either $\mu_i \neq \mu_j$ or $\sigma_i \neq \sigma_j$ for $i \neq j$, implying that the empirical densities are either skewed, or leptokurtic, or both. The inequalities between the component means may also indicate multi-modality. All of these findings are consistent with those in the preceding sections.

3.4 *GARCH Models.* – As reported before, the time series properties

of the four exchange rate series do not indicate any clear intertemporal dependence that can be exploited for modeling purposes. This is in sharp contrast with the published evidence about the exchange rates between other countries' currencies. For comparability with other studies, an attempt is made in this section to model the time series of TL exchange rates as Generalized Autoregressive Conditional Heteroscedastic (GARCH) processes, which are developed by Engle (1982) and Bollerslev (1986). Whatever dependence structure may exist in the TL series, it is more likely to be detectable in the squared and absolute series. Such dependence is naturally representable as conditional heteroscedasticity, where the variance of the series is time-dependent.

Since a flat autocorrelation function was found for all four original series, it is not necessary to specify a time-dependent mean in this application. Accordingly, the conditional (conditional on the past realized values) distribution of exchange rate changes R_t $t = 1, ..., T$, is assumed to be normal with mean μ and time-dependent variance v_t, where $v_t = \alpha_0 + + \sum_{i=1}^{p} \alpha_i (R_{t-1} - \mu)^2 + \sum_{j=1}^{q} \beta_j v_{t-j}$. The parameters satisfy the conditions $\alpha_0 > 0$, $\alpha_i \geq 0$ for $i = 1, ..., p$, $\beta_j \geq 0$ for $j = 1, ..., q$, and p and q are the orders of the process, denoted by GARCH (p,q). General expressions for the unconditional densities are not available. If $q = 0$, the well-known ARCH process is obtained and, if both $q = 0$ and $p = 0$, the simple normal distribution results with constant parameters. This nested structure makes possible the determination of the optimal order of GARCH processes for a given sample and also the assessment of goodness-of-fit: Likelihood ratios are directly calculated to perform chi-square tests. The parameters are estimated by maximum likelihood. For details, see Akgiray (1989) and Bollerslev (1986).

For the four series studied here, a GARCH (1,1) specification is found to be adequate by chi-square tests. There is no significant increase in the models explanatory power when the orders of the process are further increased. The parameter estimates and the maximum log-likelihood function values are reported in Table 8. All of the estimates are statistically significant. Applying a test (Dickey and Fuller, 1979) for unit roots, the hypothesis that $\alpha_1 + \beta_1 \geq 1$ is rejected in all samples. This indicates that the series are likely to be second-order stationary. Finally, the log-likelihood function values in Table 8 and those for the normal distribution in Table 2 indicate that GARCH (1,1) models are superior to normal laws as models of exchange rate series. This conclusion is reached by chi-square tests of fit as

TABLE 8

GARCH (1,1) ESTIMATES

Parameter	Dollar		Mark	
	Official	Free	Official	Free
α_0	.00291 (.00101)	.00867 (.00183)	.00221 (.00082)	.00481 (.00113)
α_1	.36654 (.10249)	.09418 (.00645)	.24532 (.04224)	.06637 (.00463)
β_1	.57609 (.13210)	.68848 (.05538)	.63551 (.21009)	.82359 (.06381)
log-likelihood	2139.4	1876.5	1947.9	1860.1

mentioned above. The fit of GARCH models relative to the other models remains to be seen in the following section.

4. *Comparison of Models*

The empirical evidence reported in the previous sections indicate that the mixed diffusion-jump process, the compound normal distribution, and GARCH (1,1) all fit to daily exchange rate change data better than the normal distribution. For the official rate series, stable laws with index values around 1.6 are also plausible. The next step is to determine the most descriptive model of exchange rate behaviour, and this requires statistical comparisons of the models' fit to data.

None of the four competing models can be derived by putting restrictions on the parameters of another and, hence, classical hypothesis tests based on the distribution of the likelihood ratios are not possible. Alternatively, a Bayesian posterior-probability criterion may be used, where the model with the highest posterior probability of being "correct' is selected. Assuming equal prior probabilities for all models under consideration, Schwarz (1978) has derived a simple approximation to this criterion: Select the model with the highest value of SC defined as $SC = L(\phi) - d \log$

TABLE 9

SC VALUES FOR MODEL COMPARISON

Model	Dollar		Mark	
	Official	Free	Official	Free
Normal	2124.2	1863.3	1938.9	1849.1
Diffusion-Jump	2176.4	1870.4	1966.4	1900.1
Compound Normal	2220.4	1911.9	2048.2	1901.0
GARCH (1,1)	2131.4	1867.2	1938.6	1850.8

$\sqrt{T}$, where $L(\phi)$ is the log-likelihood function value evaluated at the maximum likelihood estimates of the parameters ϕ, d is the dimension of the model (that is, the number of independent parameters), and T is the sample size. In large samples, the SC criterion can be shown to be asymptotically valid in that it selects the correct model.

Unfortunately, the stable law model has to be left out of these comparisons because neither the maximum likelihood estimates of the parameters nor reliable calculations of the likelihood values are available. The SC values corresponding to the other three models and the normal distribution model are reported in Table 9. The following general results are obtained. First, all of the models are superior to the normal distribution, a finding that fully agrees with the classical test results of the previous sections. Second, the mixed diffusion-jump process model is better than the GARCH (1,1) model in all cases. Finally, and most importantly, the compound normal distribution model is superior to all of the other models by clear margins. Therefore, among the models and the sample used in this study (with the possible exception of stable laws for official rates), the compound normal distribution is the most descriptive model of TL exchange rate behaviour.

5. *Conclusions*

This paper examines the statistical properties of the exchange rates of the Turkish lira with the U.S. dollar and the German mark. The empirical

distributions of exchange rate changes show significant departures from the normal distribution. They are more peaked in the center and have thicker tail shapes. Five probability models are fit to daily data, and the compound normal distribution model is found to have the greatest descriptive validity in general. Several interesting differences are observed between the behaviours of official and free market rate, and they are also reported throughout the paper.

The generality of the study is limited in two respects. First, the sample time period covers only two years. A longer time span would have been preferable, on both economic and statistical grounds. Secondly, although infinite-variance stable laws seem to fit to official rate samples, a complete comparison with its alternatives could not be provided for lack of reliable maximum likelihood procedures. This hints one future research direction in this area.

The intertemporal behaviour of the TL values exhibits important differences from those of other currencies. When compared with the exchange rates between the currencies of the less developed countries (for example, Latin American countries) and those of the major industrialized countries, the empirical distribution of TL exchange rate changes (especially, the free market rates) appears to be 'less non-normal' in that it contains fewer and smaller extreme values. For example, stable laws show very good fits to Latin American black market exchange rate changes (Akgiray, Booth, and Seifert, 1988) whereas the Turkish black market series seem to follow finite-variance processes. Furthermore, the TL exchange rates are also considerably statistically different from the exchange rates between the currencies of the major industrialized countries. The most important difference regards the time series properties: The TL exchange rate series exhibit no (or, very little) time dependence while significant levels of higher order autocorrelation are found in the time series of the others (see Bollerslev, 1987, and Milhoj, 1987). This may have implications for relative efficiencies of the markets, and has to be explained in terms of relative market activities. This finding would seem to be another interesting future research topic.

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L'ANDAMENTO DEI TASSI DI CAMBIO ESTERI: L'ESPERIENZA TURCA

Scopo di questo articolo è di esaminare la struttura probabilistica dei tassi di cambio quotidiani sul mercato ufficiale e sul mercato nero per il dollaro USA e il marco tedesco rispetto alla lira turca per un biennio a partire dal settembre 1985. Vengono considerati cinque possibili modelli: per la distribuzione normale, la distribuzione stabile con un esponente caratteristico inferiore a due, la distribuzione normale composta, il processo misto diffusione-salto ed un processo GARCH.

I cinque modelli sono stati tutti presentati per spiegare l'evoluzione dei tassi di cambio. Le distribuzioni empiriche mostrano significativi scostamenti dalla normalità: hanno un picco più alto al centro e code più spesse. Per i tassi sul mercato nero la distribuzione normale composta risulta la migliore in termini di capacità esplicativa. Questo modello fornisce anche una buona spiegazione per i tassi ufficiali. Vi è tuttavia qualche evidenza che anche le leggi stabili possono fornire un modello adeguato per questi ultimi saggi di cambio.

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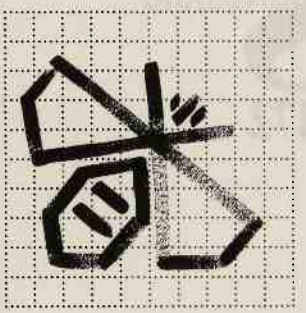

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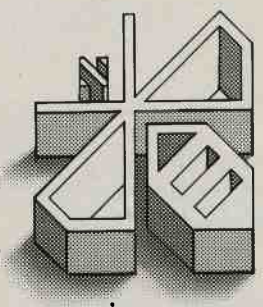

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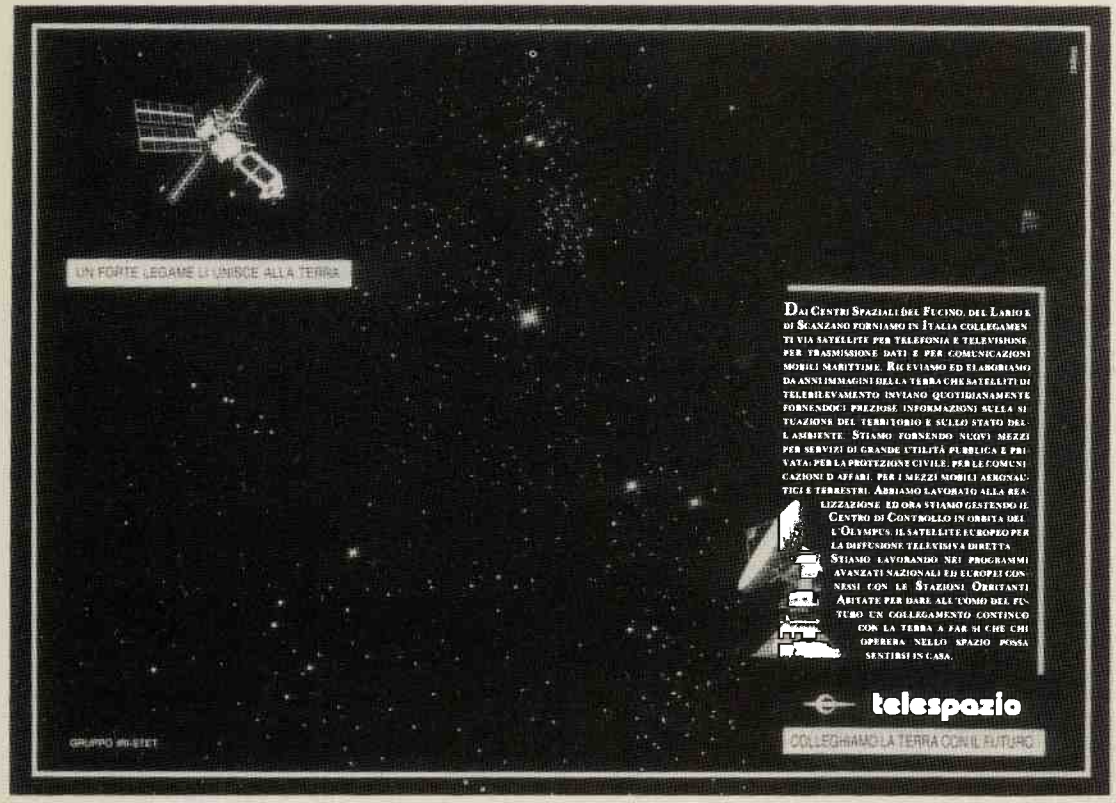

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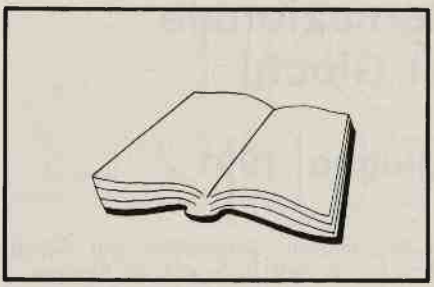

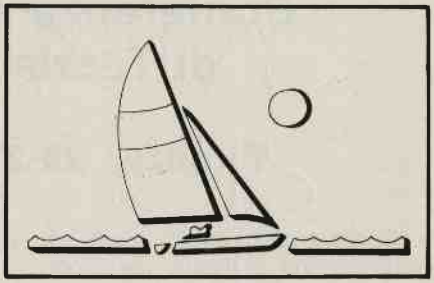

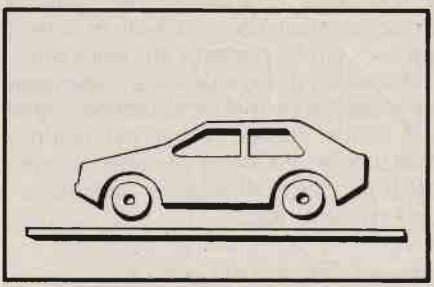

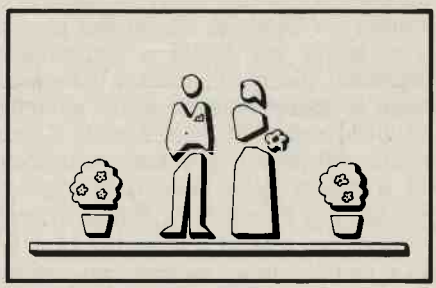

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