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UNCERTAINTY, TECHNICAL CHANGE AND EFFECTIVE DEMAND

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ABSTRACT

In the last two decades, technical change has assumed a central role on the understanding of the economic performance. The emergence of the new Neoclassical growth models and the increasing relevance of the Evolutionary school of thought are two expressions of this change. Reflecting this trend, this dissertation is about technical change. The aim of the study is to incorporate the Evolutionary and Institutional understanding of technical change into the framework of Keynes/Post-Keynesian.

We use the concepts of probable knowledge and weight of argument, which come from Keynes's theory of probability, to explain both the decision to introduce an innovation and the development of a technological trajectory. In this sense, the evolution of the weight of argument related to the decision to introducing an innovation can explain different degrees of uncertainty that exist in different stages of the development of a technological trajectory.

This discussion drives us to the analysis of the formation of expectations. Accordingly, we claim that the Keynes's taxonomy of short- and long-period expectations is insufficient to deal with continuous technical change. Thus, a new kind of expectation is proposed that is medium-period expectations. The main important feature of the latter is their influence upon the formation of long-period expectations, which will determine a partial endogeneity of the investment decision.

Finally, we analyse the impact on the effective demand due to this new taxonomy of expectations. We conclude claiming that the incorporation of medium-period expectations and its relation with long-period expectations generates a system with constantly evolving expectations. In this system, a level of employment of equilibrium, regardless the way it is defined , will never be achieved.

To my wife Fabiana

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INTRODUCTION

In the last twenty years, technical change has been widely recognised as a fundamental feature to explain economic activity. This increasing importance of technical change can be verified by some facts, as such as the emergence of the new Neoclassical growth models and the increasing role played by the Evolutionary and Institutional schools of thought within the economic debate. Following this trend, this thesis is also about technical change and macroeconomics.

The way this subject will be handled here reflects a particular view of the author. We have a strong sympathy to the Post-Keynesian interpretation of macroeconomic events. However, we acknowledge that this school of thought has been giving little attention to the whole dimension of the technological change phenomenon. A read throughout the most important works in this school will show that concerns about technical change are overlooked or are stylised as a phenomenon exogenous to the system. Being generated exogenously, it is not necessary to theorise about it, but only to analyse the implications of its introduction into the economic system.

However, in the same way as 'money matters', the way technical change is generated and incorporated into the system also 'matters'. Because of this, we also have a strong sympathy to the contributions of the Evolutionary and Institutional approach to technical change. As it will be shown, this approach has been able to analyse technical change in all its institutional dimensions (technological paradigms and technological trajectories, for example), and not only through variations on capital/output and labour/output ratios or shifts in the production function. However, we think that this school of thought shows a strong technological determinism, which overshadows the fact that investment is undertaken under conditions of true uncertainty.

Therefore, the thesis is an initial exercise of trying to incorporate some of the richness of the Evolutionary and Institutional approach to technical change into the macroeconomic framework of Post-Keynesians. It is an initial exercise for we are fully aware that this task goes far beyond a simple Ph.D. dissertation. The only claim made here is that what follows can be understood as a (modest) step in this direction.

To make this step, however, we have to keep in mind some methodological cautions to base the analysis. As it will be seen this dissertation asks for some modifications of the microfoundations of Post-Keynesian macroeconomics. However, this does not mean that we have some empathy with methodological reductionism. Reductionism is defined as a method which "involves attempts to explain the whole through its analytical reduction to its presumed microfoundations and component parts" (Hodgson 1999: 61). It is a general principle, applied in different subjects like biology and Newtonian mechanics[1], which claims that all complex phenomena can be explained in their totality in terms of one level. In economics, reductionism is expressed by the methodological individualism, which postulates that the individual responds to the outside world through the perception of its constraints and opportunities (Hodgson 1988: 54)[2].

The feasibility of the methodological reductionism as a general method of investigation has been challenged in all areas. In mechanics, for example, there is the so-called three-body problem, to which no general solution has been found. In biology, in its turn, there is a computational problem that is unmanageable due the number and fitness specifications of the genotypes.[3] Finally, the chaos theory has shown that

> we cannot with absolute confidence associate a given outcome with given set of initial conditions, because we can never be sure that the computations traced out from those initial conditions are precise enough, and that the initial conditions themselves have been defined with sufficient precision.
>
> (Hodgson 1999: 64)

For the reasons that will be explained on Chapter Five, we believe that it is impossible to explain any macro phenomenon to its constituent micro-elements. In other words, we reject reductionism as a methodological approach to understand economic events

This caution is necessary as we believe it is impossible to capture all the micro characteristics of the Evolutionary and Institutional approach to innovation in a macroeconomic framework, at least at the expense of simplicity without much gain in

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[1] For example, in biology reductionism assumes that the behaviour of organisms, groups and whole species can be explained in terms of their genes. Also, in Newtonian mechanics the particle is the elemental unit of analysis.
[2] According to Hodgson (1988: 56), von Mises brought a "explicit disccusssion of this principle into economics." In von Mises' view,

> the principle of methodological individualism involves the recognition that 'all actions are performed by individuals' and 'a social collective has no existence and reality outside of the individual member's action.
>
> (Von Mises 1949: 42)

[3] The case of the prediction of evolution with multiple loci or alleles is representative:

> even the simplest multi-locus case of two alleles at each of two loci is analytically intractable. This should not be surprising: the problem of dimensionality nine (there are nine possible genotypes, with independently specifiable fitness parameters) is already more complicated than the three-body problem in classical mechanics.
>
> (Wimsatt 1980: 223, quoted from Hodgson 1999: 64)

the understanding of the macro phenomenon. This implies that, as the following chapters will show, we have to choose some of these features to deal with, and make some simplified assumptions in relation to others. The criteria to make these choices will be the relevance (in our opinion) of some specific assumption to the event to be studied.

Two main assumptions are taken as given, and these constitute the start point of the enquiry: (i) true uncertainty is an inherent feature of innovative activity and can never be eliminated and (ii) in every investment decision there is a technological element that has to be taken into account. It is through these two assumptions that the intended step towards the incorporation of the Evolutionary and Institutional understanding of technical change into the Post-Keynesian Macroeconomics will be made.

In Chapter I, a brief review of the literature is made. This review does not intend to cover all economic literature but only that schools of thought we will be dealing with (Evolutionary and Institutional and Post-Keynesians) plus the new Neoclassical growth models as they are the main reference in economic literature. Moreover, our investigation concentrates on those aspects that are important to the rest of the research. It is necessary to delimit the investigation of these schools for, most of the time, they are interested in different aspects and implications of technical change. Thus, we assess only those features that have a direct bearing on the argument developed in the dissertation. After the discussion of those approaches, we systematise our understanding of technical change, which will be used throughout the thesis. This understanding of technical change can be summarised as follows:

> ... one often observes relatively ordered patterns of technical change in both spaces of input coefficients and product characteristics (i.e. what I have called elsewhere technological trajectories) grounded in rather invariant, incrementally augmenting, knowledge bases (i.e. technological paradigms), every now and then intertwined by major discontinuities in both the sources of knowledge and the directions of change.
>
> (Dosi 1998b: 1533)

Moreover, like Keynes and Post-Keynesians, the Evolutionary and Institutional approach acknowledges that uncertainty is always present and can never be eliminated. Thus, in Chapter II we discuss a concept of uncertainty that can be used by both schools of thought. Based on the recent literature on Keynes's *Treatise on Probability* a concept of uncertainty capable of being ranked is developed and proposed. The understanding that uncertainty can come in degrees is fundamental to explain the different kinds of uncertainty an innovator faces.

The application of this Keynesian concept of uncertainty to explain different degrees of uncertainty that exist during the development of a technological trajectory is made in Chapter III. We show that there is a weight of argument attached to every technological trajectory and it will vary according to the stage of development of the trajectory. Moreover, it is suggested that technological diffusion can be understood as a conventional process. For this, the concepts of *Social* Probable Knowledge and *Social* weight of argument are suggested.

In Chapter IV, we examine the implications of this understanding of technical change to the Post-Keynesian Theory. As we are assuming that every investment decision has some technological element involved, we investigate what the consequences for the process of expectations formation assumed by the Post-Keynesians are when the approach developed in Chapters I, II and III are taken into account. We show that the standard division between short- and long-period expectations is insufficient to deal with all important features of technical change. Thus, the concept of *Medium-Period Expectations* is developed and its connection with short- and long-period expectations explored.

Finally, in Chapter V we study the implications of this approach for Effective Demand. As it will be shown, the introduction of the assumption of continuous technical change implies that the a *constantly evolving expectation model* should be used as a norm. This conclusion is derived from the fact that the introduction of *medium-period expectations* partially endogenises the formation of long-period expectations.

In the conclusion, we make a summary of the main propositions and results of the dissertation, and we point out some of the future developments which may be pursued in line with the work done in this research.

CHAPTER I

TECHNICAL CHANGE IN KEYNES, POST-KEYNESIAN, NEOCLASSICAL AND EVOLUTIONARY THEORIES : A BRIEF REVIEW

Introduction

The aim of this chapter is to present a brief review of the way some schools of thought characterise technical change. The schools of thought chosen are analysed according to the main objective of the thesis, that is to discuss the impact of technical change on Keynes's analysis. Thus, Keynes and his followers must be the starting point, and they are analysed in the following section. The Neoclassical approach is also analysed due to its place in economic theory, especially after the rise of the so-called New Neoclassical Growth Models. Section I.2 is devoted to this school. Finally, the choice of the Evolutionary and Institutional (hereafter EI) approach is due to its particular understanding of the technical change process. As will become clear in this chapter, this approach is the one favoured by the author, thus will be considered as a landmark for the development of the thesis.

I.1 Keynes and the Post-Keynesian Approach to Innovation

It is often noted in economic literature that Keynes did not put technical change at the centre of his analysis. Few comments from him can be found on this subject. Interestingly, these few quotations do not suggest that Keynes considered technical change an incidental element of economic analysis. In his *Treatise on Money* he says,

> In the case of fixed capital, it is easy to understand why fluctuations should occur in the rate of investment. Entrepreneurs are induced to embark on the production of fixed capital or deterred from doing so by their expectations of the profit to be made. Apart from the many minor reasons why these should fluctuate in a changing world, Professor Schumpeter's explanation of the major movements may be unreservedly accepted ...

> It is only necessary to add to this that the pace at which the innovating entrepreneurs will be able to carry their projects into execution at a cost in interest which is not deterrent to them will depend on the degree of complaisance of those responsible for the banking system. Thus, while the stimulus to a credit inflation comes from outside the banking system, it remains a monetary phenomenon in the sense that it only occurs if the monetary machine is allowed to respond to the stimulus.
>
> (Keynes, *C.W.* VI: 85-86)

The above quotation explains much of Keynes's attitude to technical change. Although he recognises the role of technical change, he adds that this role can only take place if it is allowed by the monetary side of the economy, i.e. the banking system. This understanding could offer an explanation for the place that he reserves for technical change in his works.[4] Concerning the work of a monetary economy, he builds an hierarchy among economic subjects and considers that technical change should be taken into account only after the correct understanding of a monetary economy. This could be an acceptable explanation for the little concern for technical change in *The General Theory* (hereafter *GT*). In this work, the only part where technical change plays an important role is in Chapter 11 in the discussion about the expectation of prospective yields on the calculation of the *marginal efficiency of capital*. In his words,

> The output from equipment produced to-day will have to compete, in the course of its life, with the output from equipment produced subsequently, perhaps at a lower labour cost, perhaps by an improved technique, which is content with a lower price for its output and will be increased in quantity until the price of its output has fallen to the lower figure with which it is content.
>
> (Keynes, *C.W.* VIII: 141)

However, as technical change can affect a vital element of the Keynes investment theory, why did Keynes not spend more time on the analysis of this element? The only answer that occurs to us is that Keynes implicitly adopted, as did his followers, a view of technology as a blueprint, where anyone is able to use the best technique available.

I.1.1 Salter and Joan Robinson Approaches

The Cambridge (UK) tradition considers technical change to be a very important element in the understanding of the economic system. Indeed, one can say, without

[4] Moreover, one must remember that because of the depressed 1920s and early 1930s, not much investment was taking place. This also helps to understand the weak emphasis Keynes had put on technical change (Chick 1992: Chapter 1).

fear of being mistaken, that this branch of Post-Keynesians[5] understands better than Keynes himself the role of technical change in the economic analysis. However, the Cambridge tradition does not have a uniform treatment of this subject. In this section, a brief consideration of the works of Salter and Joan Robinson is given. In the next two, Kaldor and the theorists of Vertical Integration (Pasinetti and Eichner) will be considered. It has to be warned that the following analyses will briefly set out only the main aspects of each author's approach, concentrating on their characterisation of technical change.

Salter, in his book *Productivity and Change (1960)*, recognises the peculiarities of technical change for the understanding of the economic process. He starts by discussing the relationship between technical knowledge and production possibilities. He argues that there are three levels of knowledge (i) basic principles of physical phenomena (pure science); (ii) application of these principles to production (applied science) and (iii) day-to-day operations of production (rules of thumb of the craftsman).[6] These levels of technological knowledge create problems for the idea of alternative techniques given by the state of the knowledge that is implicit in the traditional production function, for it has to be made explicit to what kind of knowledge one is referring. Obviously, this discussion reflects on the definition of production function assumed by Salter.

The author chooses a concept of a production function that represents the "techniques which are feasible in principle but have not been developed because the necessary economic pressures are absent" (Salter 1960: 26). In other words, it is a planning function in a world of blueprint. What is behind this definition is the discussion about the circumstances in which a concept of production function is relevant. According to Salter's definition, the production function is relevant only in the moment of investment decision and, after that, there is no meaning for this concept.

The measurement of factors of production is made in the following way: labour is assumed to be homogeneous and measured in units of man-hours; capital is measured in terms of real investment, and "there is no need to consider directly the capital equipment already in use" (Salter 1960: 26). This definition of measurement of capital has two important features: (i) it is supposed that it avoids the problem of capital measurement implied by the capital controversy.[7] As each technique chosen at the

[5] For a discussion about the strands that originated Post-Keynesians see Harcourt and Hamouda (1992).

[6] As we will see, this taxonomy of knowledge resembles Polanyi's (1958, 1967) distinction between tacit and explicit knolwedge.

[7] There is no consensus on this point in the literature. Harcourt, for example, seems to agree:

moment of the investment decision has its own price and this price is applied only for the total real investment in that technique, the problem of aggregation of the different types of capital disappear;[8] and (ii) the choice between alternative techniques can only take place prior to the act of investment. From this moment, during all the life of the equipment, factor substitution is a short-term problem, limited by the nature of the equipment and not by the restraints of technical knowledge.

After this first discussion, Salter moves on to the analysis of the best-practice techniques and the determinants of their movements. He assumes that relative factor prices plus technical knowledge combine to determine the nature of the flow of new techniques coming into use. The movements over time of the best-practice technique are due to three main influences: the rate of advance of technical change; biases towards uneven factor savings; opportunities of factor substitution. The author suggests ways to measure each of these movements.

> The rate of technical advance is defined by reference to the rate at which unit costs fall when factor prices are constant; biases are measured by the rate at which factor proportions change when factor prices are constant; and the ease of substitution is defined by the conventional concept of the elasticity of substitution.
>
> (Salter 1960: 45)

What is important to note is that there is no comment about the factors that are behind the rate of technical change. The absence of any explanation for this rate together with

---

> The factor of production, capital, is regarded as investment and is measured in 'two dimensions: an initial real investment and the life of this investment' ([Salter 1960] p. 18). This avoids the vexed problem of measuring capital, for only the output to be produced by best-practice technique is under consideration.
>
> (Harcourt 1982: 130)

Rymes, on the other hand, seems to disagree:

> Salter apparently believed that problems associated with the measurement and addition of different kinds of *stocks* of capital goods be evaded by dealing with an *ex ante* production function or investment function. The problem is, however, merely thrown forward on to a comparison of investment in different time periods or different economies.
>
> (Rymes 1971: 71n)

[8] It is interesting to note that what allows Salter to avoid the problems related to the measurement of the stock of capital is his primary intention, which is different from the primary intentions of some participants of the capital controversy. In Harcourt's words:

> Mrs Robinson is concerned with the concept of an aggregate production function, with the capital stock of the economy as a whole as well as with marginal additions to it and with the aggregate distributive shares of broad classes of factors of production. Because she sees a common element in the incomes accruing to all capitalists, she has to value the whole capital stock. Salter, on the other hand, is concerned with investment decisions of businessmen in individual firms and industries.
>
> (Harcourt 1982: 130-131)

the fact that the movement of change in technique is analysed by the impact on factor productivity from a change in the technology outside the economic system, shows clearly that Salter assumes the *technological push* approach to technical change.[9]

An important feature of Salter's approach is the role given to the price of input both in the choice of technique and to the speed of technical change. The use of a production function which encompasses not only the blueprints already on the shelf, but also a much wider range of techniques which have not yet been developed but can be with the current stock of knowledge, allows Salter to construct an iso-product curve in which movement along it is with regard to factor substitution and not technical change. According to Harcourt, this feature of Salter's approach gives it an advantage in relation to Kaldor's approach (to be discussed below), as he

> shows that it is possible to use the idea underlying the technical progress function and, at the same time, to take account of the important distinction between the impact of technical advances, that is, the movement inwards of the iso-product curve, and the impact of changing relative factor process on the choice of the techniques to be embodied in current investment expenditures.[10]
>
> (Harcourt 1982: 133)

Moreover, he assumes that the relative prices of labour and real investment are important in determining the rate of replacement investment. Standards of obsolescence are high when real wages are high, and so, a high level of replacement investment ensures rapid adjustment to new methods. By the same token, when real wages are low, the capital stock adjusts slowly to new methods and average productivity is lower.

These two features of Salter's approach (the role played by relative prices in choice of technique and in the speed of technical change) are disputed by some authors. Rosenberg (1976), when discussing Salter's production function, argues that movement along the iso-product curve cannot be made without a change in the stock of knowledge that generates the production function itself. According to Rosenberg, what Salter means as stock of knowledge is *scientific* knowledge, and to make a movement along the iso-product curve it is necessary to produce some kind of *technical or engineering* knowledge, which is, generally, a costly process, and so, must have some *economic* impact.

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[9] The *technological push* approach to technical change claims that the main source of the innovative activity is the development of scientific knowledge. The *demand-pull*, in its turn, claims that the market signals are the main stimulus to innovation. In section I.3 below, a deeper analysis about these approaches will be made.

In the same way, the assumption that the real wage is a determinant of the part of replacement is disputed. Some studies indicate (Soete and Dosi 1983; David 1975) that the features of a new technology are generally superior to the old one so that, even if there is no change in the relative prices, the new technology could be profitably adopted.

This concept of blueprint knowledge is also presented in the work of Joan Robinson. In her discussion on economic growth, Joan Robinson sheds light on the relationship between technical progress and capital accumulation. She analyses the conditions that should be held to guarantee a steady-state growth. Among these conditions, she gives special importance to the balance between the rate of growth of technical progress and the rate of growth of accumulation of capital. In so doing, she has to assume a concept of technical progress that is similar to that used by Salter.

One can find the blueprint concept in her work in many situations, for example, when she describes the process of diffusion of technical progress. The latter is seen as a leap-frog game, where the entrepreneur with the oldest equipment scraps it, buying new equipment that provides the highest rate of profit. In this approach, the diffusion of an innovation is fostered by the pressure of competition. In Robinson's words:

> those who are obstinately conservative, or who cannot raise funds to make the investment required by new methods are finally driven out of business and their space in the economy is taken up by other men.
>
> (Robinson 1965: 85)

It is clear in the above quotation that she assumes a blueprint type of knowledge.

It is interesting to note that, despite this approach to technological knowledge, Joan Robinson touches on the problem of tacit knowledge, although she does not explore it. When discussing the technological frontier, she says that,

> [the technological frontier lies] at the technique which offers the highest rate of profit on investment at the ruling wage rate, or between the two techniques which are equally profitable at that wage rate. [...] For the economy as a whole the degree of mechanisation of the investment plans being carried out, in a given phase of technical knowledge, is governed by the level of real wages.
>
> (Robinson 1965: 107-108)

[10] **Harcourt himself (1992) adopts a characterisation of technology that allows him to define an *ex ante* production function which is similar to Salter's one.**

If there were a continuous range of techniques, every small rise in wage would bring a new technique. If there were a gap between techniques, there would be a certain range of wages over which each technique is the most profitable. However, Robinson draws attention to special cases where the suggested rule for the choice of technique may be jeopardised, of which the most important are: (i) when the minimum amount of investment necessary to introduce a new technique is so large that entrepreneur may not command sufficient finance to introduce it; and (ii) management: "An individual entrepreneur may lack capacity or inclination for managing a business of more than a certain size" (1965: 110). The question here is: Why does she not take into account the capability problem in relation to the management of the technique? Although she takes into consideration whether or not the individual entrepreneurs have the capability to deal with the size of the business, which, to some extent, necessarily implies tacit knowledge, she does not extend this concern to the problem of whether to choose and to adopt a new technique.

It should be borne in mind that both Joan Robinson and Salter are interested in the macro-consequences of technical change. Thus, the utilisation of some restrictive assumptions, such as blueprint technology, must be interpreted under this perspective. However, both acknowledge that the rate of technical progress has an important impact on macroeconomic variables. Joan Robinson, for instance, argues that there are two impacts of change on the rate of technical progress: (i) When there is a decrease in the rate of technical change, the speed of replacement of equipment decreases, creating unemployment in the investment sector. Subsequently, there is unemployment in the consumption goods sector and a slump prevails; (ii) The speeding up of innovations creates an early necessity of replacement and creates a decrease in real-wages (decreasing prices), increasing the rate of accumulation, for the increase on profits. Therefore, she establishes a relationship between 'scientific' knowledge and accumulation. This allows her to define two patterns of accumulation. The first she calls weak accumulation, that is, that situation where the rate of accumulation is lower than the rate of improving the productivity. The outcome is an increase in unemployment, known as technological unemployment. This situation, according to Robinson, leads to a decrease in the rate of expansion in the productivity growth, for the surplus of labour creates a barrier to the stimulus of the adoption of new techniques. The second situation, strong accumulation, is the opposite case; i.e. the accumulation is running ahead of technical progress. The inflation barrier effect (increase in money wages), which sets the upper limit to the possible rate of accumulation, is counteracted by the technical change, which works to decrease the real wage. However, this counterbalance effect cannot allow the accumulation to continue permanently faster than technical change. A situation will arise where the scarcity of labour will determine an increase in real wage and consequently a decline in profits thereby causing the accumulation rate to diminish. What could occur in this situation, according to Robinson, is that the technical progress would speed up to catch up with the accumulation rate.

Given the importance of the rate of technical progress in macroeconomic variables, why is this rate not analysed? As it is so important for the accumulation process, a better understanding of its features is fundamental for the economic analysis itself. The exogenous characterisation of the rate of technical change is a simplification of a deeper and complicated process.

Moreover, even assuming the blueprint approach, one can argue that neither Salter nor Joan Robinson takes into consideration an important aspect of technical progress, that is, its impact on demand. According to Nell's words:

> In her [Joan Robinson] programmatic remarks she stresses the transformational effects of technical changes, but her analytic work was largely confined to attempts to classify innovations according to their impacts on distribution [income], considered primarily from the supply side, but taking into account the impact of changes in distribution on effective demand. The obvious fact that new products transformed household technology, and so altered living patterns and the structure of family life, radically changing demand, nowhere figured in her analytical work.
>
> (Nell 1989: 382)

I.1.2 Kaldor's Vision on Technical Change

The stylised view of technical change in the Post-Keynesian tradition is a benchmark of Kaldor's work. Kaldor, like Joan Robinson, is concerned with growth problems. He argues that the distinction between the movement along a "production function", in which the state of knowledge is given, and a shift in the "production function", caused by a change in the state of knowledge, is arbitrary and artificial. He argues that the use of more capital per worker implies, inevitably, some kind of "inventiveness" by which the new technique is superior in relation to the old one,[11] although this "inventiveness" does not necessarily means an application of "basically new principles or ideas".

[11] Note that this approach is similar to the comments made by Rosenberg noted before.

Kaldor offers an alternative to the neoclassical production function - the Technical Progress function -, which relates the growth of capital to the growth of productivity. This later incorporates both factors, growth of technical knowledge and growth of capital per worker. He defines the Technical Progress Function as

> the relationship between the rate of change of gross (fixed) investment per operative and the rate of increase in labour productivity in *newly installed* equipment.
>
> (Kaldor and Mirrless 1962: 174) [12]

The basic assumption is that the annual rate of growth of productivity per worker *operating on new equipment* is a function of the rate of growth of investment per worker, i.e. $\dot{p}_t / p_t = f\left(\dot{i}_t / i_t\right)$ with $f(0) > 0, f' > 0, f'' < 0$. The Technical Progress Function is represented in Figure I.1.

As one can see, the Technical Progress Function TT' is a linear function of the form

$$(\dot{p}_t / p_t) = a + b(\dot{i}_t / i_t) \quad (1.1)$$

showing that even when the rate of growth of investment is zero, it is possible to have an increase in productivity due to factors such as learning-by-doing, improvements in factory layout and organisation and so on. The position of the curve is justified by the assumption of the existence of a continuous flow of new ideas over time. Variations in this flow are reflected in the diagram by shifts in the height of the curve.[13] A burst of new ideas raises the position of the curve.

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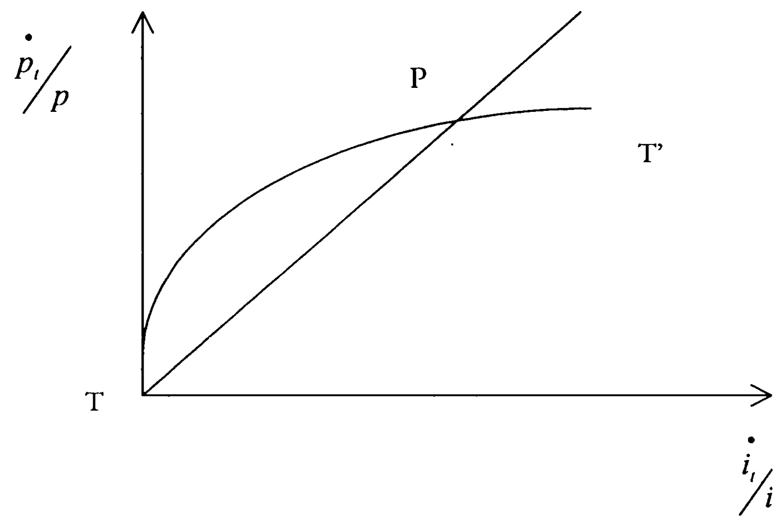
[12] There is a difference between this definition of Technical Progress Function and that one given by Kaldor in his article from 1958. Basically, in the 1958 article he assumes that the growth of the rate of capital per worker increases the labour productivity as a whole, while in the 1962 article this growth in productivity of the economy is entirely due to the infusion of new 'machines' into the system through (gross) investment.

[13] In Kaldor's words:

> The *height* of the curve expresses society's "dynamism", meaning by this both inventiveness and readiness to change or to experiment.
>
> (Kaldor 1989 [1958]: 265)

Figure I.1: Technical Progress Function



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where: $\dot{p}_t / p_t$ is the rate of growth in productivity per worker related with an operative machine of vintage *t*

$\dot{i}_t / i_t$ is the rate of growth of investment per worker.

due to the limit of the stock of technological knowledge there will be a restraint to this pattern of growth. Moreover, there will be a constraint to the growth in productivity as capital per worker increases, because of "increasing organisational, etc., difficulties imposed by faster technical change" (Kaldor 1957: 596).

The long-term equilibrium is a constant capital to output ratio, which implies an equilibrium condition in which

$$\dot{p}_t / p_t = \dot{i}_t / i_t \qquad (1.2)$$

Given this condition the equilibrium rate of growth is

$$\dot{p}_t / p_t = \dot{i}_t / i_t = a / 1 - b \qquad (1.3)$$

Thus, the long-term rate of growth is determined by the society's dynamism, which is reflected in the values of the parameters *a* and *b*. This is a crucial conclusion of the model.

The importance of Kaldor's approach is due to the fact that he manages to build a model where technical progress plays a fundamental part,

> determining not only the rate of growth of productivity but - together with other parameters - also the rate of obsolescence, the average lifetime of equipment, the share of investment in income, the share of profits and the relationship between investment and potential output ...
>
> (Kaldor and Mirrlees 1962: 188)

However, there are some aspects of Kaldor's approach that deserve comment. First, there is no place for disembodied technical progress (e.g. learning) in his model. Despite assuming both types of technical change, embodied and disembodied, Kaldor argues that the physical efficiency of machinery declines with the age of the equipment, and this feature compensates for the effects of disembodied technical change. For this reason, only embodied technical progress is taken into consideration.

Moreover, this disembodied technical progress comes exogenously, in the form of blueprints. For example, when discussing the conditions for steady growth, Kaldor claims that the rate of growth of productivity can only be higher than the rate of growth in capital per worker if the rate of growth of wages is higher than the rate of growth of productivity. This implies that at the left of point P in Figure I.1 the capital/output ratio is decreasing so, the rate of profit could be raised if the capital accumulation is stepped up. Thus, there is an assumption, which is common to all neo-Keynesian models, that there is always a technique available to compensate for the growth of the wage.

This approach is strongly rejected by Rowthorn (1975). He denies the concept of blueprint technology, when he discusses the institutional aspects of catching up. In his words:

> Rapid technical advance requires a massive and determined effort, involving the re-equipment and reorganisation of vast sectors of industry and the training and retraining of personnel, combined with an openness to new ideas, a willingness to copy and adapt foreign technology and an ability to invent new techniques as the scope for "catching-up" diminishes.
>
> (Rowthorn 1975: 10)

Secondly, according to Kurdas (1994), the same problems that Kaldor pointed out in the neoclassical production function - the distinction between a change in capital intensity (movements along the curve) and a change in technology (shifts of the function) -, can be found in his Technical Progress function. Kurdas argues that

> a change in capital intensity must require learning and developing the technique to be used, and this is not usefully shown by given parameters.

> ... Otherwise, movements along the function can change the rate of innovation that is taken as given in constructing the function.
>
> (Kurdas 1994: 42)

Hodgson (1989) has also raised three objections to Kaldor's theory of growth, all of them related to the understanding of productivity, institutions and knowledge implicit in Kaldor's theory. First, he criticises how productivity is analysed. The main point is that theories that understand productivity as directly dependent on a given technology are missing some important institutional aspects that also contribute to the absolute level of productivity. These factors are the motivation and skill of the workforce, the organisation and supervision of management. These factors are not homogeneous among plants and/or countries. Productivity is strongly related both with practical (tacit) knowledge and with the way information is transmitted and interpreted inside the firm. In Hodgson words, productivity "depends on complex institutional structures and routines and on cultural norms that are inherited from the past" (Hodgson 1989: 83).

The above criticism is directly related to the second one. Hodgson has noted that Kaldor accepts the general statement that the growth of productivity is mainly explained by the progress in science and technology. However, Kaldor maintains that the actual rate of growth of productivity varies from country to country, and from plant to plant. The latter happens even when the plants belong to the same corporation, although, it would be expected, in Kaldor's view, that they "must have had the same access to improvement in knowledge and know-how." He uses this 'stylised' fact to downplay the importance of the hypothesis that puts the progress of science and technology at the centre of the explanation of the growth on productivity.

However, as argued by Hodgson,

> Plants cannot have the 'same access to improvements in knowledge and know-how' because much relevant knowledge is 'tacit', 'unteachable', 'parcellised', embodied in habit or routine, and non-codifiable. Furthermore, even codifiable information does not become knowledge independent to the context of its transmission or of the cognitive framework of the receiver.
>
> (Hodgson 1989: 86)

Finally, Hodgson also disputes Kaldor's arguments that the manufacturing sector is the engine of growth. He concedes that the manufacturing sector has some advantages that may give it some distinctiveness. Examples of these advantages are the high 'proportion' of codifiable (explicit) knowledge used in its activities as compared to others sectors and its compact spatial organisation. These features facilitate the communication of knowledge and the diffusion of technology. However, Hodgson argues that in absence of codified knowledge to the manufacturing sector, the Kaldor-type relationship would breakdown (Hodgson 1989: 88). Thus, Kaldor's claims are dependent on the type of knowledge that is preponderant on the manufacturing sector.

I.1.3 The Vertically Integrated Approach

An important alternative approach to technical change within the Post-Keynesian literature has been proposed by Pasinetti (1981) and Eichner (1991). It has been called *Vertically Integrated*. In this approach, all the inputs used in the production processes are reduced to inputs of labour and to services from stocks of capital goods. Thus, for a certain quantity of final goods in a given period of time, a vertically integrated sector can be defined as the labour and productivity capacity (indirect labour) in the production of that specific quantity of final goods. It is called "a pure labour economy", and it is developed in such a way that the physical quantities of the economy and its price system are expressed in terms of total labour availability and their price.

It has been claimed (Milberg and Elmslie 1992) that the use of the Vertically Integrated approach to explain technical change may overcome some limitations that were very common to the old models of growth. According to Pasinetti,

> All the models of economic growth with technical progress have been developed in *macro-economic* terms, i.e. with the implicit assumption that one single commodity (or a composite commodity of invariable composition) is being produced in the economic system. And technical change has been introduced in the form of an over-all "rate of technical progress", which has been treated exactly like, and symmetrically to, the rate of population growth.
>
> (Pasinetti 1981: 62)

One of the advantages of the Vertically Integrated approach is that it provides a specific way to measure technical change that avoids some of the problems that arise in other growth models. According to Eichner (1991), assuming the measure of labour productivity as the measure of technical progress, the Vertically Integrated model does not allow some technical change occurring in one industry to be reflected in other. As he explains, in an interdependent production system, relative price movements make it impossible to determine in which industry the source of technical progress is.

> The problem is compounded by the fact that the technical progress which leads to a reduction in the costs of one industry, with a subsequent increase in the surplus being generated in value terms by that industry and/or by the industries to which it supplies material inputs, may be due to product innovation in yet another industry – without the product innovation necessarily lowering the cost of the industry that has introduced the new product.
>
> (Eichner 1991: 305)

An important benefit of the Vertically Integrated approach is the possibility that it allows one to identify how "dynamic returns, demand feedback, accumulation and exogenous factors" (Milberg and Elmslie 1992: 105) operate differently in different sectors. In other words, this approach captures intersectoral differences, without ignoring the impacts of dynamic returns due to macroeconomic factors. One can say that this approach does not deny the importance of Kaldor's dynamic returns. However, the same strong correlation between accumulation and technical change that is observed at the aggregate level no longer holds at a disaggregate one. According to Milberg and Elmslie the explanation for this result is due to the fact that aggregate analysis hides an important phenomenon that can be noticed only at the disaggregate level:

> Dynamic returns are likely to be extremely variable at the level of the vertically integrated sector since they may depend in large part on the development of a capital goods sector specifically geared toward the production of a particular final good.
>
> (Milberg and Elmslie 1992: 107)

Despite the important advantages that the Vertically Integrated model gives to the understanding of technical change, it has to be pointed out that the same old problem related to the exogeneity of technical change remains. In other words, the technological knowledge required for the use of new techniques is always available and can be used by anyone. Notwithstanding the fact that this assumption is not explicitly stated, it is not difficult to assume that it is implicit. It can be inferred from the use of industrial sectors as a whole as unit of analysis. At this point, the same criticism made above by Pasinetti in relation to traditional growth models can be used against him. He uses an over-all "rate of technical progress" that applies to each industrial sector, and the implications of this assumption are the same as they are for the aggregate models: (i) that the technical progress is going on at the same rate in all firms belonging to the same industry, and (ii) that the demand for *each* firm is expanding at the same rate. As will be shown ahead, these implications deny the existence of tacit technological knowledge, which is a fundamental feature of innovative activity.

Although Eichner also uses the Vertically Integrated approach, one can say that he expands it, for he takes into account both economic and noneconomic factors in explaining technical change. His view is in many aspects similar to that of Kaldor. However, Eichner takes into account, in an explicit way, the influence of the institutions on the rate of technical progress. He argues that society is composed of four institutional dimensions: three operative systems and one value orientation dimension. The operative systems are: (i) the economic system, which serves "to meet material needs" of the society; (ii) the political system, which produces "decisions through conflict resolution" and (iii) the anthropogenic system, which develops "individual competences through instruction and training" (Eichner 1991: 32). The value orientation institutional aspect of a society is regarded as "the stock of prevailing assumptions that guide everyday behaviour of society's members" (Eichner 1991: 33). It is a normative dimension that includes not only the beliefs about what ought to be but also all supposed knowledge. It permeates all the other three operative systems of the society. An interesting example of the value orientation dimension is science. According to Eichner,

> All that need be noted is that science, viewed as a social system that produces as its output certain types of beliefs – those validated through the experimental method – is governed by its own quite distinctive dynamic, one that should not be confused with the dynamic that operates along the economic or any of the other institutional dimensions of society.
>
> (Eichner 1991: 306-7) [14]

What is important in Eichner's analysis is that he explicitly recognises the importance of noneconomic factors in the growth of scientific knowledge and, thus, in the growth of technological knowledge. There is an interaction between the three operative systems and the value orientation institution responsible for the rise in scientific knowledge and the diffusion of innovations. A minimal level of institutional development - a political system answering to the changing economic needs of the population and an

[14] It is interesting to note how similar is the concept of value orientation with the concept of technological paradigm (see ahead). According to Eichner words,

> A part of the value orientation consists of beliefs as to how physical processes work. In modern times, these beliefs have been systematized under the rubric of astronomy, physics, chemistry and the other natural sciences, with this part of the value orientation further divided into basic and applied areas.
>
> (Eichner 1991: 306)

anthropogenic system providing a sufficient number of skilled workers – is necessary to transform the growth of scientific knowledge into rise of productivity. Summing up,

> The rate of technical progress ... depends on two sets of noneconomic factors. One is the accumulated stock of technical knowledge to which the interplay between science and technology has given rise. It is this accumulated stock of technical knowledge that will determine the maximum rate at which output per work can increase .... The other limiting factor is the present state of development insofar as the society's institutions – political, economic and anthropogenic – are concerned. It is this current level of development that will determine the society's ability to exploit the existing stock of technical knowledge.
>
> (Eichner 1991: 308– 9)

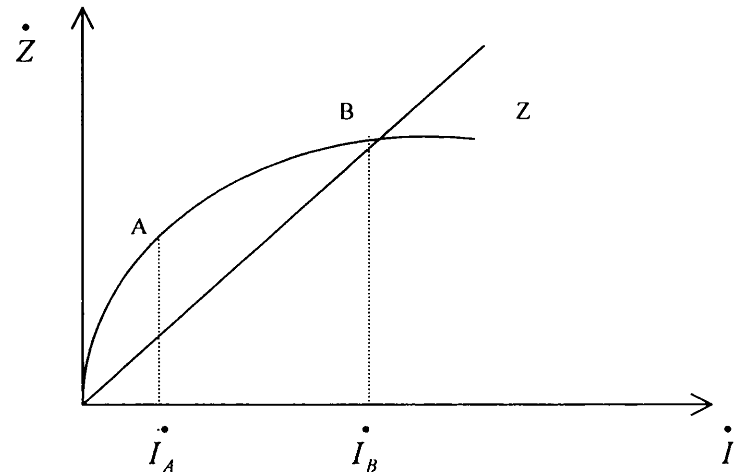
The main economic factor affecting the rate of technical progress is, according to Eichner, the secular rate of growth of investment ($\dot{I}$). As with Kaldor, this expresses the understanding of technical progress as, to a large extent, capital embodied, and being measured by the rate of decline in vertically integrated labour coefficients ($\dot{Z}$). This relationship is depicted in Figure I.2 below.

The position of the curve Z is determined by the body of technical knowledge and, thus, by the set of social institutions. If the technical knowledge increases, the curve shifts upwards. There are two factors that explain the shape of Z. The first one is related to the vintage capital stock. The shape of the curve will reflect the rate at which this latter is replaced. With a huge amount of vintage capital to be replaced, the growth of Z can be bigger than the growth of I. "However, because there is only a limited amount of vintage capital to be replaced, $\dot{Z}$ can increase more rapidly than $\dot{I}$ only at a decreasing rate" (Eichner 1991: 311). Secondly, there is a limit imposed by the rate of scientific progress and/or by the level of development along other institutional dimensions.

The point A is the exogenously determined growth of technical knowledge, and it has a slope equal to one. Up this point, the growth of output per worker is greater than one, and it is increasing quicker than the secular rate of growth of investment. As Eichner pointed out,

> ... it can be assumed that technical progress is being constrained, not for lack of the necessary scientific understanding or institutional development but rather, only for the lack of the necessary investment in new plant and equipment.
>
> (Eichner 1991: 312)

Figure I.2: Relationship Between Rate of Investment and Labour Coefficients



Beyond that point, it is the opposite. It is the lack of scientific knowledge and institutional development that constrain $\dot{Z}$.

The point *B* represents the *supply condition* for sustainable growth, for at this point the secular growth of aggregate demand ($\dot{G}$) is equal to $\dot{I}$. This equality holds because $\dot{Z}$ is identical to $\dot{G}$, as the growth of aggregate demand is limited by the rate of growth of real income, the latter being equal to the rate of growth of output per worker. Therefore, if the capacity is to increase at the same rate as aggregate demand, the rate of growth of investment must be equal to the growth of output per worker.

The same criticisms that were made about Kaldor can be made in relation to Eichner's work. Truly, he expands the analysis of the non-economic factors affecting the rate of technical progress but the incorporation of these factors in his model present the same old blueprint approach, which, as will be seen ahead, does not take into account tacit knowledge and learning process. This latter, indeed, has a major impact on the shape of the $\dot{Z}$ curve. If, for example, learning-by-doing is assumed, the position of $\dot{Z}$ should vary simultaneously with changes in $\dot{I}$. Moreover, if an increase in $\dot{I}$ implies an increase in the body of knowledge due to the learning process, the way $\dot{Z}$ is depicted in Figure I.2 implies that a decrease in the secular rate of growth of investment, $\dot{I}$, should suggest that there is an unlearning process, which is unrealistic.

I.2 Technical Change in Neoclassical Endogenous Growth Models

The literature on economic growth has significantly changed in the last fifteen years. The reason for this change is the appearance of the endogenous growth theory within the neoclassical field. These models are distinguished from the old neoclassical growth models (Solow-Swan) in that they claim that the mechanism that generates economic growth is endogenous to the economic system, not the result of forces that impinge from outside. Roughly speaking, the two main novelties in these models are the presence of increasing returns and imperfect competition. In its beginning, this literature could be divided into two approaches: (i) models where the learning-by-doing process generates externalities that are responsible for endogenous growth and (ii) models with intentional R&D investment.

The models of Romer (1986) and Lucas (1988) have been considered landmarks for the first approach. They have in common a feature which relates the accumulation of new capital of firms or individuals with an unintentional contribution to the productivity of capital held by others. This unintentional effect is called spillover, and it may happen either from investment in physical capital (Romer 1986, 1987) or human capital (Lucas 1988). In both models, "technical change is the serendipitous by-product of experience gained in the production of goods" (Young 1993).

Romer (1987), following Arrow (1962), assumes that when a unit of investment in physical capital is made, it increases not only the physical stock of capital but also the level of technology of all firms through knowledge spillovers. What is behind this assumption is the understanding that the knowledge used in R&D activities is a nonrivalrous and non-excludable good. A pure rival good is one which by its use by one person precludes its use by another. It is a pure technological attribute. Excludable goods are those which the owner can prevent being used by others. This is a function of the legal system and the technology. The spillover effect is a direct consequence of the fact of treating knowledge as a nonrival good. Otherwise, if the knowledge as input is considered as rival, it cannot be associated with increasing returns.

What is important to note is that these models, using a general equilibrium approach, can explain the divergence between private and social returns.

> If the spillovers are strong enough, the private marginal product of (physical or human) capital can remain permanently above the discount rate, even if individual investment would face diminishing returns in the absence of the

> external boosts in productivity. Growth can be sustained by continuing accumulation of the input that generates the positive externalities.
>
> (Grossman and Helpman 1994: 24)

Thus, Romer's model offers an explanation, within the general equilibrium approach, for a factor of production being paid more than its marginal contribution.

The second approach in the literature of endogenous growth claims that the learning-by-doing models do not identify the real mechanism that sustains economic growth.

> It seems to us ... that improvements in technology have been the real force behind perpetually rising standards of living. Also, we believe that most technological progress requires, at least at some stage, an intentional investment of resources by profit-seeking firms or entrepreneurs.
>
> (Grossman and Helpman 1994: 24)

The activity of the research sector produces two kinds of goods: blueprints of intermediate goods and general technological knowledge. In the first case, it is the increase in the number of blueprints that generates growth and makes it endogenous. In the second case, general knowledge can be viewed as a by-product of the research process, and it is used as input throughout the research sector. At each new blueprint, new general knowledge is created and itself is an stimulus for the development of new blueprints by all firms in the research sector (Verspagen 1992: 639).[15] The existence or not of creative destruction – meaning that each new innovation makes the existing one obsolete – will define the welfare properties in each model.

What is important in these models (Romer 1990, Aghion and Howitt 1992, Grossman and Helpman 1989, 1990, 1991 and 1994, among others) is that to assume the intentionality of the R&D research they have to drop an important feature of the old neoclassical growth models, that is, perfect competition. If firms must be able to recover their up-front outlays on research and development, then some imperfect competition in product markets is necessary to give an incentive for private investment in R&D. Thus, the leaders in the introduction of technology earn monopoly rents to reward their prior research investment. In Romer's words,

> Because a firm can control access to a discovery, it can charge a price that is

[15] In Romer (1990), for example, an individual decision to conduct R&D reduces the required amount of labour needed for subsequent inventions. Current research therefore has a positive spillover on the productivity of future research.

> higher than zero. It therefore earns monopoly profits because information has no opportunity cost.
>
> (Romer 1994: 13)

However, this appropriability of the effects of the innovation cannot be total, as some spillover effect must occur to generate increasing returns. The extension of the monopoly profits will vary according to the legal system or the occurrence of a new discovery. Barro and Sala-I-Martin (1995), for example, accept the idea that the monopoly earnings received by the innovators decrease over time as competitors learn about the new product and imitate it or create substitutes.

Two other important elements of the new Neoclassical Growth models deserve to be analysed. The first one is the role of uncertainty. It is incorporated into the analyses in two ways. Firstly, there is the uncertainty associated with the duration of the monopoly profits derived from the introduction of an innovation. In the so-called Schumpeterian models, this uncertainty involves the randomness of the time of the success of the next innovator, as these models assume that

> part of the reward from successful research is the creative-destruction effect that involves the transfer of monopoly rentals from the incumbent innovator to the newcomer.
>
> (Barro and Sala-I-Martin 1995: 242)

Secondly, also due to the randomness of the research activity, there is an uncertainty that innovators face *ex-ante* in their own research efforts. In this case, it is assumed that firms devote a chance to the development of a new product proportional to the resources attributed to R&D activities. Technical change is viewed as stochastic where the chance of a success in research activity is represented by a Poisson distribution. In other words, the success depends on the "current R&D effort by all research in the sector and not on the history of research or other variables" (Barro and Sala-I-Martin 1995: 247). Thus, also assuming profit maximisation and free entrance to the research sector, firms will invest in R&D (creation of knowledge) up to the point at which the marginal cost of additional input in R&D equals the expected gain that this input provides. The expected gain is defined as an increased probability of success times the market value of a new product (Grossman and Helpman 1994).

The second aspect to be noted is the steady-state growth assumed by the majority of these models. One key assumption in this case is the presence of continuous introduction of innovation. To generate a smooth path of growth it is necessary to assume a deterministic amount of effort to introduce a successful new product. If the discovery of new product is supposed to be random, then the smoothness at the aggregate level will be eliminated and thereby variations of the growth rate around the long-term path will occur.

To deal with this situation, some models assume a difference between micro and macro level, claiming that the randomness of R&D activity in one sector does not affect the steady state-path growth. This happens because each sector is assumed to be small and the probability of research success in each sector are independent of each other. In Barro and Sala-I-Martin words,

> The Law of Large Numbers then implies that the jumpiness in microeconomic outcomes is not transmitted to the macroeconomic variables: the adding up across a large number if independent sectors ... leads to a smooth path for the aggregate quality index Q, ... , and therefore for aggregate economic growth.
>
> (Barro and Sala-I-Martin: 248) [16]

An assessment of the new neoclassical growth models has to start with the observation that they do not represent a strong change from the old models. Important elements are present in both types of model. First of all, they continue to assume that the behaviour of savings is the determinant of the investment, in other words, savings are assumed to be prior to investment. Secondly, they continue to be locked in the equilibrium approach. This is a very problematic point and it is reflected in the way uncertainty is portrayed, using the subjective utility approach. This approach is used to describe both the investment decision and the research activity. From the point of view used in this thesis, the representation of the uncertainty using the Bayesian approach does not fit with important elements of the real world, such as for example, the non-ergodicity of some economic events and Shackle's definition of crucial decisions.[17] Despite these problems, one should recognise that the way technical change is represented in these new growth models can be considered a step forward within the neoclassical theory as it makes these models more realistic. Assumptions like increasing

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[16] The same point is made by Grossman and Helpman,

> At the micro level the growth process is uneven and stochastic. Firms continually race to bring out the next generation of product, but there may be long periods without a success in some industries. Meanwhile, other industries may experience a rapid succession of research breakthroughs. Aggregation masks this micro-level turbulence and the macroeconomic grows at a steady pace when the number of intermediate inputs is large.
>
> (Grossman and Helpman 1994: 34)

[17] A deeper discussion of these aspects will be made in Chapter II.

returns, imperfect competition, cumulative knowledge and intentional R&D are good examples of the gain in realisticness in relation to the old ones.

However, the way technology is introduced in the models creates some additional problems. Firstly, although some cumulative knowledge is assumed, the representation of uncertainty as a Poisson process, where the success of research activity is unrelated to historical research or other variables denies this same cumulative process. Secondly, the use of subjective probabilities to represent the uncertainty related to technical change is very questionable. Many authors have suggested that the uncertainty facing a innovative activity can be characterised as 'strong' (Dosi and Egidi 1991), where the probability distribution is unknown. Moreover, as will be seen in Chapter III, the introduction of an innovation can be viewed as a crucial decision and a fundamental element in making the economic environment nonergodic and, thus, subject to true uncertainty in Keynes's sense (Keynes *C.W.* VII, Chapter 12). One could say that representing uncertainty in the way it is represented in new neoclassical growth models implies the assumption of the presence of rational technological expectations (Verspagen 1992: 646). The question to be asked here is to what extent innovation – which by definition implies something new – can be conceived as a result of a process where rational expectation takes place. As Setterfield puts it,

> If innovation can be rationally expected, then in what sense are they new at the point of the introduction? In other words, in what sense are they innovations at all?
>
> (Setterfield 1994: 116)

Secondly, the assumption of rational technological expectation draws attention to another weakness of these models. It is clear that this assumption is fundamental to determining the equilibrium path of growth. The only way to predict the consequences of technological events in advance is to suppose the existence of rational technological expectations. Otherwise, the equilibrium growth path suggested by some new growth models will be much less likely to occur. As will be seen ahead, it is more plausible to consider innovation as a discontinuous process.

Thirdly, as shown before, some models assume a direct relationship between the amount of resources devoted to R&D and the outcome of the research activity. This supposition is strongly denied by many empirical works:

> While it is straightforward that some expected differential profitability is a necessary condition for private actors to undertake expensive and uncertain search efforts, to my knowledge, one lacks any convincing evidence that the intensity of search grows monotonically with the expected value of the rent streams: on the contrary, it seems, inter-sectoral and inter-temporal differences in the propensity of innovating are better accounted for, in a first approximation, by differences in opportunities and firm-specific capabilities rather that fine variations in profitability incentives (above a minimum threshold).
>
> (Dosi 1998b: 1533)

Finally, the treatment of technological knowledge as a nonrival and partially excludable good denies an important feature of this kind of knowledge, that is its tacitness. Free entry into the research sector is another way to deny this aspect. The spillover effect will be weakened if tacitness is assumed and some conclusions of the new neoclassical models will be rendered more vulnerable to criticism.

I.3 The Evolutionary and Institutional Approach

During the 1970's a new approach to the innovation process started to be developed by a group of researchers (Rosenberg 1976; Nelson and Winter 1977 among others) that will be named here Evolutionary and Institutional. This label has been chosen for two sorts of reason. First, it makes it clear that Schumpeter's writings are the initial source of inspiration, specially in relation to technical change. Second, it allows the incorporation into the analysis developments that go beyond this understanding of technical change and integrate some institutional aspects that had not been taken into account initially, such as the discussion of the competences of the firm and the importance of the institutional setting to the decision making process .[18]

As is well known, Schumpeter puts technical change at the centre of his analysis of economic development, and portrays the way by which it comes into economic activity in two different forms. In his 1934 book[19] he postulates two types of agents: (i) the entrepreneurs, whose main feature is the willingness to face the hazards and difficulties of the innovative process[20] and (ii) the 'imitators', a bigger group, "who were merely routine managers and followed in the wake of the heroic pioneers in the first group"

[18] This group is also called evolutionary. However, as this label has been used to classify theoretical approaches which cover more than technological aspects of the economic system, we prefer to use the label Evolutionary and Institutional as the main concern of the essay is technical change.
[19] Schumpeter, J. (1934) *The Theory of Economic Development* (English translation from 1912 German edition).
[20] Schumpeter rejects the concept of representative agents that are equally able to make rational calculations about the rate of return on future investment.

(Freeman 1994: 466). Later[21], he moved away from this original position and recognised that innovative activity, in general, takes place inside large firms and their R&D departments, which play an increasing role in this process.[22]

This latter understanding of the innovative activity – preserving the role of uncertainty described in the 1934 approach – was the departing point for the EI. Undertaking different empirical studies, they started to build an understanding of the technical change process that was very distinctive from those existing at that time. Initially, they tried to develop an understanding of technical change capable of challenging the two main views that prevailed in the economic literature of that time. These views were divided according to their understanding of the nature of an innovation. They are the so-called *technology push* and *demand pull* approaches. As has been seen before, the technology push approach postulates that scientific and technological inputs are the main source of innovation. In turn, the demand pull approach attributes to market mechanisms the unique determinant of technical change. The latter has its origin in a study from Schmookler (1966) about the US patents. He sought to demonstrate that inventive activity follows behind the peaks and troughs of investment activity. These findings are supposed to support the claim that changing patterns of demand are the main stimulus to invention and innovation.[23]

However, by the end of the 1970's a number of authors had started arguing that an intermediate approach could be found. In other words, they believed that neither the demand-pull nor the technology push approach could alone provide the elements for the full comprehension of the technological change process. The main point that differentiates the Evolutionary and Institutional approach from the other two is the role played by the learning process in the development and the introduction of an innovation. According to Freeman,

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[21] Schumpeter, J. (1942).

[22] This movement in Schumpeter's position is so strong that a distinction between the 'young' and the 'old' Schumpeter has become usual in the literature (Phillips 1971; Freeman, Clark and Soete 1982).

[23] The demand pull approach implicitly assumes a direct feedback between knowledge-creation to market signals and, that the change in demand patterns is the market signal that signalises the needs existent in a society. However, as pointed out by some scholars (Mowery and Rosenberg 1979; Freeman 1994, among others) the demand pull approach makes a confusion between

> 'needs' and 'demand' and between 'potential demand' and 'effective demand'. Since human 'needs, are extremely varied and often unsatisfied for long periods, they cannot alone explain the emergence of particular innovations at a particular time.
>
> (Freeman 1994: 479)

For a review of the criticisms of these approaches see Dosi 1982 and Freeman 1994.

> The picture that emerges from numerous studies of innovation in firms is one of continuous interactive learning. Firms learn both from their own experience of design, development, production and marketing … *and* from a wider variety of external sources at home and abroad – their customers, their suppliers, their contractors …, and from many other organisations – universities, government laboratories and agencies, consultants, licensors, licencees and others.
>
> (Freeman 1994: 470)

Moreover, Evolutionary and Institutional studies show that asymmetries in performance, heterogeneity and, relative stickiness in the knowledge, problem-solving capabilities and differentials in profitability among firms are important elements in the characterisation of their innovative process.

To understand this concept of technical change it is important to discuss in a deeper way two essential features of the innovative activity: *knowledge base* and *uncertainty*.

I.3.1 Knowledge Base

The knowledge base is related to the characteristics of the knowledge used in an innovation. According to Dosi (1988a: 224), various sorts of pieces of non-excludable knowledge are used in the solution of most technological problems: universal versus specific; public versus private; and articulated versus tacit.

Universal knowledge refers to knowledge that has a large applicable understanding, based on principles that are well known and pervasive, whilst specific knowledge means that particular to some activities. Moreover, there is that knowledge that is public in the sense that it is available in scientific and technical publications as opposed to knowledge that is private because it is protected by laws (patents). Finally, some sorts of knowledge are well articulated and for the most part are written down in manuals, books and so on. In contrast, there is also that kind of knowledge that is tacit, meaning that it comes from an inarticulated experience and practice. Given the relevance of tacit knowledge to our discussion, we thing that a further analysis of this concept is worthwhile.

The concept of tacit knowledge has been synthesised by Polanyi (1958; 1967) in the following statement: "*We can know more than we can tell*" (1967: 4; italics in original). Basically, the meaning of tacit knowledge can be understood when we realise that we can recognise the face of our neighbours without being able to explain how we recognise a face. To explain this fact Polanyi goes to the Gestalt psychology, which argues that human beings may know a physiognomy by interacting their awareness of its particulars without being able to identify these particulars. In others words, "perception is determined in terms of the way it is integrated into the overall pattern" (Nonaka and Takeuchi 1999: 216). While *Gestalt* assumes that all images are intrinsically integrated, Polanyi argues that knowledge acquisition is "the outcome of an active shaping of experience performed in the pursuit of knowledge" (Polanyi 1967: 6).

Polanyi stresses the importance of experience, self-involvement and commitment to the understanding of tacit knowledge when he identifies tacit knowing as indwelling. As pointed out by Nonaka and Takeuchi:

> To know something is to create its image or pattern by tacitly integrating particulars. In order to understand the pattern as a meaningful whole, it is necessary to integrate one's body with the particulars. Thus, indwelling breaks the traditional dichotomies between mind and body, reason and emotion, subject and object, and knower and known. Therefore, scientific objectivity is not a sole source of knowledge. Much of our knowledge is the fruit of our own purposeful endeavours in dealing with the world.
>
> (Nonaka and Takeuchi 1995: 60).

The role and importance of tacit knowledge to organisations have been emphasised by the work of Nonaka and Takeuchi (1995; 1999). They have developed the theory of the *Knowledge-Creating Company*, which argues that the dynamism of a firm is related to its capability to create new knowledge, disseminate it throughout the organisation, and embody it into products, services and systems (Nonaka and Takeuchi 1999: 214).

The distinction between tacit and explicit knowledge is on the centre of their analysis. While explicit knowledge can be expressed in a systematic and formal way in the form of hard data, scientific formulae, codified procedures or universal principals, tacit knowledge, as Polanyi has pointed out, is highly personal and hard to formalise. These features transform it in a kind of knowledge that is very difficult to communicate to others or share with others. The claim made by the authors is that whereas Western companies are mainly concerned with explicit knowledge their Japanese counterparts have been taken tacit knowledge as the primary and most important form of knowledge. In this difference, then, lies the explanation for the performance of Japanese companies, as tacit knowledge provides the basis upon which organisational knowledge is created. Accordingly, the latter is created during the time that tacit knowledge is communicated and shared within the organisation. In the authors words,

> Creating a new knowledge is … not simply a matter of learning from the others or acquiring knowledge from the outside. It has to be built on its own, frequently requiring intensive and laborious interaction among

> members of the organisation. ... To create knowledge, the learning that takes place from others and the skills shared with others need to be internalised – that is, reformed, enriched and translated to fit the company's self-image and identity.
>
> (Nonaka and Takeuchi 1999: 217)

As knowledge creation inside the firm is fundamental to the innovative process, the view that firms *only* process information form the outside in order to innovate is greatly undermined. Firms actually create new knowledge and information in order to redefine both problems and solutions. During this process firms are recreating their own environment.

What is important to note in this approach is that tacit and explicit knowledge are considered mutually complementary entities. It is through the social interaction between tacit and explicit knowledge that human knowledge is created and expanded.[24] As Choo points out,

> Tacit knowledge, while it remains closely held as personal know-how, is of limited value to the organisation. On the other hand, explicit knowledge does not appear spontaneously, but must be nurtured and cultivated from the seeds of tacit knowledge. Organisations need to become skilled at converting personal, tacit knowledge into explicit knowledge that can push innovation and new-product development.
>
> (Choo 1998: 8)[25]

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[24] The fact that organisational knowledge manifests itself through social interaction shed lights on the role of the culture in the organisational learning process. Culture plays an important role in moulding the perceptions and preferences of the agents, facilitating the social interaction necessary to the creation of knowledge.

[25] As the above quotation shows, the key element here is the way by which both types of knowledge are converted into each other. This is what Nonaka and Takeuchi have called knowledge conversion. Four are the modes of knowledge conversion. The first one is called socialisation. It is the conversion of some tacit knowledge into another tacit knowledge. It is a process of sharing experiences and thereby creating tacit knowledge such as shared mental modes and technical skills. Second, there is the transformation of tacit knowledge into explicit knowledge. This is called externalisation. It is triggered by dialogue or collective reflection that generated new concepts or models. The third mode is labelled combination, as it convert explicit knowledge into explicit knowledge. It implies that the "reconfiguration of existing information through sorting, adding, combining and categorising of explicit knowledge ... can lead to new knowledge (Nonaka and Takeuchi 1999: 222). Finally, there is the conversion of explicit knowledge into tacit knowledge (internalisation). It is closely related to 'learning by doing'.
These four modes of conversion are the basis of the "spiral of organisational knowledge creation". According to Nonaka and Takeuchi's words:

> First, the socialisation mode usually starts with building a "field" of interaction. This field facilitates the sharing of members' experiences and mental modes. Second, the externalisation mode is triggered by meaningful dialogue or collective reflection", in which using appropriate metaphor or analogy helps team members to articulate their hidden tacit knowledge that is otherwise hard to communicate. Third, the combination mode is triggered by "networking" newly created knowledge and existing knowledge from the other sections of the organisation, thereby crystallising them into a new product, service or managerial system. Finally, "learning by doing" triggers internalisation.
>
> (Nonaka and Takeuchi 1999: 223-4)

It is important to note that the organisation by itself cannot create knowledge. In the process of knowledge creation the mobilisation and conversion of tacit knowledge, which lies at the individual level, is an essential

The way different types of knowledge are combined and used in some innovative activity will define the knowledge base of that activity. The knowledge base is "the set of information inputs, knowledge, and capabilities that inventors draw on when looking for innovative solutions" (Dosi 1988b: 1126). Obviously, different activities (sectors) have different knowledge bases and, thus, the importance of each kind of knowledge discussed above will differ. This explains why the organisation of research activities and the characteristics of the innovative activity vary across sectors, and why different industrial sectors have varying degrees of appropriability of the benefits of the introduction of innovation.

The concept of knowledge base and its implications can be better understood with the help of two important contributions made by the EI, that is: the concepts of technological paradigm and technological trajectory.

When studying the innovative process, the Evolutionary and Institutional approach noticed that, despite the diversity and the uncertainty associated with innovation, a relatively ordered process of technical change can emerge. To explain this, Dosi (1982) uses Kuhn's concept of scientific paradigm (Kuhn 1962) to define, through analogy, the concept of technological paradigm (hereafter TP) as a

> 'model' and 'a pattern' of solution of *selected* technological problems, based on *selected* principles derived from the natural sciences and on *selected* material technologies.[26]
>
> (Dosi 1982: 152)

The concept of TP implies a set of *heuristics*[27] - e.g., Where do we go from here? Where should we search? What sort of knowledge should we draw on? (cf. Dosi 1988b: 1127) - and a prescription of *directions* of technical change to pursue and those to neglect and, these *heuristics* and *directions* are shared by the community of practitioners in each particular activity. What is important here is to note that the innovative activity is not a random process, where for each innovation the investor is free to look in any specific direction. The innovator is always constrained by the TP in which he is grounded. As there are different TPs, each technology embodies a representation of specific forms of

aspect. The mobilised tacit knowledge is "organisationally amplified" through the conversion modes and becomes crystallised at higher level.

[26] It is worth noting that the technological paradigm is very similar in concept to the technological regime (Nelson and Winter 1977), technological guidepost (Sahal 1981), and focusing devices (Rosenberg 1976).

[27] "A *heuristic* is 'any principle or device that contributes to the reduction in the average search to solution' (Newell, Shaw, and Simon 1962: 85)" (quoted from Nelson and Winter 1982: 132).

knowledge on which a particular activity is based and has its specific procedures, competences and heuristics (Cimoli and Dosi 1995).

Thus, at any moment in time, there is always a TP that determines the features of the innovative activity for every sector of the economy, imposing a selective, precise and ordered pattern of technological change.

There are in the Evolutionary literature two other approaches to technical change that resemble the concept of technological paradigm that deserve a further analysis. The first one is the so-called Techno-economic paradigm (Freeman and Perez 1988). According to Freeman and Perez (1988: 45-6), one can classify an innovation in the following categories: incremental innovation; radical innovation; changes of technological systems and changes in 'techno-economic paradigm'. The first two are well known in innovation literature and will not be discussed here[28]. Changes of technological systems refer to the technical change that affects several branches of the economy, giving rise to entirely new sectors. A combination of radical, incremental, organisational and managerial innovations are at the base of this kind of change, affecting more than a few group of firms. Examples of this type of innovation are the cluster of synthetic materials innovations and petro-chemical innovations among others (Freeman and Perez 1988· 46-7).

The last type of innovation (changes in 'techno-economic paradigm' or 'technological revolutions') is the most important due to its pervasive effects throughout the economy.

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[28] According to Freeman and Perez, incremental innovations

> occur more or less continuously in any industry or service activity although at differing rates in different industries and different countries, depending upon a combination of demand pressures, socio-cultural factors, technological opportunities and trajectories. ... They are frequently associated with the scaling-up of plant and equipment and quality improvements to products and services for a variety of specific applications. Although their combined effect is extremely important in the growth of productivity, no single incremental innovation has dramatic effects, and they may sometimes pass unnoticed and unrecorded.
>
> (Freeman and Perez 1988: 44-5).

An example of incremental innovations is the upgrade from the 486 computer to Pentium computer
In the same way, radical innovations

> are discontinuous events and in recent times are usually the result of a deliberate research and development activity in enterprises and/or in University and government laboratories. ... Radical innovations are unevenly distributed over time ... [but] whenever they may occur, they are important as the potential springboard for the growth of new markets, and for the surges of new investment associated with booms. ... [However] they do bring about structural change but in terms of their aggregate economic impact they are relatively small and localised, unless a whole cluster of radical innovations are linked together in the rise of new industries and services, such as the synthetic materials industry or the semiconductor industry. [Example: Nylon] There is no way in which nylon could have emerged from improving the production process in rayon plants or the woollen industry.
>
> (Freeman and Perez 1988: 45).

It is a change of a technological system, which affects the whole system, implying the emergence of many clusters of radical and incremental innovations. Almost every sector of the economy is impacted by this type of change. The label of 'techno-economic' paradigm is chosen to stress its difference from Dosi's 'technological paradigm'. In the authors' words,

> The changes involved [in the change in techno-economic paradigm] go beyond engineering trajectories for specific product or process technologies and affect the input cost structure and conditions of production and distribution throughout the system.
>
> (Freeman and Perez 1988: 47).

A distinctive element of a techno-economic paradigm is its organising principle. It is found not only in a new range of products and systems, but essentially "in the dynamics of the relative cost structure of all possible inputs to production". For a new techno-economic paradigm to emerge it has to have a particular input or set of inputs (key factor) that must fulfil the following conditions: (i) clearly perceived low and rapidly falling relative cost; (ii) apparently almost unlimited availability of supply over long periods; and (iii) clear potential for the use or incorporation of the new input or inputs in many products and processes in different sectors of the economy (Freeman and Perez 1988: 48).[29]

The discussion of changes of techno-economic paradigm throughout the history is used by the authors to explain economic cycles in the capitalist society. Every cycle is characterised by the emergence and falling of a techno-economic paradigm.

The concept of "technological regime" (Nelson and Winter 1982; Winter 1984) has also produced a great impact on the understanding of the process of technical change in the Evolutionary approach. It is very similar to the concept of technological paradigm., as we shall see. Its proponents, first, identify three sources of ideas and skill that the search activity can rely on. First, firms can imitate. This means that the searching firm draws knowledge from other firms that undertake the same type of activity. Second, firms may search for themselves (inward) for the necessary knowledge to improve their routines. Finally, the external environment, not counting other firms that operates in the same activity, can be a major source of knowledge. In this case, there are two extreme situations. On the one hand, organisations may only make use of the prior

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[29] The authors argue that microelectronics has today a combination of these conditions. Also they are able to identify five changes in the techno-economic paradigm until the 1990s with the respective key factor: i) 1770 to

education and experience of their personal. On the other hand, it may exist a situation where the external environment provides fully developed and codified knowledge leaving to the firm the only task of adapting this knowledge to the unique circumstance of its own organisation. It is in between these two extremes that firms will obtain pieces of knowledge that can be useful in the improvement of their own routines (Winter 1984: 291-93).

These three sources of knowledge are used to define of "technological regimes". Arguing that the search activity should not be restrained to only one of these categories, Winter maintains that,

> it is clear, ..., that there are big differences among industries and technologies regarding the role of the sources. Along with differences on the relative importance (somehow measured) of the different source, there are differences on a variety of related aspects, including such matters as the intrinsic ease or difficulty of imitation, the number of distinguishable knowledge bases relevant to a routine, the degree to which success in basic research translate easily into success in applied research (and vice-versa) the size of the resource commitment typical of a project and so forth. *To characterise the key features of a particular knowledge environment in these various respect is to define a "technological regime".*
>
> (Winter 1984: 293, italics added)

As one can see, technological regime is a cognitive concept, which affect technician's beliefs about what is feasible or at least worth attempting (Nelson and Winter 1982: 259). In this sense, the search activity, and so technical change, should be understood as simultaneously constrained and guided by the technological regime.

Technological trajectory (hereafter TT) is another key concept to the understanding of technical change in the Evolutionary approach. Given the innovative opportunities defined by each paradigm, technological trajectory can be associated with the fulfilment of these opportunities and can be "measured in terms of the changes in the fundamental techno-economic characteristics of articrafts and the production process" (Cimoli and Dosi 1995: 246). This concept has a direct relationship with the concept of progress. In Dosi's words:

> The *normal* problem solving activity determined by a paradigm, can be represented by the movement of multi-dimensional trade-offs among the technological variables which the paradigm defines as relevant. Progress can be defined as the improvement of these trade-offs.

1840, cotton; ii) 1840 to 1890, coal; iii) 1890 to 1940, steel; iv) 1940 to 1980, energy (especially oil); and v) 1980 until now, chips (microelectronics).

(Dosi 1982: 154)

Dosi gives an example of the relationship between technological paradigm and trajectories:

> ... the semiconductor-based paradigm in microelectronics or oil-based paradigm in organic chemicals broadly determine the scope and direction of technical progress – i.e. the 'trajectories' in both product and process technologies (for example, miniaturisation and increasing chip density in semiconductors; polymerisation techniques in organic chemicals, etc.).[30]
>
> (Dosi 1998b: 1534)

Some important features of Technological Trajectories are worth noticing:

i. Progress along the trajectory is *local* – meaning that it is in the neighbourhood of the technique in use where the development of new innovations is likely to occur - and *cumulative* – in a sense that the new development is often built upon past experience of production and innovation;[31]

ii. The more powerful the trajectory[32], the more difficult it is to switch from one to another. The explanation for this is related to the fact that as one accumulates knowledge, one becomes locked into the trajectory. If he changes trajectory, he has to start from the beginning in the problem-solving activity;

iii. *A priori* it is difficult to make judgements about the superiority of one trajectory over another. As Dosi explains

> [...] an unequivocal criterion can be easily identified only *within* a technological paradigm (i.e. *along* a technological trajectory). Comparison (even *ex-post*) between different trajectories might yield sometimes, although not always, to ambiguous results. In other words, it might occur that the 'new' technology is 'better' than the 'old' one in several chosen dimensions, but it might still be 'worse' in some others.
>
> (Dosi 1982: 154)

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[30] He continues,

> Together, technological paradigms bind the scope for dynamic interfactoral substitution (so that, for example, irrespectively of the relative price of energy, it is difficult to imagine, given our current knowledge base, a technology for the production of hyperpure silicon which would not be very energy-intensive ...).
>
> (Dosi 1997: 1534)

[31] The probability of new advances is related to the position that the innovator occupies vis-a-vis the technological frontier. The nearer the technological frontier, the greater the possibility of introducing an innovation, and the greater the knowledge accumulated.

[32] The power of a trajectory is defined by the range of opportunities that it has and the strength of its cumulative aspect.

Three important implications arise from the concept of technical change discussed above. First, it is very clear that technology is not a free good that one can pick up off the shelf. The concepts of knowledge base and cumulativeness show very clearly that the alternatives that an innovator is faced with are limited, meaning that the number of directions of the search activity are predetermined.[33]

Second, it is the emergence of a new technological paradigm, rather than the market, which defines what the potential innovations are. This does not mean that the market mechanism has no role as an inducement to innovate. According to Dosi,

> In the most general terms, private profit-seeking agents will plausibly allocate resources to the exploration and development of new products and new techniques of production if they know, or believe in, the existence of some sort of yet unexploited scientific and technical opportunities; if they expect that there will be a market for their new products and processes; and, finally, if they expect some economic benefit, net of the incurred costs, deriving from the innovations.[34]
>
> (Dosi 1988b: 1120)

Finally, the concepts of TP and TT are a powerful instrument in the analysis of why innovative activity differs among sectors. It will be the features of the TP and the TT that will define the difference among the degrees of appropriability and levels of opportunities of technological advances.

I.3.2 Uncertainty

The second essential feature of the innovative activity, uncertainty, plays an important role in the understanding of technical change by the EI approach. According to Freeman and Soete (1997: 242-5), there are three kinds of uncertainty that affect the innovative activity: business, technical and market uncertainties. The first one is related

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[33] As pointed out by Freeman,

> ...one of the most important findings of neo-Schumpeterian research is the demonstration that technical knowledge can seldom be obtained 'off the shelf' and that it almost always requires processing and modification to be used effectively ... Without this assimilation and improvement rather inefficient results are likely to follow, especially in developing countries.
>
> (Freeman 1994: 473)

[34] As this quotation shows, the market does have a role to play in this process. However, this role is constrained by the features of the TP. Inducement to improve the level of profits always exists in a business operation. As explained by Rosenberg (1976: 110) however, since this incentive is so general, it does not explain either why a specific innovation is introduced or the timing of its introduction. Moreover, as some studies indicate (Soete and Dosi 1983; David 1975), the features of a new technology are generally superior to the old one, so that even if there is no change in the relative prices, the new technology could be adopted profitably. What has to be understood is that the market incentives *alone* cannot provide a clear understanding of the technical change process. However, some market incentives, "*coupled with the paradigm-bound, cumulative, and local nature of technological learning* can explain particular rates and directions of technological advance" (Dosi 1988b: 1143).

to environmental variables (political, economic, legal, etc.) and affects all decisions related to the future. This kind of uncertainty is not specific to the innovative activity, but to economic decisions as a whole. The other two kinds of uncertainty are project specific. Technical uncertainty refers to realised standards of performance under various operating conditions for a given expenditure on R&D, while market uncertainty refers to the extent to which the innovation will be commercially successful for a given product specification (Kay 1979:18).

Despite the fact that these categories of uncertainty appear in every innovation, the degree of uncertainty varies according to the type of innovation. Freeman and Soete (1997: 244) show that there is a qualitative difference between the uncertainty associated with a radical product innovation, which is of very high degree, and that related to the introduction of a product differentiation, which is of a much lower degree (Table I.1). This difference in the degree of uncertainty is related to the development of technological paradigm and technological trajectories, in the sense that they focus the direction of search and give better grounds for the formation of technological and market expectations (cf. Dosi 1988b: 1134).[35]

Notwithstanding the fact that these degrees of uncertainty are related to different aspects of the innovative activity, they have the same basic sources. According to Dosi and Egidi the sources of uncertainty are,

[35] It is important to note that although it can be *reduced*, uncertainty is never *eliminated*. According to Dosi,

> even when the fundamental knowledge base and the expected directions of advance are fairly well known, it is still often the case that one must first engage in exploratory research, development, and design before knowing what the outcome will be [...] and what some manageable results will cost, or, indeed, whether very useful results will emerge (Mansfield et al. 1977).
>
> (Dosi 1988b: 1143)

Table I.1: Degrees of Uncertainty Associated with Various Types of Innovation

1	True Uncertainty	Fundamental research
		Fundamental invention
2	Very high degree of uncertainty	Radical product innovations
		Radical process innovations outside firm
3	High degree of uncertainty	Major product innovations
		Radical process innovations in own establishment or system
4	Moderate uncertainty	New 'generations' established products
5	Little uncertainty	Licensed innovation
		Imitation of product innovations
		Modifications of products and processes
		Early adoption of established process
6	Very little uncertainty	New 'model'
		Product differentiation
		Agency for established innovation
		Late adoption of established process innovation and franchised operations in own establishment
		Minor technical improvements

Source: Freeman and Soete 1997: 244.

> *incompleteness of the information set*, which means the lack of all the information which would be necessary to make decisions with certain outcomes and *knowledge incompleteness*, which means the inability of the agents to recognise and interpret the relevant information (limitations on the computational and cognitive capabilities of the agents).
>
> (Dosi and Egidi 1991: 145)

When related to the introduction of an innovation, the first source (*incompleteness of the information set*) means that when someone starts to search for a solution to a technological problem, he lacks some fundamental information, and this lack of information makes the innovative activity completely uncertain. This information might include, for example, the length of time that it will take for the innovation to be found; the cost of this innovation; and its acceptance by the market. One is, therefore, faced with strong uncertainty, which means the impossibility, even in principle, of defining the probability distribution of future events (cf. Dosi and Egidi 1991). Thus, the innovative activity is not an activity subject to risk but to *true uncertainty.*

The second source (*knowledge incompleteness*) is based on the concept of procedural uncertainty. There is here a clear distinction between knowledge and information. Access to the latter does not guarantee the acquisition of the former. The acquisition of knowledge lies in the ability to process information, and the latter depends on the computational and cognitive capabilities of the agents. As pointed out by Nonaka and Takeuchi (1995: 58) knowledge is a function of a particular stance, perspective or intention. It is related to beliefs and commitment. Information, in turn, provides the meanings to a new interpretation of events and object. It is a necessary medium or material for obtaining and building knowledge. The understand of information as a flow of messages and knowledge as created, given the beliefs and commitment of its holder, by that very flow of information, shed lights on the second difference between knowledge and information. The former, unlike the latter, is about action, i.e. it is intrinsically related to human action.

Despite these two distinctions, there is one aspect upon which both knowledge and information has a common ground. Both are context-specific and their meaning is directly related to that context.[36]

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[36] Another interesting approach to the use of knowledge and information inside a firm is provide by Choo (1998), who has developed the theory of the Knowing Organization. The latter can be understood as a development of Nonaka and Takeuchi's theory of knowledge creation. He starts his argument claiming that there are three arenas of creation and use of information inside a firm: sense making, knowledge creating and decision making. These three processes are highly interconnected and throughout their interaction, a holistic view of organisational information use emerges.

Sense making is about the use of information by the organisation to make sense of changes and development in its external environment. It is a process of interpretation of news and messages related to its surrounds. As pointed by Weick,

> The goal of organisations, viewed as sense making systems, is to create and identify events that recur to stabilise their environments and make them more predictable. A sensible event is one that resembles something that has happened before.
>
> (Weick 1995: 170, quoted from Choo 1998: 5)

The outcome of a sense making process is the development of models of understanding that provides both meaning and common interpretation to events that occurs outside the firm.

The second area of knowledge use is called knowledge creation. This concept is borrowed from Nonaka and Takeuchi's theory of knowledge creation and it is integrally applied in Choo's discussion. Finally, there is the decision-making area of information use. The understanding of this process takes into account the work of Simon (1976) on bounded rationality. Due to limitation of the cognitive capabilities of the individuals, a perfect maximizer rational behaviour cannot be achieved by individuals. Moreover, the organisation itself guides its members' behaviour by mastering the decision premises upon which decisions are made. To deal with bounded

So, uncertainty here has its source in the lack of knowledge, despite the fact that information could be available. To deal with this uncertainty the agents develop a 'rational behaviour', which implies the search for stable rules and procedures (routines), which give them some security with which to face uncertainty.

The use of routines in the innovative activity may sound a little odd as innovation represents something new. However, there is no contradiction in this approach. What should be clear is the difference between the 'search' for an innovation and the outcomes of the use of this innovation.[37] The uncertainty relates to the outcomes of the research activity not to this activity itself. One could correctly argue that at initial stages of the research activity the uncertainty faced by this activity is strong. Nevertheless, as some knowledge becomes consolidated, or in other words, as some *heuristics* are established, one could assume strong patterns (routines) of a high predictability in the research activity. The words of Nelson and Winter synthesise the point:

> We propose to assimilate to our concept of routine all of the patterning of organizational activity that the observance of heuristics produces, including the patterning of particular ways of attempting to innovate. ... But we emphasize, ..., that viewing innovative activity as "routine" in this sense does not entail treating its results as predictable.[38]

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rationality, organisations and organisational actors simplify the decision process using routines, rules and heuristics.

What is important in this approach is the recognition that the Knowing Organisation employs these three modes of organisational information use as a whole, transforming them in mutually supportive arenas. As Choo points out,

> The three modes of information use complement each other by each supplying some of the missing pieces necessary for the other to function. Sense making provides enacted environments or shared interpretations that serve meaningful contexts for organisational action. Shared interpretations help configure the organisation intent or knowledge vision necessary to regulate the knowledge conversion process in knowledge creation. Knowledge creation leads to innovation in the form of new products and new competences. When it is time to select a course of knowledge-derived innovation, decision-makers follow rules and premisses to simplify and legitimatise their action.
>
> (Choo 1998: 17-8).

[37] In Nelson and Winter's words:

> ... the relationship of routine behaviour to innovation is centered on a simple distinction between organizational *activity* directed to innovation (or problem-solving more generally) and the *results* of such activity.
>
> (Nelson and Winter 1982: 132)

[38] Nelson and Winter give an illustrative example:

> ... the case of systematic sequential search of a well-defined population for an element with attributes that makes it the solution to a well-defined problem. When and whether a solution will be found may be quite uncertain, but the search itself follows a routine with a simple structure: select element, test for desired attributes, terminate with success if attributes are present, select next element if they are not.
>
> (Nelson and Winter 1982: 132)

(Nelson and Winter 1982: 133)

Placing the discussion in the terms that were discussed before, one can say that the research routines codify the procedures and knowledge involved in the solution of a particular problem, and are conditioned by the technological paradigm.[39]

To sum up, the EI approach to technical change assumes that substantive and procedural uncertainties are essential features of the innovative activity and, in order to deal with them, routines are developed. These routines, in turn, are contingent on the competences and heuristics of the technological paradigm, which allows the emergence of the concepts of appropriability, opportunity and cumulativeness, making the understanding of the technical change unique. Moreover, it was shown that uncertainty varies according to different types of innovation, decreasing from a situation in which there is a high degree of uncertainty - usually in research activities - to situations with a low degree of uncertainty - development activities.

I.4 Conclusion

The short review presented in this Chapter shows that there are important elements in the innovative activity that are fundamental to any theoretical discussion about the implications of technical change for the economic activity. The EI approach argues, convincingly, the existence of a robust 'stylised fact' about technical change. That is, a dogged heterogeneity among firms in relation to the knowledge and problem-solving capabilities they embody, and the relative stickiness of these capabilities over time. This 'stylised fact' is responsible for wide asymmetries in performances and profitability differentials (Dosi, 1998b: 1533). This means that a study of the impact of technical change on macroeconomic variables must take into account this 'stylised fact' and its sources.

On what follows in this thesis, some elements of technical change discussed above will be taken for granted. In other words, factors such as cumulativeness, learning, tacit knowledge, technological paradigms and technological trajectories will be the pillars to the study of technical change in investment decision within the Post-Keynesian approach.

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[39] The concept of path-dependency is very useful in grasping why these routines are conditioned by the technological paradigm. For a discussion of this point, see David (1985) and Rosenberg (1994).

Like Keynes and the Post-Keynesians, the EI approach assumes the existence of an uncertainty that is never eliminated. Thus, it makes sense for the connections between the technological uncertainty stressed by the Evolutionary and the Keynesian concept of uncertainty to be the first aspect to be analysed. First, however, it is necessary to consider the meaning of uncertainty from the Keynes and the Post-Keynesian point of view. This point is tackled in the next Chapter.

CHAPTER II

KEYNESIAN UNCERTAINTY AND DEGREES OF UNCERTAINTY

Introduction

The discussion made in the previous chapter has shown that uncertainty is an important element when technical change is to be considered. The aim of this chapter is to discuss and to define a concept of uncertainty that will then be used in the following chapters.

This concept of uncertainty must be able to explain from a theoretical point of view the different degrees of uncertainty that are present in the innovative process. My claim here, like other scholars, is that this concept can be founded on Keynes's writings, especially on the *Treatise on Probability*. In what follows we intend (i) to discuss and define a concept of uncertainty capable of being ranked; (ii) to discuss the limits of the widely used Subjectivist Expected Utility approach and explain why it is inappropriate to deal with uncertainty and (iii) to show that this concept is compatible with the concept of *crucial decisions* and *nonergodicity*.

II.1 Keynesian Uncertainty

The concept of uncertainty in Keynes has been a subject of debate since the publication of the *General Theory*. Initially, the main feature of this discussion was the distinction between 'risk' and 'uncertainty'.[40] While the Neoclassical approach argued that only situations of risk were analytically tractable in economic analysis, heterodox schools - especially the Post-Keynesians - maintained that economic analysis should not neglect 'true' uncertainty. However, since the early 1980's the debate has changed. Despite the fact that the previous distinction still remains, within the heterodox field a discussion about the existence of "Keynesian Uncertainty" in the *Treatise on Probability* and its link to the *General Theory* has emerged (Carabelli 1985, 1988, 1992 and 1995; O'Donnell

[40] This distinction first arises in Knight's works:

> It will appear that a *measurable* uncertainty, or 'risk' proper, as we shall use the term, is so far different from an *unmeasurable* one that it is not in effect an uncertainty at all. We shall accordingly restrict the term 'uncertainty' to the cases of the non-quantitative type.
>
> (Knight 21: 20)

1989, 1990, 1991a; Lawson 1985, 1988; Runde 1990, 1991, among others). Thus, I think that it is important to look at the *Treatise on Probability* before we define what is understood here as Keynesian uncertainty.

II.1.1 Keynes's Probability

The *Treatise on Probability* (Keynes *C.W.* VIII, henceforth 'the *Treatise*') is a philosophical work which integrates discussions of logic, rationality, epistemology, ethics and probability. Despite its comprehensive scope, for the present we will only look at those aspects that are related to our discussion of uncertainty.

For Keynes, probability is about logical relations between sets of propositions of premisses and conclusions. Let the conclusion be the set of propositions a, and the set of premisses, h. If knowledge of h justifies a rational belief in a of some degree, one can say that there is a probability relation between a and h. This relation can be written as: a/h.

As one can see from the definition above Keynes's "probability was embodied in arguments and judgements which had no direct relationship with empirical and physical entities and which referred to the process of reasoning, rather than to the happening of events" (Carabelli 1988: 15). The probability relation or the degree α of rational belief that it entails ranges from a situation of certainty ($a/h = 1$), meaning that the relationship between a and h is one of complete entailment, to a situation of impossibility ($a/h = 0$), where a and h are contradictory. A situation where $0 \leq a/h \leq 1$, means that the probability relation warrants a degree of belief intermediate between 0 and 1.

However, it is important to note that what is described here as certainty does not mean truth. Truth is a property of a proposition while certainty is a logical relation between propositions. When the situation of $a/h = 1$ occurs, this means that a logical relation between two propositions allows us to believe that a follows from h with certainty. Thus, the probability relation is defined solely in terms of the relation between the conclusion and the premisses. If, after establishing a probability relation of type a/h, new evidence h_1 appears, this does not invalidate the previous probability relation, but gives rise to a new one of the type a/hh_1.

There are some properties of Keynes's probability that are worth discussing more fully. Firstly, probability is an attribute of the relation between propositions, not of things in themselves:

> No proposition is itself either probable or improbable, just as no place can be intrinsically distant; and the probability of the same statement varies with the evidence presented, which is, as it were, its origin of reference.
>
> (Keynes *C.W.* VIII: 7)

Secondly, as probabilities are connected to logic and not to psychology, they are never subjective, but always objective as associated with knowledge of the logical relation between the premisses and the conclusion:

> But in the sense important to logic, probability is not subjective. It is not, that is to say, subject to human caprice. A proposition is not probable because we think it so. When once the facts are given which determine our knowledge, what is probable or improbable in these circumstance has been fixed objectively, and is independent of our opinion.
>
> (Keynes *C.W.* VIII: 4)

The premisses *h* represent all knowledge (corpus of knowledge) that an individual possesses. So, as individuals are not identical, the premisses *h* will vary between them. The same conclusion could be supported by different sets of premisses, as the latter will vary among individuals. It is clear that there is a subjective element in it. However, as noted by O'Donnell (1989: 41), this subjectivity of the set of premisses *h* does not affect the objectivity of the probability relation, as objectivity refers to the logical relation between *a* and *h*, and not to *h* alone.

Thirdly, following from the second property, probability is always concerned with rational belief, and not with mere belief or psychological belief.

Fourth, for Keynes, the concept of probability has an universal application:

> His theory of rational inference thus takes the whole of human thought as its domain, ranging across areas as diverse as actuarial studies, legal disputation, moral reasoning, metaphysical speculation, psychical research and mathematical argument, not to mention daily life and all branches of the natural and social sciences.
>
> (O'Donnell 1989: 38)

A final important property of Keynes's probability is that not all probability relations can be numerically measurable. On the contrary, in Keynes's view, a probability relation is, in general, a non-numerically measurable quantity:

> Only probability relations which are of the *same kind* and in the *same unit* of quantity are numerically measurable and therefore numerically comparable. ... Moreover, this impossibility of numerical measurement is not a product of mental incapacity or lack of knowledge, but it arises from the nature of the case itself.
>
> (Carabelli 1992: 8; see also, Carabelli 1995: 138)[41]

Let us take a closer look at this property. Keynes starts by arguing that a numerical measurement of probability is possible where there is a number of equally probable alternatives. Keynes calls the rule that should be used to establish this equiprobability as *the Principle of Indifference* (POI)[42]. In a less formally elaborated version the POI asserts:

> ...if there is no *known* reason for predicting of our subject one rather than another of several alternatives, then relatively to such knowledge the assertions of each of these alternatives have an *equal* probability. Thus *equal* probabilities must be assigned to each of several arguments, if there is an absence of positive ground for assigning *unequal* ones.
>
> (Keynes *C.W.* VIII: 45)

However, Keynes shows that stated in this way, the POI implies contradictions. An interesting example concerns the determination of the probability of a book being red. In the absence of contrary evidence this probability will be ½ according to the POI (there are two exclusive alternatives - being red or not being red - about which there is no reason to ascribe unequal probabilities). However, the probability of the book being black is also ½, and the same applies for the alternative 'the book is blue'. Thus, one is faced with the impossible case of three exclusive alternatives that are all equally likely.

Keynes also argues that a rejoinder to this contradiction could be made by claiming that we know the proposition: "Two different colours cannot be predicted of the same subject at the same time; and that, if we know this, it constitutes relevant outside evidence. But such evidence is about the predicate, not about the subject" (C.W. VII: 46). Thus, the conclusion is that POI is a necessary but not sufficient condition of equiprobability.

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[41] These characteristics of probability explain situations called rational dilemmas. These are analogous to moral dilemmas, such as conflicts of duties and moral rules, which are typical in ethics.

> In reasoning or in judgement, rational dilemmas arise from the conflict between heterogeneous, opposite or incommensurable reasons that cannot be weighed one against the other using a common scale.
>
> (Carabelli 1995: 140)

[42] Keynes (*C.W.* VIII: 44) argues that the rule provided by James Bernoulli - *the principle of non-sufficient reason* - is clumsy and unsatisfactory, and so he prefers to elaborate *the Principle of Indifference.*

Keynes made his point in the following way. First, he shows that the POI relies on two kinds of judgement: one regarding relevance (or irrelevance) and one concerning preference (or indifference). Given two probability relations, a/h and a/hh_1, with identical conclusions but a different set of premisses, the judgement of relevance implies that:

if $a/h \sim^* a/hh_1$ then h_1 is irrelevant to the argument

if $a/h \succ^* a/hh_1$ or (3.1)

$a/hh_1 \succ^* a/h$ then h_1 is relevant to the argument.[43]

In addition, given two probability relations, a/h and b/h, with identical premisses but a different set of conclusions, the judgement of preference implies that:

if $a/h \sim^* b/h$ then there is an indifference

if $a/h \succ^* b/h$ or (3.2)

$b/h \succ^* a/h$ then there is a preference.

Thus, two alternatives will be considered equally probable if the judgement of indifference prevails between them. But this judgement involves a previous judgement of irrelevance.[44] However, Keynes introduces an additional rule, claiming that the alternatives must be indivisible relative to the evidence.[45] The definition of 'divisible' is the following:

> Let $\varphi(x_1)$, $\varphi(x_2)$, $\varphi(x_3)$ be values of the same propositional function.[46] Then an alternative $\varphi(x_1)$ is divisible if there are x_2, x_3 such that, on [h], '$\varphi(x_1)$' is

[43] In Keynes's words:

> h_1 is irrelevant to [a] on the evidence h, if there is no proposition, inferable from h_1h, but not from h, such that its addition to evidence h affects the probability of [a].
>
> (Keynes *C.W.* VII: 59)

He continues in a footnote on the same page,

> That is to say, h_1 is irrelevant to [a]/h, if there is no proposition h_1' such that $h_1/h_1h = I$, $h_1/h \neq I$, and $[a]/h_1'h \neq [a]/h$.

[44] "This condition states that [h_1] is irrelevant to [a] on [h] if [a] on [hh_1] is as probable as [a] on [h]" (Runde 1994b: 101).

[45] As pointed out by Runde, a single application of POI does not avoid the contradictions of the book example shown before:

> The root of the problem, in these cases, is that one or more of the alternatives are a disjunction of subalternatives of the same form. The negation of the hypothesis that the book is red, for example, includes the hypotheses that the book is black, that it is blue, and so on.
>
> (Runde 1994b: 101)

[46] "If [$\varphi(x_1)$, $\varphi(x_2)$], etc., are propositions, and x is a variable, capable of taking the values [x_1, x_2], etc... then [$\varphi(x)$] is a propositional function" (Keynes *C.W.* VIII: 60 n.1). The statement $P(\varphi(x_1)/h)$ should be read as 'the probability on h that x is φ'.

equivalent to '$\varphi(x_2)$ or $\varphi(x_3)$', $\varphi(x_2)$ and $\varphi(x_3)$ are mutually exclusive, and each is possible when [*h*] is true.

(Runde 1994b: 101)

To judge whether or not the two alternatives $\varphi\ (x_1)$ and $\varphi\ (x_2)$ are equiprobable (i. e. whether or not they are suitable to be measured and compared in a cardinal way), it is necessary to verify, first, if the evidence is symmetrical with regard to x_1 and x_2, and second, if $\varphi\ (x_1)$ and $\varphi\ (x_2)$ are indivisible relative to *h*.

Therefore, in order to assign numerical probability to a given alternative, it is necessary, according to Keynes, to use judgements of relevance to distinguish relevant evidence, and then to determine whether indifference or preference exists between the alternatives on such relevant evidence. When the judgement of indifference prevails between the indivisible alternatives, then the mathematical calculus may be applied as they are equiprobable.

O'Donnell gives an example:

> Consider, for example, a supposedly fair dice [sic] with three red numbers and three green numbers. Judgements of relevance determine that the colour differences are immaterial and may be ignored. Judgements of indifference then establish that the probability of throwing any one of the numbers is the same as throwing any other. All six alternatives are thus equiprobable, the probability of each being one-sixth.
>
> (O'Donnell 1989: 57).

Despite the fact that probabilities are usually not measurable in a cardinal way, there are situations in which non-numerical probabilities can be compared in a ordinal way. To do so, they have to conform to either of two standard forms:

a) They have identical premisses but the conclusions are different but overlapping (a/h and ab/h). In this case $a/h \succ ab/h$, as the same set of premisses has to support a greater set of conclusions. "For example, given black clouds in the sky [*h*] the probability of rain alone [*a*] is higher than the probability of rain and hail combined [*ab*]" (O'Donnell 1989: 58).

b) The inverse case: they have identical conclusions and different but overlapping premisses (a/h and a/hh_1). In this case, h_1 must have only one independent piece of knowledge. Whether a/h is greater or less than a/hh_1, will depend on whether h_1 is favourable or not. For example, take the case where h = black clouds in the sky and a = today will rain. Suppose that h_1 =

it is the rainy season. As h_1 is favourable premisses then $a/hh_1 \succ a/h$. If h_1 = the weather report says that today there will be no rain, then $a/h \succ a/hh_1$.

For Keynes, however, the cases where cardinal comparisons are possible are not the general rule. Usually, the probability relations are not comparable on either ordinal or cardinal terms, i. e. neither if $a/h \succ^* b/h$ nor $b/h \succ^* a/h$.

An interesting way to represent Keynes's theory of probability is suggested by Koopman (1940). In this article he defines the axioms and the algebra of *intuitive probability*, and he identifies Keynes's theory of probability as an example of this type of probability. The *intuitive* thesis in probability asserts that probability derives directly from the intuition, both in its meaning and in the majority of laws which it obeys. Contrary to the common use of probability, the *intuitive* approach claims that experience should be interpreted in terms of probability and not the inverse. Thus, *intuition* comes prior to objective experience. The main aphorism of this thesis is that "knowledge is possible, while certainty is not" (Koopman 1940: 269).

The importance of the intuitive probability to our discussion is that it simplifies the conditions for the comparability between probabilities, without discrediting the main aspects of Keynes's interpretation. According to Koopman (1940: 270), "the fundamental view point of the [intuitive probability] is the primal intuition of probability expresses itself in a (partial) ordering of eventualities."

Let a_1, h_1, a_2, and h_2 be propositions, where the meaning is perceived by an individual that does not know whether this apprehension is true or false.

> Then the phrase '[a_1] on the presumption that [h_1] is true is equally or less probable than [a_2] on the presumption that [h_2] is true', conveys a precise meaning to his intuition. ... That is ... a first essential in the thesis of intuitive probability, and contains the ultimate answer to the question of the meaning of the notion of probability.
>
> (Koopman 1940: 270)

This could be represented in symbolic forms of comparison in probability as:

$$a_1 / h_1 \geq^* a_2 / h_2 \quad (3.3)$$ [47]

[47] Where "$\geq^*$ is the qualitative probability relation 'at least as probable as' " (Runde 1997a: 223).

This is precisely the kind of comparison that Keynes discusses in the *Treatise on Probability*. So, hereafter we will use the above symbolic form to describe Keynes's approach.

To conclude, what is important is that in Keynes's approach probability is a branch of logic. As pointed out by Carabelli (1988: 18), "Keynes's logic of probability appealed to those categories traditionally associated with the theory of belief, opinion, limited knowledge, logical doubt and ignorance, i.e. uncertainty and probability". Logic in this sense is not restricted to demonstrative knowledge or truth relations. According to Keynes, probability arguments, in general, are non-demonstrative and non-conclusive and thereby generally opposed to the Cartesian/Euclidean mode of thought. Moreover, this logic is "non-demonstrative because it refers to organic relations that would not be amenable to formal representation" (Dow 1996a: 7).[48]

II.1.2 Weight of Argument

Another important element in Keynes's approach is the concept of weight of argument. Keynes's main concern in discussing probability is to show that one can act rationally in situations where certainty about the future is absent. In these situations one should look not only at the probability relation but also at the amount of the evidence - evidential spread - that support this probability. Here Keynes brings into the discussion the concept of the weight of argument.

Runde (1991) argues that three definitions of weight can be found in the *Treatise*. The first one comes from the following quotation:

> One argument has more weight than another if it is based on a greater amount of relevant evidence.
>
> (Keynes *C.W.* VIII: 84)

The relevance or not of one piece of evidence is defined as $a/h \neq a/hh_1$, h_1 being a new independent piece of evidence, and this definition of weight might be written as $V(a/h)$. In a situation where the new evidence h_1 is relevant a comparison of the form $V(a/hh_1) \succ V(a/h)$ can be established. Despite this, the degree of belief warranted by the

[48] According to Dow,

> An organic system involves interdependencies that preclude the selection of one set of axioms as universally causal; it also involves interdependencies that are complex and evolutionary, and thus not amenable to formalization with respect to separable elements within a single system of reasoning.
>
> (Dow 1996b: 15)

probability relation does not necessarily increase in the same way. Weight possesses different attributes from probability. The latter is a (usually partial) logical relation between an hypothesis and the evidence bearing on it. Weight, in the present definition, is the comparison between the absolute amounts of relevant evidence; i.e. it is related to *h*. It might be regarded as an indicator of the extent to which we feel justified in being guided by the probability judgement warranted by the relevant probability relation. Thus, weight and probability are two autonomous and independent properties of an argument. The greater the amount of relevant evidence, the greater the weight of argument. However, as the probability judgement has independent properties from the weight, the magnitude of the probability may either increase or decrease.

In the second definition, weight is regarded as the balance between the absolute amount of relevant knowledge and relevant ignorance.[49] This may be represented by

$$V(a/h) = K_r/I_r \qquad (3.3)$$

where K_r is the relevant knowledge and I_r is the relevant ignorance.

The last definition could be named as a relative definition of weight, as it is referred to the *degree of completeness of the information set on which a probability is based.* This is expressed, according to Runde (1990: 281), as

$$V(a/h) = K_r/(K_r + I_r) \qquad (3.4)$$

It is worth noting that, in spite of different definitions, the relationship between the weight and the probability mentioned before remains the same, that is, the increase in a weight of argument does not necessarily mean an increase in the probability.

Notwithstanding this similarity, two aspects deserve more attention. The first one is related to the meaning of 'relevant ignorance', which appears in the last two definitions. As Runde (1991) perceptively notes, it is always possible to know, or at least identify, the factors that affect our probability relation, and about which one is ignorant. Secondly, whilst the first definition entails that new evidence invariably increases the weight, in the last two cases new evidence could decrease the weight if it implies the

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[49] In Keynes's words:

> The magnitude of the probability of an argument ... depends upon a balance between what may be termed the favourable and unfavourable evidence; a new piece of evidence which leaves the balance unchanged, also leaves the probability of the argument unchanged. But it seems that there may be another respect in which some kind of quantitative comparison between arguments is possible. This comparison turns upon a balance, not between the favourable and the unfavourable evidence, but between the ***absolute*** amounts of relevant knowledge and of relevant ignorance respectively.
>
> (Keynes *C.W.* VIII: 77)

increase of relevant ignorance. A new piece of evidence can show that our previous relevant knowledge was wrong, decreasing the weight while simultaneously increasing knowledge of the relevant ignorance.

Finally, it is well known that Keynes assumes a direct relationship between weight and *confidence* in using the probability estimate as a guide to conduct. From the discussion above it is possible to see that the definition of weight as a *degree of completeness of information* is much more appropriate to the understanding of this relationship. The different definitions of weight have opposite consequences for this relationship. In the first definition, as we have seen, new relevant evidence always increases the weight and, as a consequence, the confidence must increase. On the other hand, confidence can either decrease or increase if one assumes the definition of weight as degree of completeness of information, for the reason that new evidence may increase the relevant ignorance or knowledge. Thus, as the latter definition of weight takes into account both ignorance and knowledge, it will be adopted in the following discussion.

Summing up, Keynes is concerned with situations where frequency probability cannot be used. The use of *intuitive* probabilities can help understand the rationality in this kind of situation, and Keynes's probability incorporates the main aspects of the *intuitive* approach. It is more about logical relations than experience of events, and despite this fact, allows the comparison of the form of $a_1 / h_1 \geq^* a_2 / h_2$. Moreover, in order to act, one has to take into consideration not only the probability itself but also the set of pieces of evidence that bears on this probability. To assess this evidence, Keynes provides the concept of weight of argument, which, in its most comprehensive form, is defined as the degree of completeness of the information set. This definition allows the incorporation into the framework of analysis of both relevant knowledge and relevant ignorance.

In what follows we intend to show how these two main aspects of the *Treatise* - probability relation and weight of argument - have been used by scholars (Runde 1990; Dow 1995, Dequech 1997) to define uncertainty in a Keynesian sense and, in addition, to demonstrate that Keynesian uncertainty admits degrees.

II.2 Degrees of Uncertainty

The main claim in this section is that Keynes's theory of probability can provide the basis to the claim that there are *degrees of true uncertainty*.[50] In this section, I will discuss Keynes's view of the concept of uncertainty and elucidate the arguments based on it.

Two notions of uncertainty emerge from the *Treatise*,[51] both of them related to the absence of knowledge of the probability relation. In the first one, uncertainty can be described as a situation where the probability relation (*a/h*) is *unknown*. It is "*unknown* to us through our lack of skill in arguing from given evidence. The evidence justifies a certain degree of knowledge, but the weakness of our reasoning power prevents our knowing what the degree is" (Keynes *C.W.* VIII: 32). It is not a case of one having too little evidence, but of our inability to identify the probability relation, although this probability exists, at least in principle. It is worth noting that this notion of uncertainty is similar to Simon's (1976) concept of bounded rationality. However, it is not necessary to appeal to bounded rationality to describe the incapacity of the agent to identify the probability relation. As pointed out by Dow (1995: 118-9), one key aspect of the world that makes it impossible to ascertain the probability relation is that, as Keynes himself acknowledges (*C.W.* X: 262), the economic system is organic and open. According to Dow,

> An open system is one where not all the constituent variables and structural relationships are known or knowable, and thus the boundaries of the system are not known or knowable.
>
> (Dow 1996b: 14)

It is clear that there are some ontological features of the world that are fundamental for the existence of the uncertainty.

The second notion is stronger than the first one, as it claims that the absence of probability relation is because "there is no probability at all". It is possible to identify these notions of uncertainty in the 1937 *QJE* article:

> By 'uncertain' knowledge, let me explain, I do not mean merely to distinguish what is known for certain from what is merely probable. The game of roulette is not subject, in this sense, to uncertainty; nor is the prospect of a Victory bond being drawn. Or, again, the expectation of life

[50] The term 'true uncertainty' will be used here to stress the difference between Keynes's view and the Subjective Utility approach (risk).

[51] Keynes himself does not explicitly define uncertainty. However, the interpretation suggested here shares the agreement of many scholars (see, for example, Lawson 1985, 1987; Runde 1990, 1991; O'Donnell 1989).

> is only slightly uncertain. Even the weather is only moderately uncertain. The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence, or the obsolescence of a new invention, or the position of private wealthowners in the social system in 1970. *About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not know.*
>
> (Keynes *C.W.* XIV, pp. 113-114, italics added)[52]

From what has been said before, one can conclude that Keynes's notions of uncertainty have both epistemological and ontological aspects. Uncertainty is epistemic when its cause is a lack of skill in identifying the probability relation. Uncertainty, however, is also ontological, as when the probability relation does not exist due to the organicity and openness of the world. However, it should be noted that these concepts are not mutually exclusive.[53]

Runde (1991, 1990) argues that these two notions of uncertainty – unknownness and absence of probability relation - do not exhaust the ways Keynes uses the concept of uncertainty. He claims that uncertainty could be related to the amount of information, in some sense, upon which the probability relation is based. In other words, uncertainty can be related to the weight of argument if the latter is defined as a *degree of completeness of information on which a probability is based.* Despite the fact that this notion is not fully explored in the *Treatise*, Runde gives two quotations from the *General Theory* that indicates that Keynes believed uncertainty could be related to the weight of argument:

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[52] O'Donnell gives a very interesting interpretation of this passage based on Keynes's philosophical framework:

> The first key word is 'scientific' which ... may be translated as 'rational'. The second key word is 'calculable', for which two options are open. If taken in the narrow cardinal sense, the contention is that only numerical probabilities are unavailable. This option leaves open the possibility of knowledge of non-numerical probability. But these, too, Keynes apparently wants to exclude, for his intention is to go *beyond* the distinction between certainty and probability. The sense of uncertainty he is seeking to identify is more than that implied by a knowledge of probabilities. Not only are the numerical probabilities of roulette excluded, but so are those weather forecasts for which a probability (whether cardinal or ordinal) could conceivably be established. This leads to interpreting 'calculable' in the wider ordinal sense, in which case we have full-blown irreducible uncertainty with no known probability whatsoever, numerical or non-numerical. We are landed in the realm of *unknown probabilities* which arise from a weakness of reasoning power in relation to given data. It is in this sense that agents 'simply do not know' - they are deprived, by a deficiency of logical insight, of knowledge of *a/h*. There is simply insufficient data relative to logical ability to from a probability of any kind; expressed in related terms, the weight of argument is extremely low for events in distant future.
>
> (O'Donnell 1989: 260)

[53] In Dequech's words,

> The notion of uncertainty is always epistemological in the sense that it is associated with the lack of some kind of knowledge (...), and knowledge is the subject of epistemology; at the same time, the notion of uncertainty always has an associated view of reality, and has an ontological counterpart, given that ontology refers to the study of the nature of reality.
>
> (Dequech 1997: 24)

> The state of long-term expectations, upon which our decisions are based, does not solely depend, therefore, on the most probable forecast we can make. It also depends on the *confidence* with which we make this forecast - on how highly we rate the likelihood of our forecast turning out quite wrong.
>
> (Keynes *C.W.* VII: 148)

And:

> The liquidity-premium, it will be observed, is partly similar to the risk-premium, but partly different; - the difference corresponding to the difference between the best estimates we can make of probabilities and the confidence with which we make them.
>
> (Keynes *C.W.* VII: 240)

It is clear from these quotations that confidence is the key element in this interpretation of uncertainty. As it was shown above, the concept of weight, as a degree of completeness of information, appears to be the best one to capture the role of ignorance in the assessment of confidence in the probability relation. Therefore, the complete absence of probable knowledge should be interpreted as the extreme case of uncertainty. If it is impossible to establish the probability relation, either because there is no basis for probability at all or the ability to determine or identify it is inadequate, the existence of any degree of confidence is also impossible. Thus, this situation could be interpreted as an extreme case not only for uncertainty, but also for confidence.

From this extreme position, one can move to situations where uncertainty prevails because of a low weight of argument, which implies low confidence. Thus, there is a *qualitative* change in the uncertainty, from a situation in which a probability relation does not exist to another one in which a probability relation does exist but the weight is low. Moreover, as the weight of argument increases, the confidence follows in the same direction and the uncertainty decreases. In this approach, probable knowledge is taken into account as a guide to conduct, and the degree of reliability of this probable knowledge - the confidence it merits - determines the degree of uncertainty that exists in a specific situation. So the concept of weight allows the understanding of uncertainty as a relative concept.

Dow (1995) goes further in the development of the concept of degrees of uncertainty. She argues that to estimate uncertainty in terms of weight, one must bring into consideration the knowledge of what constitutes relevance. Therefore, it is required to have "some degree of belief in a hypothesised structure on which to base an estimate of weight" (Dow 1995: 124).

Although we agree with this general statement, we think that to define what is relevant or not it is necessary to go further in the analysis. First, the relation between weight and probability should be clearly understood. Despite possessing different attributes, they cannot exist without each other. Weight is not a property that exists in isolation. It is related to the evidence that bears an hypothesis and, so, it is related to a specific probability relation. [54] A same amount of evidence can bear different degrees of belief in different conclusions. The relevance of a given set of evidence will differ for different kinds of conclusions. Note that this holds whatever definition of weight we are dealing with. All definitions refer to the relevance of the evidence, and this evidence cannot be evaluated without reference to the conclusion.

The main point here is to note that there is a difference between to define to what extent the amount and quality of *h* gives confidence on the probability relation (which is related to the discussion about the weight) and to acknowledge that it is possible to establish a logical relation between *a* and *h* (which implies a discussion about what gives rise to a probability relation). Our claim here is that the understanding of the latter is essential to answer the question about what constitutes relevance.

Keynes answers the question about how a probability relation arises, by bringing into discussion the concept of secondary proposition (*q*). It is a proposition that describes a particular characteristic of a primary proposition. It is the knowledge of the secondary proposition (*q*) that supports the degree of rational belief in *a*/*h*. In Keynes's words,

> The proposition (say, *q*) that we *know* ... is not the same as the proposition (say, [*a*][55]) in which we have a probable degree (say, α) of rational belief. If the evidence upon which we base our belief is *h*, then what we know, namely *q*, is that the proposition [*a*] bears the probability relation of degree α to the set of propositions *h*; and this knowledge of ours justifies us in a rational belief of degree α in the proposition [*a*].
>
> (Keynes *C.W.* VIII: 11)

In our view, Keynes's secondary proposition and Dow's (1995) "hypothesised structure on which to base an estimate of weight" are very much alike. For we can only evaluate whether a set of evidence is relevant or not, and so estimate the weight of argument, if

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[54] Some authors, like O'Donnell in the end of footnote 46, interpret *unknown probability* as low weight of argument (in its relative concept). I think that this interpretation is contradictory to the understanding of uncertainty as the logical impossibility of establishing the probability relation. If it is impossible to assert a probability relation it is also impossible to measure the weight. If it is impossible to assert the logical relation between *a* and *h*, so it is impossible to know what is relevant (knowledge or ignorance) about it.

[55] Keynes uses *a* and *p* interchangeably to represent the set of conclusions. To avoid confusion to the reader we substitute *p* for *a* in Keynes's quotation.

we refer to the factors that allow us to have a degree of belief that there exists a logical relation between the hypothesis (*a*) and the evidence that bears it (*h*). This factor is the secondary proposition.

Now the discussion turns to whether the secondary proposition can be treated as uncertain. This is not a consensual matter. Keynes, himself, was ambiguous about this point (Runde 1994b: 103).[56] To clarify the matter, one should enquire into the nature of the direct knowledge, which is the essence of the secondary proposition: Is this direct knowledge true and certain or a *priori* thought? Lawson (1987: 960-62) provides an answer to this question. He argues that direct knowledge has both a relative and an absolute nature. He starts by asserting that

> ... knowledge can be understood, not as the building of a superstructure upon an unchanging foundation, but as proceeding in stages where the foundations at each new stage is the previous one. The course of acquiring and developing knowledge, provisional starting points come to be questioned and criticised and existing views are rethought and reinterpreted.
>
> (Lawson 1987: 960)

Knowledge in this account is provisional as it is delimited by the circumstances in which it is used and it is subject to rethinking and reinterpretation. In this sense it has a relative nature: "The directness of knowledge is relative to the background of the knower" (Lawson 1987: 961). However, at the same time, it is absolute in relation to this background. The claim here is that, as relative and susceptible to change, direct knowledge can be subject to uncertainty.

One has now two orders of uncertainty that work together. First, there is uncertainty about the secondary proposition, or in other words, uncertainty about the "hypothesised

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[56] This ambiguity can be seen through the following quotations:

> A probable degree of rational belief in a proposition ...arises out of knowledge of some corresponding secondary proposition. A man may rationally believe a proposition to be probable when it is in fact false, if the secondary proposition on which he depends is true and certain.
>
> (Keynes *C.W.* VIII: 11)

> While it is important, in establishing a control of direct judgment by general principles, not to conceal its presence, yet the fact that we ultimately depend upon an intuition need not lead us to suppose that our conclusions have, therefore, no basis in reason, or that they are subjective in validity as they are in origin. It is reasonable to maintain with the logicians of the Port Royal that we may draw a conclusion which is truly probable by paying attention to all the circumstances which accompany the case, and we must admit with as little concern as possible Hume's taunt that 'when we give the preference to one set of arguments above another, we do nothing but decide from our feeling concerning the superiority of their influence'.
>
> (Keynes *C.W.* VIII: 76)

structure" that gives rise to a probability relation. This structure should be used to evaluate the relevance of the evidence. Uncertainty, in this sense, is inversely related to a lower order of knowledge regarding this structure. Second, there is uncertainty about the *degree of completeness of information on which a probability is based.* From this perspective, the limit situation is one where knowledge about the probability relation is absent and ignorance is complete.[57]

We think that an example can help to understand the argument. Suppose the following four situations, in which different persons are asked to assess the likelihood of rain the next day. In situation one, an alien has just arrived at earth, coming from a planet with a completely different atmosphere. The situation can be described as follows: the conclusion is the proposition (*a*) 'it will rain tomorrow'; the evidence (*h*) is 'annual series of atmospheric pressure, temperature and rain in the last fifty years, and the actual atmospheric pressure and temperature, and he is asked to assess the probability a/h. As he is an alien, he does not know the relation between atmospheric pressure and rain, in other words, he does not know the structure that should be used to assess the uncertainty. In this case, the probability relation will be unknown and there will be no weight to be assessed. It is an extreme case of uncertainty.

In the second situation, an ordinary person, who knows the relation between atmospheric pressure and rain by personal experience and by reading newspapers (i.e. has a degree of belief in the structure[58]), receives as evidence the series of pressures, temperatures and rain in the last fifty years but not the all the actual measures (only the temperature). He is faced with the same question: 'will there be rain tomorrow?' In this case, he can establish the probability relation a/h and so, he can evaluate the relevance of the evidence he has. As important pieces of information are missing, one can say that he is facing a high degree of uncertainty due to low degree of belief in the structure and low weight of argument.

In situation three, the set of evidence is the same as in the previous case, but the person is a professor of climatology. As an expert he possesses a knowledge of the structure that allows him to have a higher degree of belief in the structure than the ordinary

[57] However, this situation is admitted as not feasible:

> As uncertainty is compounded at higher recursive levels, our necessary conceptual structures become complex, counterintuitive and involuted to the point that they collapse under their own weight. Put in another way, absolute ignorance is incompatible with knowledge of absolute uncertainty.
>
> (Dow 1995: 124)

[58] As this person does not has a formal education in climatology he cannot has a full certainty about the structure.

person at situation two. So, despite having the same set of evidence, the uncertainty faced by the professor is lower than the ordinary person. It is a case of high degree of belief in the structure and low weight.

Finally, we can have a situation in which the professor received the same set of evidence as the alien. In this case, the degree of uncertainty is low as there is a higher degree of belief in the structure and a high weight.

To sum up this section, we think that it is necessary to present a working definition of Keynesian uncertainty. As shown before, it is possible to find in Keynes's writings three different definitions of uncertainty. To avoid unnecessary confusion we think that a simple definition, sufficiently capable of incorporating all three notions, should be used. Uncertainty will be characterised by situations in which the evidential set upon which the decision-maker has to decide does not provide a completely reliable knowledge to guide conduct. This unreliability is due both to the amount and quality (relevance) of the evidence, and, to the provisional feature of the knowledge necessary to judge the evidential set.[59]

Under this definition of uncertainty it is possible to explain situations that are qualitatively different, that is to say, subject to different degrees of uncertainty. The extreme situation of uncertainty - complete absence of probable knowledge - and situations in which probable knowledge exists - where weight is interpreted as a measure of gradability of uncertainty - are captured in this definition, eluding any confusion. Qualitative degrees of uncertainty can be visualised in Table II.1.

[59] This definition is similar, not identical, to Dequech (1997). He advocates a notion of uncertainty "in which knowledge, due to the paucity of evidence, is incomplete to an extent that makes it not completely reliable as a guide to conduct" (Dequech 1997: 21). My disagreement with this definition is that the use of "the paucity of evidence" as the origin of uncertainty captures only one dimension of the evidential set: its size. However, there is another dimension that it is important to take into account, that is its 'quality' or "relevance".

Table II.1: Scale of Qualitative Degrees of Uncertainty

Uncertainty	Absence of probable knowledge	non-existence of (a/h)	(A)
		lack of skill to recognise (a/h)	
	Probable knowledge	low degree of belief in (q) and low weight	Uncertainty decreases as you move from (A) to (B)
		low degree of belief in (q) and high weight	
		high degree of belief in (q) and low weight	
		high degree of belief in (q) and high weight	(B)

The above discussion about the structure, its relativeness and uncertainty may raise questions about the famous debate between Keynes and Ramsey (1988[1931]), related to the existence or not of logical Relations of Partial Implications. This debate has implications for the enquiry about the use of Subject Expected Utility theory as representative of situations of uncertainty. To avoid misunderstanding, we think that it is appropriate to make explicit our position about this matter.

II.3 Keynesian Uncertainty and Subjective Expected Utility

The Subjective Expected Utility (SEU hereafter) theory holds a special place in economic literature for its claim that it is able to deal with all uncertain situations. As the approach to uncertainty that we are using is different from SEU, this section will discuss the limitations of SEU and elaborate on the reasons it is not used in this study.[60]

The main problems with SEU centre around the following elements of the theory: (i) the assumption that it is always possible to transform beliefs into numerical probabilities; (ii) the axiom of exchangeability of events; and (iii) the independence

[60] It should be noticed that this section does not intend to cover all aspects of SEU, only to show the main arguments that justify why it is not used here.

between action and future states of nature. We will take a closer look at each of them in turn.

The central assumption of SEU is that beliefs can be represented by a probability distribution if they are *coherent* or rational, i.e. if some axioms are fulfilled, beliefs can be measured according to the disposition to bet that subjects have in a specific situation. According to De Finetti:

> It is a question simply of making mathematically precise the trivial and obvious idea that the degree of probability attributed by an individual to a given event is revealed by the conditions under which he would be disposed to bet on that event.
>
> (De Finetti 1980[1937]: 61)

The procedure used in this transformation is called the reference–lottery technique. Suppose that an individual has a preference ordering of future possible outcomes a, b, c, in the form of $a \succ b \succ c$, and that $u(a) \succ u(c)$ are arbitrary utility numbers assigned for the outcomes a and c respectively. He is asked to choose between the certainty of b and a lottery of a with probability p and c if not p. In other words, the subject is asked to choose between the following actions

$$A_1 : u(b) \text{ if } p,\ u(b) \text{ if } \neg p \text{ and}$$

$$A_2 : u(a) \text{ if } p,\ u(c) \text{ if } \neg p \qquad (3.6)$$

where:

$u(\cdot)$: is the utility of the outcome a, b or c;

p : is the probability of a

$\neg p$: the negative of p.

If the subject expresses indifference between A_1 and A_2 this implies that his belief in the occurrence of b is p. What is important to note is that to express indifference the subject must be able to make a composite assessment about values and beliefs in such a way that A_1 should be regarded as exactly equal to A_2. It is not difficult to see that those requirements are very demanding, and imply that the subject's beliefs are assessed in a very precise and determinate way. However, when the concept of weight of argument, as discussed in section I. 2, is taken into consideration, it is reasonable to assume that sometimes the subject's beliefs regarding p are vague because of the low weight of the evidence. In this case, the subject may be unable to decide the precise value of p at which the indifference between a sure value (A_1) and a lottery (A_2) should be expressed.

Moreover, if the lottery implies an outcome that is extreme, such as bankruptcy for example, it may be impossible to find a probability that makes the subject indifferent between the sure outcome and the lottery.

According to Runde (1994b), three possibilities arise from the situation where the subject is unable to assign definite numerical probabilities to his beliefs. The first one is to express indifference as *arbitrary* value, attributing, as a consequence, an *arbitrary* value *p*. However, it is doubtful whether this solution deserves to be called the subjective probability of *p* (Runde 1994b: 117). The second one is the refusal to express preference or indifference between A_1 and A_2 and therefore the refusal to bet. As beliefs are measured only through acts, this refusal means that the subject's beliefs remain unknown. Finally, there is the option of expressing the value of *b* as a range of possible values of *p*. This option represents a very distinct field of research where beliefs are modelled as non-additive probabilities or a convex set of probabilities. What is important to note is that these alternatives are evidence of a strong dispute on the universal applicability of the expected utility approach.

A comparison between SEU and the Keynes/Koopman approach reveals an interesting point. As SEU assumes that beliefs can be numerically measured, it follows that beliefs can always be compared. On the other hand, according to Keynes and Koopman most of the time probabilities are not comparable because of the fundamental problem of *unit*. According to these authors it is perfectly feasible to have situations where neither $a_1 / h_1 \succeq^* a_2 / h_2$ nor $a_2 / h_2 \succeq^* a_1 / h_1$ can be assigned, without saying that they have the same probability. As Kyburg and Smokler (1980: 12) argue, this proposition reflects the intuitive aspect of our opinions. For example, they argue that it is very difficult to compare the belief in the proposition that tomorrow it will rain, after listening to the weather report, to the belief in the proposition that the coin about to be tossed will land heads up; "the degree of two beliefs are simply different". In Keynes's words, they do not have the same *unit* and so cannot be compared.

Even if it is assumed that beliefs can be measured by the betting behaviour of the individual, there is another important component of SEU that deserves careful scrutiny . The degrees of belief must show *coherence*, which is defined in two ways: weak coherence and strong (strict) coherence.

> In the case of the weak definition of coherence, the bettor is incoherent if he so bets that he *must* lose money, while in the case of strong definition of

> coherence, the bettor is incoherent if he bets in such a way that he *may* either come out even or lose money.
>
> (Kyburg and Smokler 1980: 14)

The axiom of coherence shows one feature of SEU that most of the time is overlooked by its followers; that is, its rationality is normative. De Finetti, after arguing that the calculus of probability is used, unconsciously, by *coherent* men in all circumstances of life, added the following footnote:

> Such a statement is misleading if, as unfortunately has sometimes happened, it is taken too seriously. It cannot be said that people compute according to arithmetic or think according to logic, unless it is understood that mistakes in arithmetic or in logic are very natural for all of us. It is still more natural that mistakes are common in the more complex realm of probability; nevertheless it seems correct to say that, fundamentally, people behave according to the rules of coherence even though they frequently violate them (just as it may be said that they accept arithmetic and logic). *But in order to avoid frequent misunderstandings it is essential to point out that probability theory is not an attempt to describe actual behaviour*; its subject is coherent behaviour, and the fact that people are only more or less coherent is inessential.
>
> (De Finetti 1980[1937]: 71, italics added)

The same normative claim is made by Ramsey:

> We found that the most generally accepted parts of logic, namely, formal logic, mathematics and the calculus of probabilities, are well concerned simply to ensure that our beliefs are not self-contradictory. ... But this is obviously not enough; we want our beliefs to be consistent not merely with one another but also with the facts ... Yet it may humanly speaking be right to entertain a certain degree of belief in them [truth or falsity of a proposition] on inductive or other grounds: a logic which proposes to justify such a degree of belief must be prepared actually to go against formal logic. ... *This point seems to me to show particularly clearly that human logic or the logic of truth, which tells men how they should think, is not merely independent of but sometimes actually incompatible with formal logic.*
>
> (Ramsey 1988[1931]: 42, italics added)

Indeed, this distinction between the normative aspect of SEU and actual human behaviour has been shown in many experiments, perhaps the most famous of which is Ellsberg's paradox. This experiment is important as it reveals the salience of the weight of argument as a guide to conduct, in contrast to the SEU approach in which it is based on calculable, numerically measurable probability alone. The Ellsberg paradox can be explained as follows. Suppose there are two urns with 100 balls in each. In the urn 1 there are 50 red balls and 50 black balls and urn 2 has an unknown distribution of red and black balls. People are asked to assign the probability of drawing a red ball from each urn. In so doing, they assign a probability of 1/2 that a red ball will come up in a draw.[61] After that they are asked to choose between to bet on whether a red ball will be drawn from urn 1 or urn 2. In the experiment most of the subjects chose to bet that a red ball would be drawn from urn 1. However, this choice is incompatible (according the axioms of SEU) with the probabilities that they have assigned before. They should be indifferent between the two options as they have assigned equiprobabilities for red in both urns.

Many scholars have tried to explain this contradiction and, indeed, a very interesting field of research has been developed, claiming that there is a problem of ambiguity in the Ellsberg Paradox.[62] However, others (Runde 1994a, 1994b, McCann 1994) also have shown that this paradox[63] can be explained by the use of Keynes's probability theory. Runde (1994b) shows that the comparison between the bets on drawing red from each urn cannot be made as these choices are not symmetrical, in that the existence of relevant evidence for the bet on urn 1 has no counterpart in the bet relating to the second choice.[64] Moreover, the choice made by the subjects demonstrates that evidential weight plays an important role in the decision process, sometimes greater than that played by the probabilities themselves. The subject chose to bet on urn 1 as the weight of argument bearing on it was greater than that relevant to the bet on urn 2. Thus, the "Ellsberg paradox is an example of situations in which preferences are not revealing of probabilities at all" (Runde 1994a: 141).[65]

Another important concept for the subjectivists is that of *exchangeable events* (or in other words, "equivalence", or "symmetry"). It is this concept that provides the connection between subjective probability and the classical procedures of statistical inference, by asserting that despite the differing subjective probabilities that people believe in, the

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[61] Note that for each urn itself the evidence is symmetrical and the subject can assign equiprobabilities.

[62] According to Frisch and Baron (1988), "ambiguity is uncertainty about the probability, created by missing information that is relevant and could be known". This is different from situations where information is *non-existent* at the moment of decision as in the extreme case of Keynesian uncertainty. There is no space here to make a discussion of these theories. For those that are interested in this theme the following references are a good start: Camerer and Weber (1992) and Kelsey and Quigin (1992).

[63] Carabelli (1996) made an interesting point in claiming that the Ellsberg Paradox can only be called paradox in relation to Bayesian rationality. She argues that if another rationality is assumed, like the one that emerges from Keynes's works, the pattern of behaviour expressed in Ellsberg's experiment can be considered rational.

[64] According to Keynes, for two alternatives to be comparable,

> There must be no *relevant* evidence relating to one alternative, unless there is *corresponding* evidence relating to the other; our relevant evidence, that is to say, must be symmetrical with regard to the alternatives, and must be applicable to each in the same manner.
>
> (Keynes *C.W.* VIII: 60)

[65] The Ellsberg paradox violates Savage's complete ordering axiom.

results of applying the procedures of Bayesian inference are the same (Kyburg and Smokler 1980: 15). The prior probabilities are modified according to experiment and experience. The axiom of exchangeability of events claims that the temporal order of occurrence does not affect the probability one is interested in. Consider the probability of drawing a red apple from a basket of unknown composition of green and red apples on the tenth attempt. Whether the sequence of the previous nine trials are in the form of three red apples followed by six green apples or six green followed by three red or a mixture of this proportion, does not affect the probability distribution of the tenth trial. However, the latter is conditional on the outcomes of the previous nine trials. The usual assumption from the subjectivist approach that samples are independently and identically distributed with unknown distribution functions is justified by the concept of *exchangeable events*.[66]

An important implication of the exchangeable events concept is the reversibility of events (Vercelli 1995). The concept of time implicit in this approach is not historical but logical. Irreversibility implies that the cost of mistakes is higher and cannot be reliably evaluated in advance such as in, for example, the case of structural change.

The last point to take into account is the *independence* between actions of the agent and states of nature. This assumption is problematic when *crucial* decisions are taken into consideration.[67] One of the consequences of this type of decision is that the future is *created* and therefore it implies human agency transforming 'states of the world' and generating structural change.[68] Indeed, it is extremely difficult to deal with innovation and accept this imposed and artificial independence. Future states of the world depend on whether an innovation is introduced or not and the type of innovation. Moreover, the decision-maker has to take into account not only his decision but those of others as well, about which he may very well be completely ignorant. As Shackle pointed out, the

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[66] Vercelli (1995: 261, n.14) claims that "it may be shown that the condition for exchangeability is practically the same as those for ergodicity".

[67] A full discussion of this concept will be made in the next section.

[68] This feature also implies a concept of uncertainty that explicitly denies the possibility of forming a probabilistic distribution. In Shackle's words:

> ...where there is knowledge there is not uncertainty. Uncertainty, *unknowledge*, is what confronts the chooser of action - when his act of choice is going to be *once-for-all*, when it is going to be crucial, when it is going to be an experiment the making of which will *destroy the possibility* of ever making that experiment again. In such a case we cannot say what will happen, even if we only claim to say it half-heartedly, as a 'probability'. We can only attain some notion of the kind of thing that *can* happen.
>
> (Shackle 1983: 109)

From the quotation above, it is clear that probabilistic frequency distributions can only be used in situations that can be repeated infinitely and in identical circumstances, which is not the case for crucial decisions.

understanding of probability as distributionally measurable, as assumed by SEU, is highly constrained in these situations. This understanding implies that probability is an additive measure that is distributed over an exhaustive list of states of the world. However, there is sufficient reason to assume that in a situation where the relevant states consist of alternative assumptions about a complex future state of affairs, the individual would not be able to list all possible relevant assumptions.[69]

Some supporters of SEU claim that this problem can be solved by assuming that the agent takes into account only the future states of the world that he *can* imagine. This is sufficient to apply and satisfy the axioms of SEU. However, the problem is that the individual knows that there are some future state of the world which could possibly occur and which he does not know about. He knows that he does not encompass all future states of the world in his calculation. Crotty (1994) has similar argument:

> When knowledge of the future is subjective and imperfect, as it always is, the expectations of rational agents can never be fully and adequately represented solely by probability distributions because such distributions fail to incorporate the agent's own understanding of the degree of incompleteness of their knowledge.
>
> (Crotty 1994: 114)

Therefore, in these situations, ambiguity or Keynesian uncertainty prevails.

II.4 Degrees of Uncertainty, Crucial Decisions and Nonergodicity

In the Keynesian literature about uncertainty, there are numerous references to the concept of 'nonergodicity' to justify an interpretation of uncertainty as a rigid concept that cannot be graded (Davidson 1982/1983, 1993, 1995). Shackle's discussion about *crucial decisions* or *unique experiments* has been widely used to justify the nonergodicity of the economic environment. In this section we will show that the existence of degrees of uncertainty does not contradict an understanding of the world as a nonergodic system.

[69] On this point, Shackle makes another critique that is clearly explained by Ford:

> This is simply that *probability* is a *distributional variable*. If the set of exhaustive, mutually exclusive, outcomes should be expanded, by the individual imagining that some consequence that an extra outcome appears in the set, every outcome that was a member of the original set must be accorded a lower probability of occurrence to enable the new outcome to be accommodated: the probabilities of the (exhaustive) states of nature must sum to unity. Such an effect seems counter-intuitive, since nothing need have occurred to cause the individual to adjust his opinions about the intrinsic nature of the likely attainment of any particular outcome.
>
> (Ford 1990: 31)

Indeed, we will show that even in Shackle's writings it is possible to find elements that support this argument.

II.4.1 Shackle's decision process and potential surprise

The concept of knowledge for Shackle is fundamental to the understanding of his work. For Shackle, knowledge is directly related to certainty. Where there is knowledge there must be certainty. This position is expressed in many passages, for example:

> Knowledge would not deserve that name if it gave us several conflicting accounts and answered our question "What will follow if I do this?" in more than one way. [...] Knowledge must consist in a statement which is unique.
>
> (Shackle 1970: 106)

If knowledge means certainty, where there is uncertainty there is no knowledge. These situations will appear, according to Shackle, in circumstances where *crucial, non-empty* decisions apply. An *empty* decision is the mere account of a formal solution to a formal problem. It is that situation where a person has a complete and certain knowledge about all possible choices and all possible outcomes of each choice. It is a mechanical and inevitable action (Shackle 1959: 291).

When one looks at Shackle's definition of 'decision', one realises that empty decisions are not true 'decisions' in his account. He argues for an understanding of 'decision' as a commitment to the first step in an action of choosing among a plurality of rival and mutually exclusive hypotheses, about which it is impossible to know the relevant consequences (Shackle 1958: 35). Obviously, this is far from a situation of complete knowledge and deterministic actions as in the case of empty decisions.

By contrast, the *crucial, non-empty* decision implies the impossibility of repetition of the decision process "because its very performance destroys forever the conditions in which it was undertaken, which form an essential part of it" (Shackle 1970: 109). It is a unique decision that brings new information "which agents will need to take into account in the future courses of action" (Andrade 1997: 13). Some examples of crucial decisions are investment, accumulation of wealth, and finance. In Shackle's view, when crucial decisions such as these are made, there is no knowledge.

If a decision is a process of commitment by the decision-maker with an action-scheme whose outcome is unknown, the question that should be raised is about the process in which such a decision is made. Here, Shackle introduces his concept of expectation.

According to him, the decision-maker is concerned with the consequences of his choice in the future. As the outcome is not known beforehand, he has to resort to imagination to figure what will be the possible outcomes. It is the enjoyment or satisfaction provided by these outcomes that will guide the choice of the decision-maker. However, Shackle argues that there is a distinction between free or pure imagination, and what he calls expectations. In Shackle's words:

> There are of course pleasures to be had from mere day-dreaming, but they are of a different sort from those of expectation. These latter we may call enjoyment by *anticipation*. When we speak of what the decision-maker *can* visualise, we mean what he can *anticipate*, that is what he can imagine without a sense of unrealism.
>
> (Shackle 1958: 42)[70]

Nevertheless, based in this concept of expectations, how are decisions made? This question brings into account another important contribution of Shackle, that is, his concept of *potential surprise*. The latter can be explained as follows.

> Between a feeling of certainty that a given event will happen (or some particular answer to a given question turn out to be the truth), and a feeling of certainty that it will not, there seems to be a continuous range of different levels at which our *degree of belief* can stand.
>
> (Shackle 1943: 101)

This degree of belief is measured by an operation by which the decision-maker asks himself how much "intensity of shock or surprise" he "would feel if, without there having been any change in the knowledge available to him on which he based his belief in it, he were to learn that this belief is mistaken ... The measure so obtained is what we may call the *potential surprise* associated ... with a given hypothesis" (Shackle 1943: 101).

So, there is an direct relationship between the degree of belief in one possible outcome and its potential surprise value. The higher the degree of belief, the higher the potential surprise. It is clear that the concept of potential surprise is directly related to novelty. What makes the degree of potential surprise differ among different hypotheses is the possibility of the emergence of new and special factors, of which there is no evidence at the present for the decision-maker. Thus, surprise means that the individual's structure of expectations either contains a misjudgement or has been incomplete.

[70] **Elsewhere, Shackle uses this limitation to the imagination of the decision-maker to define 'decision' as a "choice in face of bounded uncertainty" (Shackle 1959: 293).**

To conclude our discussion of Shackle's approach to the decision process, it is necessary to bring into the framework the concept of the *attention-arresting power* of the hypotheses. The impossibility of feeling certain about one future outcome - meaning the impossibility of feeling that a particular unique result will be attained in future - does not imply that the decision-maker does not desire a "unique focus for his imagination, that is to say, that he will not centre his hopes on *one particular* level of success" (Shackle 1943: 103). The real incentive for choosing an action is the enjoyment of anticipating a high level of success (attention-arresting power).[71] The intensity of enjoyment is a decreasing function of the degree of potential surprise and increasing function of the outcome.

The combination of the potential surprise and the attention-arresting power, produces what Shackle calls *focus-values*. These will be the best (focus-gain) and the worst (focus-loss) outcomes that concern the decision-maker. Comparing these focus-values, he will assess the attractiveness of his course of action in comparison with others. They provide a clear-cut and simple basis of comparison between different alternative and exclusive courses of action.

II.4.2 Davidson's nonergodicity approach

The technical definition of ergodicity classifies a system as ergodic if the stochastic process is such that time and space averages will coincide for infinite realisations.[72] If the realisations of a stochastic process are infinite in number, the space and time averages tend to converge. As a consequence, if the process is ergodic the data obtained from past realisations can provide a useful (safe) guide to decisions about the future (Davidson 1982/83: 185). Thus, economic systems governed by an ergodic process show timeless (ahistoric) and immutable relationships. Accordingly, if the averages do not tend to converge, the system is classified as nonergodic.

The concept of ergodicity is used by Davidson (1995) to classify theories in economics. He argues that economic theories could be classified in two groups according to their understanding of the process that governs reality: (i) immutable reality, meaning the theories that assume that the world works as an ergodic system; and (ii) mutable reality,

[71] The similarity between this concept and the concept of *animal spirits* in Keynes is clear.
[72] In Davidson's words: "Space averages refer to a fixed time point and are formed as averages over the universe of realisations ... . Time averages ... refer to a fixed realisation and are formed as averages over an indefinite time space" (Davidson 1982/83: 185).

where a world is conceived as a nonergodic system. This taxonomy implies different ontologies.

Those theories classified in the first group admit, implicitly or explicitly, that reliable information can always be supplied by the present and the past. They differ regarding how much, if any, reliable information about the immutable reality can be obtained by agents in the short run. According to this criterion, ergodic theories can be sub-classified in two types: those that claim that in the short run, "the future is known or at least knowable"; and those which claim that "in the short run, the future is not completely known due to some limitation in human information processing and computing power" (Davidson 1995: 109). Thus, the main difference is epistemological. For the first sub-group there is no uncertainty, while for the second sub-group uncertainty is due to a failure in the acquisition of information. In both cases, uncertainty is epistemological, not ontological.[73]

Using the concept of ergodic systems, Davidson defines uncertainty, in both the short and long run, as the absence of governing ergodic processes. What the above theories claim as uncertainty is, in fact, *risk*. If the reality is immutable (ergodic), then the matter is to find a way to collect information from past events and make them available to the decision-maker. Moreover, if the environment is ergodic, all possible future outcomes are known in advance. However, he correctly claims that, in economic life, this kind of situation is very rare, and important economic events operate in a *nonergodic* reality.

One of the main factors that makes economic events nonergodic is Shackle's crucial, non-empty decision. As shown before, crucial, non-empty decisions are unique in that they cannot be repeated. Uncertainty applies to situations of nonergodicity, and in these cases, no data can be used as a reliable guide to the future. "Decision-makers in these situations believe that no relevant information exists today that can be used as a basis for scientifically predicting future events" (Davidson 1993: 430). Nonergodic theories are: Keynes's *General Theory*, Post-Keynesian monetary theory, the post-1974 writings of Sir John Hicks and G.L.S. Shackle's crucial experiment analysis.

[73] Davidson classifies the following theories as ergodic: Type 1 - Classical perfect certainty models; actuarial certainty equivalents, such as rational expectations model; New Classical models; and some New Keynesian theories. Type 2 - Simon's bounded rationality; Savage's expected utility theory; New Keynesian models such as asymmetric information and co-ordination failure theories; and Austrian theory.

Some authors who are important to the development of this approach strongly deny of any kind of *degree* of uncertainty. Knowledge, for Davidson, is defined as the inverse of uncertainty.[74] Nonergodic processes are, in Davidson's account, those situations where there is uncertainty; where these predominate knowledge is completely absent and uncertainty is absolute. As there is no place for more or less knowledge in these cases, Davidson concludes that there is no case for more or less uncertainty.

The behaviour of the agent is described as follows: first, the decision-makers have to recognise what kind of environment they are dealing with. "The problem facing every economic decision maker is to guess whether (a) the phenomenon involved is currently being governed by distribution functions which are sufficiently time invariant as to be presumed ergodic - at least for the relevant future, or (b) nonergodic circumstances are involved" (Davidson 1987: 148). If the latter is the case, sensible economic agents "try to form *sensible expectations* which rely on the existence of social institutions that have evolved (e.g. contracts and money) to permit humans to cope with the unknowable" (Davidson 1993: 149).

Questions arising from the above view are: what exactly defines *sensible agents*? Is it proper to define knowledge in such dualist way?

II.4.3 A critique of Shackle's unknowledge and Davidson's approaches

As we have seen above, Davidson's approach is founded on Shackle's concept of crucial decisions to justify the existence of nonergodicity in economic life. What will be argued here does not deny the existence of crucial decisions as one of the determinants of nonergodicity, but rather claim that it is possible to find in Shackle's work elements to justify the existence of degrees of uncertainty and then to show that the latter is compatible with nonergodicity. To do this, it is necessary to scrutinise the concept of knowledge used by Shackle to demonstrate that it is in itself contradictory to the concept of potential surprise. By revising this concept of knowledge and, thus, by making it conform to the concept of potential surprise, it is possible to argue in favour of the existence of degrees of uncertainty. Finally, we return to Davidson's work to demonstrate that it is also possible to accept the concepts of crucial decision and nonergodicity together with the idea of degrees of uncertainty.

[74] He is very explicit about this matter: "Once technical definitions of the concept of *uncertainty* and its inverse, *knowledge*, ..." and "knowledge's inverse, the concept of *uncertainty regarding real world future events...*" (Davidson 1987: 147).

An assessment of Shackle's view must start with the recognition of his most important contribution, which is the concept of the *crucial decision*. It is fundamental for the understanding of the effects of uncertainty on the decision process. As shown before, it implies that "the person concerned cannot exclude from his mind the possibility that the very act of performing the experiment may destroy forever the circumstances in which the choice is made" (Shackle 1990[1956]: 6). It is a creative action.

However, two points in Shackle's framework deserve some further comments. First, as pointed out by Andrade (1997: 15), there is a "extreme form of methodological individualism underlying his subjectivism". The individual appears to behave and to reason as if he is alone in the world. The social relations that he is involved in do not affect his choices, and these are performed only taking into consideration what is in the mind of the economic agent.

Second, Shackle has a very restricted and contradictory concept of knowledge. He has a dualistic[75] approach: "Where there is knowledge there is not uncertainty", and accordingly where there is no knowledge there is uncertainty. Knowledge, thus, is only conceivable in situations of complete certainty.

However, when he defines expectations he imposes limits on the imagination process which the decision-maker goes through to anticipate some possible outcomes. He explicitly says that expectation is "what he [the decision-maker] can imagine without a sense of unrealism". Yet, to define what is possible or not in this sense implies the acknowledgement that the decision-maker must have some knowledge about what is unrealistic and what is not.

This definition of 'expectation' contradicts his definition of knowledge, as shown above. The main point here is that Shackle differentiates between what he calls imagination and knowledge. Despite the fact that he argues that an individual, when making his expectations, must constrain his images in two ways, "making them in the first place compatible with the individual's beliefs about the nature of things and about human nature, so that they represent something that seems to him possible in abstract"

[75] According to Dow,

> Dualism is the propensity to classify concepts, statements and events according to duals, belonging to only one of two all-encompassing mutually-exclusive categories with fixed meanings: true or false, logical or illogical, positive or normative, fact or opinion, and so on.
>
> (Dow 1996b: 16)

(Shackle 1959: 288), and second trying to anticipate what possible transformation could happen in future,[76] he does not accept an individual's belief as a kind of knowledge.

However, how can a decision-maker define what can be possible or not in a situation of complete lack of knowledge? As Shackle said in his article of 1959, one can only avoid a choice in the face of chaos and anarchy if one has some knowledge about what is possible or not.[77]

Indeed, Shackle uses the expression 'bounded uncertainty' to define decision. Here, again, when he uses the adjective 'bounded' to qualify uncertainty, he contradicts his definition of uncertainty as unknowledge. If between a situation of certainty, which means knowledge, and a situation of uncertainty meaning unknowledge, there is a situation of 'bounded' uncertainty, then this latter must imply 'bounded' or *partial knowledge*. Moreover, the discussion of potential surprise reveals this contradiction. To construct the potential surprise curve one has to measure the intensity of shock or surprise of an unexpected outcome. In doing so, one has to 'imagine' the hypothetical outcomes and compare them in terms of 'surprise'. This should be done, using Shackle's words "*without there having been any change in the knowledge available to him on which he based his belief in it*" (1943: 101, italics added). Nevertheless, if knowledge for Shackle means, as shown before, "a statement which is unique" - i.e. certainty - there is only one possible outcome and any other should be regarded as impossible. From this point of view, there is no basis to ascribe different degrees of surprise to impossible outcomes. Thus, the construction of the potential surprise curve must imply a concept of knowledge that does not denote certainty.

To conclude, the contradiction between Shackle's concept of knowledge and his potential surprise curve can be eliminated if one replaces the concept of knowledge as certainty with the concept of probable knowledge that appears in Keynes's *Treatise*.

Very similar conclusions can be derived from an assessment of Davidson's contributions. As noted before, Davidson's approach is grounded in Shackle's works to sustain his concepts of nonergodicity and absence of knowledge, as defining features of uncertainty. Two aspects will be analysed here: the sources of ergodicity and their

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[76] "...attaching then to named future dates and restricting them to such transformations of his existing situation as seem to him possible in the time-span between 'now' and 'then'" (Shackle 1959: 288).
[77] In Shackle's words:

> ... for a man who thought that any act could have any sequel whatever, and that there was no possibility of excluding *anything* as incapable of following from any stated course of action, would believe any one act just as eligible, just as wise and efficient, as any other ....

implication for the knowledge possessed by the decision-maker and the concept of knowledge used by Davidson. Let us look at the first aspect.

Davidson claims that an important element that makes the economic world nonergodic is the role played by technical change. In his words,

> To restrict entrepreneurship to robot decision-making via Bayes' theorem, ..., is to provide a descriptive analogy of modern real world economies which ignores the role of the Schumpeterian entrepreneur - the creator of technological revolutions and change.
>
> (Davidson 1982/1983: 193)

However, while innovation guarantees the nonergodicity of the world, it does not necessarily imply complete ignorance about patterns of technical change. The concepts of *technological paradigms* and *technological trajectories* developed by the EI approach to technical change (Dosi 1982) can be used to show that at any moment in time, there is always a technological paradigm that determines the features of innovative activity for every sector of the economy, *imposing a selective, precise and ordered pattern of technological change.*[78] The pattern of technical change will be disorderly only in situations characterised by a shift in the technological paradigm.

It must be made clear that what has been claimed here is not that the outcome of the innovative process can be perfectly forecast, but rather that there is an ordered pattern of change originating from the introduction of an innovation. This feature of innovative activity allows the emergence of a kind of knowledge that is not complete or certain, but that can be used to guide the decision-maker. In other words, there is a probable knowledge in the innovative activity that is not contradictory with the nonergodicity feature of this activity.

The second aspect to be analysed is Davidson's definition of knowledge. We think that the above discussion shows that in order to restrict uncertainty to unknowledge it is necessary to use a narrow definition of knowledge. If one understands imagination as a process in which previous knowledge is employed, one must be open to conceive that uncertainty and knowledge can exist in gradations.

It is interesting to take a look at the debate between Davidson and Runde (1993), as it reveals a contradiction in Davidson's approach which is similar to the contradiction in

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(Shackle 1959: 293)

[78] A discussion about the use of the concept of probable knowledge to the understanding of the technical change process, will be made in the next chapter.

Shackle's approach. Runde (1993) argues that Davidson has two positions when he discusses uncertainty: official and unofficial. The main point of the official position is the relationship between knowledge and ergodicity. Ergodicity is a precondition for the existence of knowledge, and as ergodicity is a feature of some aspects of the world, it is an ontological precondition. In Runde's words:

> Davidson's official position thus consists of an epistemological dichotomy between knowledge and uncertainty and a corresponding ontological opposition between ergodic and nonergodic processes.
>
> (Runde 1993: 384)

The consequence of this concept of knowledge is that the dualist approach, knowledge on the one side and uncertainty on the other, does not give space for 'sensible expectations'. This dichotomy implies that either expectations exist because one has knowledge (ergodic systems), or no expectations can be asserted as no knowledge exists. 'Sensible expectations', as claimed by Runde, must imply a third category, which is (fallible) probable knowledge.[79]

Davidson's reply is not sufficient to invalidate Runde's point. Davidson denies that he accepts empirical regularities as criteria for science. His denial of the prevalence of ergodic processes is used to justify his non-acceptance of this approach. Indeed, he argues that empirical realism

> is neither a necessary or a sufficient condition for 'science'. The primary goal of science is to explain. If one can also predict on the basis of 'empirical regularities', then that is icing on the scientific cake. Scientists, however, should 'know' in what areas they cannot search for past empirical regularities to predict the future. In these nonergodic areas of economic science, human beings can and should develop 'certain important [institutional] factors which somewhat mitigate in practice the effect of our ignorance of the future'.
>
> (Davidson 1993: 431)

[79] According to Runde:

> by treating knowledge as one pole of a simple opposition it becomes impossible to distinguish between the epistemological status of different kinds of knowledge. I would go along with Davidson on the kind of truth and certainty guaranteed by sound a *priori* reasoning, for example, and ignore the question of whether or not the standard axioms of logic and rules of inference are themselves not to some extent arbitrary. But our knowledge of the 'facts' of science or history is a different thing entirely, resting as it does on a shaky base of observation, perception, and inference. By adopting a conception of relative or probable knowledge, Davidson could accommodate this difference, namely, that knowledge based on experience is fallible, whereas the knowledge arrived at by sound reasoning (and assuming the truth of the premisses or axioms) is not.
>
> (Runde 1993: 395, n.14)

However, from the quotation above, it is possible to see that Davidson stopped halfway. The logical consequence of the acceptance that economic science and human beings can and do develop institutions, is that some kind of knowledge must be derived from the development of institutions. Likewise, as institutions exist to deal with nonergodic situations, some kind of knowledge could exist in nonergodic processes.

Davidson's account of the process of sensible expectations formation is also problematic. Davidson argues that the decision-maker makes two sequential steps to form expectations. The first one is to guess whether a specific event is ergodic. After that, if the guess (belief) is that the event is nonergodic, the agent looks for the existence of social institutions on which to base his sensible expectations. It is as if the decision-maker and the social structure were independent. However, as pointed out by Lawson (1997a: 83) the "social structure is the, typically unacknowledged, condition of all our actions as well as the, usually unintended, consequence". There is no two-step sequence in the decision process. The decision-maker is interacting with the social structure before asking whether some event is ergodic or not. In Runde's (1993: 390) words: "Social structures thus not only permit and facilitate human agency, but presuppose it".

The main point here is that the acknowledgement of the nonergodic process is not a distinctive process separated from the acknowledgement of the institutions that exist to deal with it. Institutions exist before the decision maker forms his expectations and they are reproduced through the engagement of the decision-maker with them. They are an antecedent element in the process of forming expectations and, in some degree, they shape those expectations. The important question is about the stability and endurability of these institutions. If, in the eyes of the agent, they are stable and endurable, he can, despite the nonergodicity, have a *probable* knowledge about the future course of events and feel himself *less uncertain* about the future. As Andrade has pointed out,

> Complexity and the passage of time make us ignorant or uncertain about many relevant current and future events that take place in our environment. However, there is a form of (incomplete) knowledge in the existing system of rules and conventions.
>
> (Andrade 1998: 132)

Summing up, crucial decisions and nonergodicity should not be considered as features of the economic process that make it impossible to discern degrees of uncertainty. The prevalence of crucial decisions and nonergodic processes not only do not vitiate the existence of a concept of probable knowledge, but also supply the basis for claiming that there is a continuum of degree of uncertainty inherent in these processes.

II.5 Conclusion

In this chapter we have developed a concept of uncertainty that is capable of being ranked. This concept relies on the discussion about the weight of argument and the relevance of the evidential set. Moreover, we have shown that the acceptance of the existence of degrees of uncertainty does not contradict the understanding of the world as a nonergodic environment. Also, we have shown that the concept of probable knowledge is an intrinsic element of both Shackle's and Davidson's works. They themselves, do not recognise it but, as we have seen, it is necessary to understand the concepts of potential surprise in Shackle and sensible agents in Davidson. In the next chapter we will apply this concept of uncertainty to the study of the innovative process.

CHAPTER III

PROBABLE KNOWLEDGE AND TECHNICAL CHANGE

Introduction

The discussions in Chapters I and II show that there is an important element linking the Evolutionary and Institutional (EI) approach to innovation and Keynes's theory of probability, that is, decision-making under uncertainty. As shown in Chapter I, uncertainty is an irreducible element in innovative activity: it is always present when some technological solution is sought. Moreover, the discussion in Chapter II regarding Keynes's theory of probability tries to explain how rational behaviour can emerge within an uncertain environment. Thus, in the first part of this chapter we attempt to interpret the introduction of innovations using the concepts of *technological paradigm*, *technological trajectories* and *probable knowledge*. Moreover, in the second section the concepts of *social probable knowledge* and *social weight of argument* are developed and used to explain the process of diffusion of a new technology.

III.1 Introduction of Innovation and Keynes's Probability

In Chapter I, we saw that the Evolutionary and Institutional approach to technical change uses the concept of routines to explain individual behaviour in uncertain environments. Also, we have seen that the latter is a fundamental feature of innovative activity. The question to be raised here is whether routines are sufficient to understand the decision to introduce and/or develop an innovation. Our claim is that it is not. Routinised behaviour is not only a characteristic of the innovative activity, but rather it is present in every situation of human life. Indeed, the concept of routines developed by Nelson and Winter (1982) acting in the economic analysis in a similar manner as gene in biology has strong similarities with a much earlier work of Veblen. The latter was the first theorist to apply Darwinian ideas[80] to economics. The role of habits and routines[81]

[80] According to Hodgson,

in framing human behaviour and its role as heritable characteristics have been recognised by Veblen in 1899. In his words,

> Men's present habits of thought tend to persist indefinitely, except as circumstances enforce a change. These institutions which have so been handed down, these habits of thought, points of view, mental attitudes and aptitudes, or what not, are therefore themselves a conservative factor. This is the factor of social inertia, psychological inertia, conservatism.
>
> (Veblen 1899: 190-1)

By the same token, the concept of natural selection is also applied for the social-economic dimension:

> The life of man in society, just as the life of other species, is struggle for existence, and therefore it is a process of selective adaptation. The evolution of social structure has been as process of natural selection of institutions.
>
> (Veblen 1899: 188)

The last phrase of the previous quotation is important as it shows clearly that despite Veblen's acknowledgement of the biotic foundations of social life, he explicitly denies that the explanation of human behaviour can be done only in genetic terms. In his words:

> Darwinian natural selection works in the basis of three principles. First, there must be sustained variation among the members of a species of population. ... Second, ...there has to be some mechanism through individual characteristics are passed on through generations. Third, natural selection itself operates either because better-adapted organism leave increased numbers of offspring, or because the variations or gene combinations that are preserved are those bestowing advantage in struggling to survive.
>
> (Hodgson 1999: 97)

[81] Habits can be defined as "a more or less self-actuating disposition or tendency to engage in a previous adopted or acquired from of action" (Camic 1986: 1044). They are essential for human behaviour in complex situations as they supply human beings a way to act without undertaking rational calculations involving a vast amount of complex information. In addition, they are important for the acquisition of all sorts of skills:

> At first, whilst learning a technique, we must concentrate on every detail of what we are doing. Eventually, however, intellectual and practical habits emerge, and this is the very point at which we regard ourselves as having acquired the skill. Thereafter, analytical or practical rules can be applied without full, conscious reasoning or deliberation.
>
> (Hodgson 1994: 304)

An essential feature of habits is that they are personal. They are related to a single individual. On the other hand, routines are related to a group and are components of institutions. Hodgson (1994) gives a good example about how habits and routines are combined. He said,

> [Firm is an institution], which may embody a particular routine, involving several persons, when faced with a given environmental stimulus. In enacting this routines it is, of course, likely that individual habits will also be involved.
>
> (Hodgson 1994: 304)

> If … men universally acted not on the conventional grounds and values afforded by the fabric of institutions, but solely and directly on the grounds and values afforded by the unconventionalised propensities and aptitudes of hereditary human nature, then there would be no institutions and no culture.
>
> (Veblen [1909]1934: 143)[82]

Moreover, as we will see later, some authors (Farmer 1995, Giddens 1984, Lawson 1997b) argue that habits and routines are related not only to situations of uncertainty but they are essential to facilitate both the interactions between individuals and to give 'ontological security' (a sense of stability and recognisability) to human beings.

However, our claim is that since they are part of today situations, routines cannot by themselves alone explain the behaviour of the innovator faced with uncertainty. They are an important component of this behaviour and must be taken into consideration; nonetheless they are insufficient to provide a full understanding of it. In the case of technical change, routines as defined by the technological paradigm and technological trajectories, reduce but do not eliminate the uncertainty. They are fundamental in a problem-solving activity since they help in

> the identification of relevant information, the application of pre-existing competences or the development of new ones to the problem solution and, finally the identification of the alternative courses of action.
>
> (Dosi and Egidi 1991: 150).

However, the last act of a problem-solving activity - choice under uncertainty - remains to be made. That is to say, which course of action should the agent take? What is it that makes an investor decide between the immediate introduction of an innovation or postponing it? To answer these questions, we think that the use of Keynes's theory of probability can be helpful, as it is related to the decision-making process under uncertainty.

There are two fundamental elements to be explored in the connection between Keynes's thought and the EI approach. The first one is uncertainty. To make the argument clearer, we first analyse the effects of technological and market uncertainty on the innovative decision, assuming that business uncertainty is very low. Later in the chapter business uncertainty will be incorporated into the argument.

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[82] For a further discussion on relations between Veblen and Darwinianism, see Hodgson 1998 and 1999.

As shown in Chapter I, in the EI paradigm, innovative activity involves two sources of uncertainty: the incompleteness of the information set and the incompleteness of knowledge. However, it is worth noting that these two sources of uncertainty fit comfortably within the definition of Keynesian uncertainty discussed in the previous chapter. The *incompleteness of the information set* is nothing more than a problem of low *weight of argument.*[83] What is missing in the information set is the relevant knowledge about the innovation. Moreover, the acknowledgement of the existence of relevant ignorance creates uncertainty. The lack of information is not a problem of imperfect information, but rather reflects the fact that the future is unknown and unknowable. The impossibility of knowing *a priori* the length of time it will take for the innovation to be found, the cost of this innovation, and its acceptance by the market, all have the same nature, e.g. what Keynes identified as the impossibility of knowing *a priori* "the price of copper and the rate of interest twenty years hence, or the obsolescence of a new invention" (*C.W.* XIV). Moreover, *knowledge incompleteness* can also be interpreted as a *lack of skill* in recognising the main probability relation (*a*/*h*) or a problem of low weight. The specification of the sources of uncertainty by the EI approach only helps us to understand the different degrees of uncertainty associated with different innovations. However, from a theoretical point of view, the Keynesian approach, being more comprehensive, is capable of encompassing the EI approach to uncertainty. Thus, as a starting point to the discussion proposed here, we think that the use of Keynesian uncertainty can provide new insights into the analysis of technical change.

The second aspect to be analysed is the knowledge used in an innovative activity. There are important contributions from the EI approach that help us understand this issue. First of all, as we saw in Chapter I, one has to keep in mind that there are different types of innovation with different degrees of uncertainty (Freeman and Soete 1997; Kay, 1979). Roughly speaking, the most important difference is between radical and incremental innovations,[84] where the former is based on completely new knowledge and the latter on pre-existing knowledge.

The decision-making process related to radical or incremental innovation will differ according to the role of previous knowledge. Here the concepts of technological

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[83] Recall from Chapter II that, *weight of argument* has been defined as *the degree of completeness of the information set* upon which the decision is made. It can be measured as the ratio between relevant knowledge and total relevance (knowledge plus ignorance).

[84] It is acknowledged that it is very difficult to classify every innovation into this simple dichotomy. However, for the purpose of the dissertation it is very useful as important conclusions related to the behaviour of the firm can be achieved based on the different mix of knowledge associated with each type of innovation.

paradigm (TP) and technological trajectory (TT) are very helpful. One can, in a simplified manner, identify the introduction of a new TP as a radical innovation, and the development of one of many possible TTs as a process of incremental innovation. Therefore, in the case of radical innovation, the knowledge (premise) that will be used as a ground for the innovation decision is limited and extremely weak, and the future response of the market is very uncertain. On the other hand, the incremental innovation is based on existing knowledge, defined by the TP. Thus, as one develops along a TT, the introduction of successive incremental innovations result in the accumulation of knowledge and so the premise for the decision becomes better founded. The process here described captures an important feature of the EI approach, that is, the local and cumulative feature of technological learning. As Cimoli and Dosi point out,

> Local means that the exploration and development of new techniques is likely to occur in the neighbourhood of the technique already in use. Cumulative means that current technological development ... often builds upon past experience of production and innovation, and it proceeds via sequences of specific problem-solving junctures.
>
> (Cimoli and Dosi 1995: 246)

One of the most important kinds of knowledge is tacit knowledge - that knowledge that comes from experience but is not codified in manuals or books. Tacitness is a fundamental factor in the cumulative aspect of the innovative activity. As one moves along a TT, one's knowledge increases for two reasons: (i) the innovator improves his understanding of the technology that he is using,[85] and (ii) he improves his knowledge about market behaviour in relation to this previous innovation. Thus, there is a learning process, which is similar to the learning process implicit in Keynes's theory of probability. What is changing in this process is the weight, defined as the degree of completeness of the information set. A successful move along the TT increases the relevant knowledge about the technology and market behaviour in relation to this specific technology and, simultaneously, decreases the relevant ignorance. As a consequence, the state of confidence in the success of the introduction of a new innovation becomes greater.

Moreover, at each improvement of the product/equipment, the set of premisses increases; and as past innovations have been successfully introduced, the new premisses work to increase the probable knowledge about the success of a new innovation. Moreover, as the knowledge about the TP increases the understanding about what constitutes relevance becomes better grounded. This approach helps us to understand the different degrees of uncertainty associated with different kinds of innovation.

As noted before, probable knowledge can be seen as a guide in situations where uncertainty prevails, and the degree of reliability in this probable knowledge - confidence - determines the degree of uncertainty that exists in a specific situation. In the case of the development of a successful technological trajectory, one can see that the reliability on the probable knowledge about the success of the introduction of a innovation is increasing and the degree of uncertainty is decreasing. Thus, the confidence on this probable knowledge as a guide to conduct increases as well.

However, there are situations in which either the introduction of an innovation is not successful or the search for technological solutions leads to the creation of new knowledge that increases the uncertainty about the future[86]. In these cases the relevant ignorance is increasing due to ignorance about market conditions (meaning the acceptance of the innovation) or because of ignorance about the technology itself. In both cases, the weight is decreasing and so is the confidence. Thus, the degree of uncertainty increases and may either determine a change of the technological trajectory or show the need for more research in the same trajectory.

It can be argue that the use of the *"principle of maximum weight"* (O'Donnell 1989: 74-5; 1991: 77) can give the solution about whether or not to change to another technological trajectory after a failure. This principle claims that when deciding about what course of action to undertake, it is rational to choose that which has the greatest weight of argument.[87] According to O'Donnell, this applies to cases where the

> [S]ame conclusion *a* to which increasing amounts of evidence $h_1, h_2, \ldots, h_n$ are relevant, each successive evidence set exceeding but including the previous

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[85] Remember that technology is never a free good. The technological solution for one specific problem is always constrained by the technical characteristics of the technological paradigm, and these characteristics are not known *ex-ante*.

[86] This is very common in situations in which the new knowledge contradicts previous knowledge taken for granted.

[87] In O'Donnell words:

> given a number of probabilities a/h_1, a/h_2, ... a/h_n where the conclusion is invariant and each successive evidence set (h_l) includes the data (h_{l-1}) of the previous argument, the rational individual adopts a/h_n because it is associated with the maximum available evidence and the greatest weight of argument.
>
> (O'Donnell 1989: 74-5)

> set. A typical example would be accumulation of evidence over time in research investigating a particular hypothesis.
>
> (O'Donnell 1991b: 76-7)

One can see that the example suggested by O'Donnell in the previous quotation is exactly the case we are discussing in this chapter.

What has so far been discussed can be formalised in the following way. The main question faced by the innovator when deciding whether or not to develop and to introduce an innovation is its profitability. In terms of Keynes's probability the question is: What is the reliability of the success of an innovation (conclusion *a*) given the features of the TP and TT (premises *h*)? Formally we have:

ag_j = conclusion: "the innovation g_j will be profitable", where:

j = technological age of the innovation;

if g_j is a radical innovation, then $j = 1$;

if g_j is an incremental innovation, then $j > 1$;

h_j = set of premisses when the innovator is deciding whether or not to develop and introduce an innovation j;

Basically h_j is the knowledge about the variables that affect the investment decision, including the knowledge about the technical characteristics of the new innovation, the knowledge of the outcome (successful or not) of the introduction of the innovation g_{j-1} (in other words, the knowledge about the TP and TT).

$V_j(ag_j/h_j)$ = is the weight of argument related to the development and introduction of an innovation j. V_j is the relevant knowledge and relevant ignorance about the technological trajectory in relation to its potential frontier.

Thus, what one wants to know is whether the existing probable knowledge is a reliable guide on which to act. In other words, whether or not one can have confidence on the probable knowledge about '*a*' (success) for the innovation *g*, which has a technological age of *j*.

Now, one has to analyse this question in such a way as to incorporate the concepts of technological paradigm and technological trajectory. Table III.1 pulls together earlier material on the accumulation of knowledge (increasing weight) and degrees of

Table III.1: Types of Innovation and Degrees of Uncertainty

Type of Innovation (Technological Trajectory)	Order of Knowledge about the Structure	Weight of Argument $V_j = K_j / (K_j + I_j)$	Probable Knowledge ag_j/h_j	Degree of Uncertainty (υ_j)
Fundamental research Fundamental invention j = 0	Non-existent	Non-existent	absent or lack of skill to recognise ag_j/h_j	υ_1: True uncertainty (extreme case)
Radical product innovations Radical process innovations outside firm j = 1	Low order of knowledge of structure	V_1: Very low weight $K_1 < I_1$	ag_1/h_1	υ_2: Very high degree of uncertainty $\upsilon_2 < \upsilon_1$
Major product innovations Major process innovations in own establishment or system j = 2	High order of knowledge of structure	V_2: Low weight $V_2 > V_1$ $K_1 < K_2 < I_2$	$ag_2/h_2 > ag_1/h_1$	υ_3: High degree of uncertainty $\upsilon_3 < \upsilon_2$
New 'generations' established products j = 3	High order of knowledge of structure	V_3: Medium weight $V_3 > V_2$ $K_2 < K_3 \approx I_3$	$ag_3/h_3 > ag_2/h_2$	υ_4: Moderate uncertainty $\upsilon_4 < \upsilon_3$
Licensed innovation Imitation of product innovations Modifications of products and process Early adoption of established process j = 4	High order of knowledge of structure	V_4: High weight $V_4 > V_3$ $K_3 < K_4 > I_4$	$Ag_4/h_4 > ag_3/h_3$	υ_5: Little uncertainty $\upsilon_5 < \upsilon_4$
New 'model' Product differentiation Agency for established innovation Minor technical improvements Late adoption of established process j = 5	High order of knowledge of structure	V_5: Very high weight $V_5 > V_4$ $K_4 < K_5 > I_5$	$ag_5/h_5 > ag_4/h_4$	υ_6: Very little uncertainty $\upsilon_6 < \upsilon_5$

uncertainty attached to the development of a TT, so that the technological-age is increasing as one works down the Table. It can be seen that as technological-age increases, the relevant knowledge and weight increase and the degree of uncertainty decreases in a systematic way.

At the beginning of the process the knowledge about the technological paradigm is scarce. In this case, probable knowledge does not exist due either to the absence of the probability relation or the lack of skill in recognising it. This is the extreme case of uncertainty, and *animal spirits* or institutional factors will determine the decision regarding the development of the paradigm and the trajectory.

A qualitative change occurs when one moves from stage 0 to stage 1. A previous fundamental discovery has been made and, thus, it is possible now to recognise the probability relation, despite the fact that some degree of uncertainty about this fundamental discovery exists (this explain the low order of knowledge of the structure). In this situation, a development of a specific technological trajectory can start. However, in this case the weight of argument is very low due to the acknowledgement of the predominance of the relevant prevalent ignorance in this phase. Both the technological knowledge and the market responses to the innovation are very weak and, thus, the degree of uncertainty is very high.

It is important to note how the two dimensions of uncertainty (structure and weight) are working. In Table III.1, the structure, which will define whether the evidential set is relevant for the development of a specific technological trajectory, is the technological paradigm. In a simplified manner we can say that at the initial stage – fundamental research - the uncertainty related the technological paradigm is great. This explains the non-existence of both the knowledge of the structure and the weight. As the knowledge about the technological paradigm starts to increase – stage 0 to stage 1 – a technological trajectory can be developed. Thus, when the major innovations start, a low degree of belief on the knowledge about the structure (TP) has already been established, but the relevant ignorance stills greater than the relevant knowledge and, consequently, a high degree of uncertainty prevails.

As a technological trajectory initiates its development there is the occurrence of three processes:

a) after introducing the innovation g_1, the innovator goes through a process of learning, which creates tacit knowledge about the innovation. This allows him to increase his understanding of the possible future improvements in the innovation;

b) as this knowledge is tacit, the technological asymmetries between the innovator and his competitors increase, thus increasing his confidence that he will not be superseded by another competitor with a better innovation;

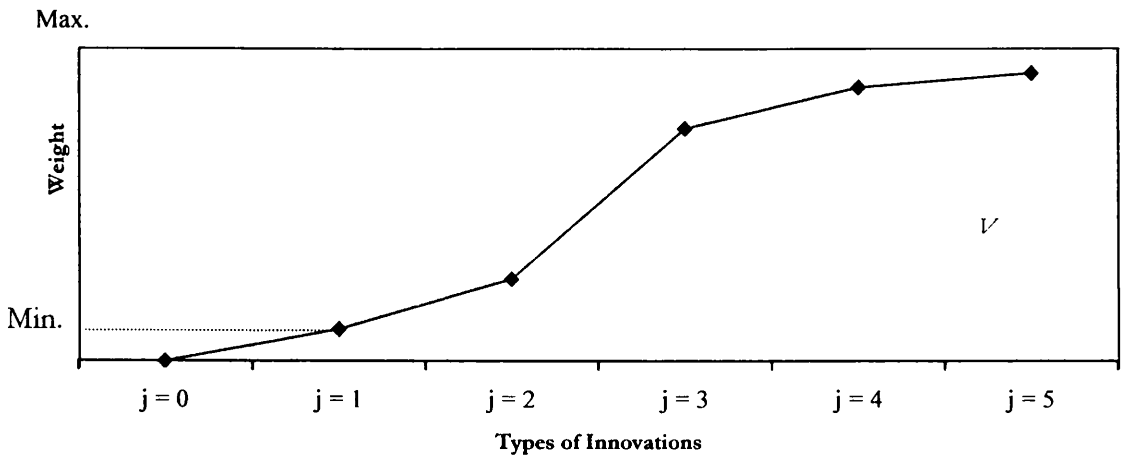
c) as the innovation g_1 is introduced with success – it has been accepted by the market – the investor becomes more confident about the possibility of success of the incremental innovation g_2.

These processes operate to increase both the knowledge of the structure and the weight for the next innovation and decrease the degree of uncertainty attached to each successive innovation. At the end of the trajectory (product differentiation), the relevant knowledge - technological and economic viability - is very well established and there is a very low degree of uncertainty. A good example of this situation is the computer industry. For the firms that are well established in the market, the uncertainty inherent in the decision to introduce a new generation of personal computer is very low due to the relevant knowledge these firms possess.

The main claim made here is that the evolution of a technological trajectory can be explained by the evolution of the weight related with the uncertainty inherent to that specific trajectory. The degree of uncertainty associated with each technological trajectory can reveal the stage of development of that specific TT. However, it should be made clear that even at later stages uncertainty will never disappear. Even when a TT is well consolidated, there will be always true uncertainty related to the success of the introduction of an innovation.

The evolution of the weight of argument related to the introduction of different types of innovations can be visualised with the help of the Figure III.1. It represents the development of a successful technological trajectory. It should be noticed that it is a purely illustrative representation and there is no suggested numerical qualification involved. The six different stages showed on Table III.1 are represented on the horizontal axis. The ordinal measure of the weight is capture on the vertical axis. Notice that a *minimum* and a *maximum* are indicated on the vertical axis. The minimum refers to the minimum weight necessary to introduce a radical product (process)

Figure III.1: Successful Technological Trajectory and Evolution of Weight



innovation (j = 1).[88] With zero weight no innovation is introduced into the market, as a certain amount of knowledge is necessary to introduce a product into the market.

Maximum weight means certainty. As we are dealing with innovation, the uncertainty never cease to exist. Thus, the weight due to the development of a technological trajectory never achieves its maximum point.

As one can see from the picture, it is suggested that the *V* curve presents a 'S' shape. At the beginning (fundamental research) the relevant knowledge is non-existent. The learning process goes on at a slow pace suggesting that the weight increases at a slow rate at the initial stages. After the second phase of the development (j = 1) it starts to grow at an increasing rate until phase three starts (new generations of established products). This can be explained due the fact that once the investor manages to locate himself inside a technological trajectory, the weight begins to increase in a crescent rate. From stage 3 ahead, a new product has been established, which implies that the relevant knowledge is consolidated. This means that the rate of growth of weight decreased due the fact that relevant ignorance is insignificant and relevant knowledge is well established.

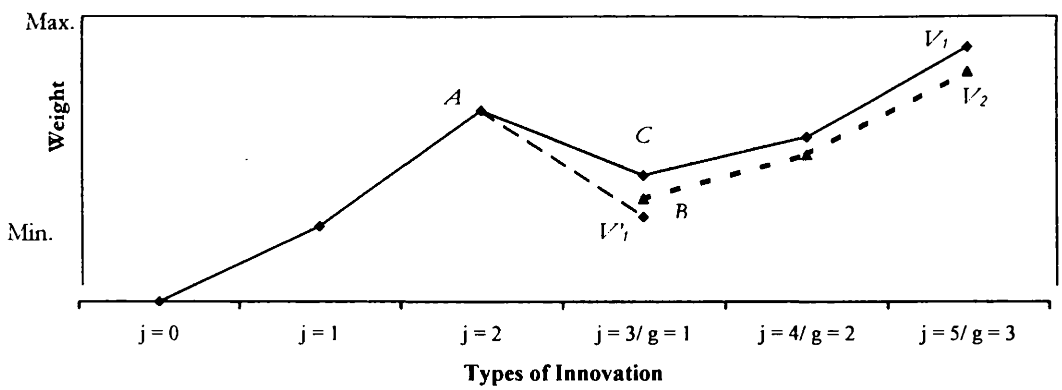
However, this is a case of a successful trajectory. As noted before, an innovator can also be surprised by the introduction of a product with better technology, or if the research process shows that the relevant ignorance is bigger than was initially supposed. The innovator's response in this situation will depend on whether the new technology introduced by the competitor and/or the outcome of the research process represents a change in the technological paradigm. A change of the TP will affect not only the weight, but also the knowledge of the structure. There is no alternative for the investor other than to change his trajectory. If there is no change in the TT, there is no modification of the knowledge about the structure, but the weight decreases nonetheless. In this case, two things can happen: either the innovator allocates more effort on the research process to improve the performance of his innovation or he changes his trajectory. One important aspect in determining what decision should be made is the position of the innovator along the trajectory: the further he is on the technological trajectory (or the nearer he is to phase 6) the more difficult it is to change trajectory.

The Figure III.2 in next page, shows a failure on the introduction of the type of innovation j = 2. In this case there is a sharp drop on the weight due to innovation j = 3. The principle of maximum weight discussed before will determine what course of action the investor will take. The available alternative technological trajectory, defined by the capabilities of the firm, is represented by curve V_2. At its beginning it has an weight represented by point *B*. Whether the investor will decide to change the trajectory or not, will depend on the extent of the decrease of the weight. If this fall is like the segment *AC* in Figure III.2, there will be no change of trajectory, as the innovation j = 3 has a bigger weight than the weight related to the development of a new technological trajectory (point *B*). However, if the decline of weight is like the segment AV'_1, the changing trajectory will be more rational to the investor as it possesses a greater weight. So, the innovator will launch the innovation (g=1), and will develop the technological trajectory represented by V_2.

We have seen that one special feature of the Keynes's probability theory is the independence of probability relation and the weight of argument. We thing that this property can also be exemplified in the case of the development of a technological trajectory. Suppose that a firm has been developing a successful technological trajectory. Moreover, suppose that the internal R&D of the firm finds out that the specific technology has achieved its frontier. In a situation like this the weight of argument about that specific trajectory is high (there is no relevant ignorance). However, the probability of success of the next product to be lunched by the firm is

[18] O'Donnell (1989: 71-2) argues that weight has non-zero limit. For the reasons explained in footnote 16 in Chapter II, we disagree with this interpretation. The approach used here assumes that when the fundamental research starts (j = 0) there is non-existent probability relation, and so there is no weight to be established.

Figure III.2: Failed Technological Trajectory and Evolution of Weight



very low. The reason for that is the lack of technological improvement in the new product and so, the possibility that a competitor supersedes the firm in technological terms. Thus, we have a situation with high weight and low probability of success.

The last question to be raised here is the following: to what extent does the use of probable knowledge improve the description of the decision-process related to the introduction of an innovation? Part of the answer has been given before, as it was argued that routines are insufficient to deal with the last act of a problem-solving activity, that is, the final choice in each problem-solving process. However, what remains to be considered is the role of probable knowledge (and weight of argument) in dealing with *all* aspects of uncertainty inherent in the innovative activity.

Although the discussion so far has mainly been concerned with technical and market uncertainties, a full account of the decision to introduce an innovation warrants the analysis of business uncertainty as well. As an investment decision, the introduction of an innovation has to deal with *all* aspects of this decision, not only those affected by technological and market factors, but also by the investors' perception of the economic environment as a whole.

The weight of argument in this case should not be viewed as incorporating only the relevant knowledge and ignorance related to technological and market problems, but also the relevant knowledge and ignorance of *all aspects* that affect the investment decision. In this sense, the increase in technological knowledge of a technological trajectory does not necessarily increase the probable knowledge of the success of the introduction of an innovation if the business ignorance was increasing for some other reason. In this case, even when moving along a successful technological trajectory, a decision about the introduction of an innovation may be postponed.

III.2 Diffusion of Technology, *Social Probable Knowledge* and *Social Weight of Argument*

Our aim in this section is to develop an understanding of the process of diffusion of technological knowledge using some elements of Keynes's theory of probability. We will argue that this process is a conventional one, in which the concept of ***social weight of argument*** - the *degree of completeness of the social information (knowledge) set* possessed by a social group - plays an important role. In what follows we will develop the argument along these lines: First, a summary of the main aspects of Keynes's approach will be made, basically analysing how the concept of convention emerges. Secondly, we will explore some expansions of Keynes's viewpoint from a *critical realist* point of view. In doing so, it will be shown that the discussion of conventions assumes a broader perspective, giving it an ontological feature in which social structure plays an important role. Moreover, we will try to extend some concepts of Keynes's theory of probability to the understanding of human behaviour in situations of uncertainty, introducing the concepts of ***social probable knowledge*** and ***social weight of argument***. With these concepts in hand, the process of diffusion of technological knowledge is analysed in the last section.

III.2.1 Keynes's Convention

Convention will be defined here as "the ever present structural conditions or generalised procedures for human actors maintained by (tacit) general agreement" (Andrade 1998:120). Despite the fact that human action draws upon and reproduces conventions, they exist independently of any agent.

To have a better understanding of this definition, we think that a brief look at some aspects of its development is warranted. Keynes was one of the first scholars to draw attention to the importance of conventions in economic affairs. He introduces the discussion of conventions in his analysis of how rational behaviour can emerge in situations of uncertainty. The striking feature of these situations is the fragility of the knowledge possessed by individuals. "The outstanding fact is the extreme precariousness of the basis of knowledge on which our estimates of prospective yield have to be made" (C.W. VII: 149).

Despite this insecure knowledge about future events, humans have to act, and have to do this in a way that, as Keynes said, allows them to save their face as rational economic men. He suggests that, notwithstanding the uncertainty, agents act based on habits and conventions, meaning that they have some hypotheses to guide their decisions. What are these hypotheses?

i) Human agents adopt a passive behaviour concerning the future. "Single investors did not think they could influence or determine the future" (Carabelli, 1988: 224). In addition, it is considered that recent facts are "a more serviceable guide to thc future than a candid examination of past experience would show it to have been hitherto" (C.W. XIV: 114);

ii) We employ conventional judgement. "We endeavour to fall back on the judgement of the rest of the world which is perhaps better informed" (C.W. XIV: 114).

The act of following these conventions makes it possible for the decision-maker to deal with uncertainty, and as long as the agent can rely on the maintenance of the convention (Keynes C.W. VII: 152), his affairs will present a considerable measure of continuity and stability.

This does not mean that in Keynes's approach there is no space for unpredictable behaviour. Despite the existence of conventions, animal spirits will always exist.

> Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as a result of animal spirits - of a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities.
>
> (Keynes C.W. VII: 161)

The point here is that in Keynes's approach there are always elements of continuity and unpredictability when decisions are to be made in situations of uncertainty.

To conclude this part, one could summarise what should be considered rational under uncertainty, according to Keynes's view, as simply to act where there are sufficient good reasons to do it (Lawson 1993). Thus, in situations where uncertainty prevails the act of following conventions is perfectly rational, despite the fact that this does not necessary mean maximising behaviour.

III.2.2 Expanding the Concept of Conventions

In recent years, the concept of conventions has been the subject of intense debate. One facet of this debate is the comparison between Keynes's early philosophical work and later economic writing, especially in relation to the role of intuition on judgement. Although interesting, we shall not enter this debate[89] here, restricting the discussion to some contributions that, in our view, contribute to deepening of the main points made by Keynes and are related to the main aim of this section.

The first contribution comes from Davis (1994b; 1997), who defines convention as a structure of interdependent judgements. This definition basically comes from one of the three 'techniques' defined by Keynes: "... we endeavour to fall back on the judgement of the rest of the world which is perhaps better informed" (C.W. XIV: 114). Davis (1994b: 238) argues that according to Keynes it is necessary for people to have some acquaintance with other people's thinking on similar subjects and in similar contexts in order to form a conclusion. In this sense, judgement becomes more akin to a process of interaction among people ("interdependent judgement") rather than to atomistic individual actions.

The main argument behind this understanding of Keynes is the analysis of what explains the rational belief in a proposition. In the General Theory, Keynes, according to Davis, answered this question with the notion of expectation. Expectations are based on conventions, which, for Davis, could be explained by the "interaction between individuals commonly involved in attempting to establish each others motives on a common subject" (Davis 1997: 216).

The stability of the conventions, in turn, comes from the engagement of the individuals in this 'specular behaviour'. Everybody is trying to attribute motives to others - trying to think about others activities. This interaction among individuals enables them to establish some confidence in one another's motives.

[89] For a discussion of this subject see Davis (1994; 1997), Lawson (1993), Runde (1994c), Littleboy (1990) and Fitzgibbons (1988) among others.

Despite the importance of Davis's contribution to the understanding of conventions in Keynes, the case of the structure of interdependent judgements is only one case exemplified by Keynes (Runde 1994a). The other two do not fit into this definition, being more in the nature of inductive rules of thumb employed by agents in situations of high uncertainty (Runde 1994c: 249). The case highlighted by Davis should be viewed as a complement to the other two 'techniques' suggested by Keynes, especially when it is impossible to make judgement of probability.

A wider account of conventions is supplied by Lawson (1995, 1997a, and 1997b). He provides an understanding of conventions that takes into account an ontological view of the social reality, which is much more comprehensive than that suggested by Keynes. In Lawson's view, a social structure is both a condition and a consequence of human agency. This is what Giddens (1984) calls the duality of the structure. In Lawson's words,

> Human intentional activity does not create social structure, ... the latter is presupposed by such activity. Instead individual agents draw upon social structure as a condition for acting, and through the action of the individuals taken in total social structures is reproduced or (in part at least) transformed'.
>
> (Lawson 1997b: 103)

However, the process of drawing upon, reproducing and transforming the social structure is not necessarily a conscious act of human beings. Existing social structure is, most of the time, an unacknowledged condition for action and an unintentional consequence of the actions of all individuals. What makes it possible for human beings to act unconsciously in this way is the fact that society is constituted by a set of positions, which define obligations, duties and rights. These, in turn, are related to other groups in an internal way[90]. These relations allow a social group - a set of people distinguishable by a specific set of social position - to have, tacitly or not, a "shared understanding of the aspects of human practices, their motivations, underlying intentions and so meanings, etc." (Lawson 1995: 87).

The main conclusion to note here is that any human action involves two things: capability and knowledgeability.

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[90] A relation is said to be external when the objects that are related are not constituted by the relationship in which they stand to each other (coffee and milk for example). Internal relation means that the objects that are taking part in the relation are what they are by virtue of the relationship itself (landlord and tenant).

> That an agent is capable means that he or she could have acted otherwise: they have individual and social power.[91] That they are knowledgeable refers to their practical consciousness about their own behaviour and the conditions of their own activities (see Giddens 1982: 8-11). The core of this knowledgeability is knowledge of social rules, a knowledge which cannot necessarily or always be expressed discursively.
>
> (Farmer 1995: 71)

What emerges here is that to act, or in Farmer's words, 'to be effective social actors' a human being must have a huge amount of social knowledge, meaning to know how others typically act, are likely to act, and understand their own and others' actions (Farmer 1995: 71).

Having this approach in mind, Lawson developed his own interpretation of Keynes's conventions. Keynes's suggestion that "we endeavour to conform with the behaviour of the majority or the average" could, now, be interpreted as a claim in favour of the knowledgeability of the decision-maker. Convention is only taken into account by the decision-maker because he or she knows (i.e. has social knowledge) that conventions are followed by others and are thereby being reproduced or sustained.

Likewise, it is not only social knowledge that gives rise to convention. According to Lawson, there are psychological motivations to pursue conventional behaviour. These are the impulse to develop trust and confidence, which are important psychological needs for human beings. In other words, a sense of stability and sameness, which Giddens (1984) called ontological security. These psychological motivations can be found in Keynes when he writes:

> The essence of this convention - though it does not, of course, work out quite so simply - lies in assuming that the existing state of affairs will continue indefinitely, except in so far as we have specific reasons to expect a change.
>
> (Keynes C.W. VII: 152)

or

> For, assuming that the convention holds good, it is only these changes [a genuine change in the news over the near future] which can affect the value of his investment, and he needs not lose his sleep merely because he has not any notion what his investment will be worth ten years hence.
>
> (Keynes C.W. VII: 152)

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[91] This is a precondition for the transformation of the social structure.

Summing up, according to Lawson's view there are two factors that determine conventional behaviour: (i) the existence of a social knowledge that is necessary to reproduce and transform the social structure; and (ii) psychological needs of human beings.

A fundamental question must be raised here: how does this social knowledge emerge? The answer to this question is related to an understanding of one of the two conditions for human action, that is knowledgeability. Human beings know (consciously or not) what they are doing, and in acting on the basis of this knowledge they pass their knowledge on to others. In Giddens words, "if there is any continuity to social life at all, most actors must be right most of the time; that is to say, they know what they are doing, and they successfully communicate their knowledge to others" (1984: 90). By interacting with each other, members of social groups are able to exchange their knowledge and so establish a common understanding about the reality that they share. However, there is nothing that guarantees the social knowledge generated in this process is correct and complete. Human conceptions may constitute inappropriate and sometimes even false conceptions of most of what is going on (Lawson 1995: 87). This is particularly likelv to be the case in situations where fundamental uncertainty exists.

Let us discuss this point a little further. It is accepted that daily life situations are characterised by routinized behaviour (Lawson 1995, 1997a; Farmer 1995). The durability of social relations is a condition for and a consequence of the existence of rules and routines. However, for a routine to be established all actors affected by this routine must have a common understanding about the situation in which that specific routine applies. For example, the passengers of a train know that every time the train stops due to a mechanical failure they do not have to disembark to try to solve the mechanical problem. It is known, through a routinized behaviour, that the driver of the train will try to solve the problem and will keep the passengers informed about what to do. In the same way, the driver of the train does not have to tell the passengers that it is not necessary for them to go outside the train and try to push it to restart the engine. The positions that both driver and passengers hold allow them to understand the situation and determine what they have to do. What this example tells us is that in every situation characterised by routines there is a component of social knowledge.

What has been described above, as mentioned before, also applies to situations of uncertainty. However, there is an important aspect here that deserves more attention.

For this, we must develop the concept of collective uncertainty. The latter refers to those situations that affect a whole community in a similar, but not identical, manner.

The information set that grounds decision-makers has two components: that set of information shared by everyone in a specific community which emerges through the relations inside the social structure and the information available to each decision-maker. The former can be labelled, as we demonstrated before, as social knowledge.[92] However, as we are dealing with situations of uncertainty, this knowledge is precarious, and should be called social probable knowledge.

It is known that institutions provide a ground to act in situations of uncertainty. By institutions we mean not only habits, routines, rules and conventions[93] but also formal institutions such as unions, companies and government agencies.[94] Hodgson, expressed this point very well when he wrote that

> it is impossible for an individual to think and act in any specific field of the application of knowledge without being influenced by the institutional set-up. Information is culturally processed: it is never transmitted raw but is selected, arranged and perceived through institutions.
>
> (Hodgson 1988:120)[95]

Take a researcher as an example. He has to go to the library to collect the data he needs for his work. However, he knows that to improve his productivity he can add a modem to his computer and, instead of going to the library, access the data using the Internet. He knows this through contact with other researchers; through the information that he received from the libraries; through the newsletter from the research association and so on. In other words, he knows how to improve his productivity through the institutional set-up that surrounds him. This institutional set-up allows him to have a social probable knowledge about how to improve his productivity. It is social in that it is shared by the people who belong to the same specific collectivity. It is probable because whether or not he will be able to improve productivity will also depend on other elements; for example, his ability to deal with the Internet; the quality of the modem; the interaction

[92] It is important to stress that *social knowledge* here is an emergent phenomenon, meaning that it cannot be reduced to the sum of *individual* knowledge. *Social knowledge* is conditioned by and depends upon *individual* knowledge, but it is not predicable from it.
[93] To be aware of a convention, for example, allows the investor to have a knowledge about the behaviour of the majority of the competitors.
[94] Contracts, for example, allow a knowledge about future supply of inputs and also future demand. By the same token, organisations like industry confederations gather and spread information allowing for a socialisation on knowledge.
[95] To be consistent with the terminology used here we will call this institutional set-up the social structure.

of the modem with the rest of the computer; and the way the data is available on Internet.

What is important to note here is that the social structure provides grounds upon which to act but it does not eliminate the uncertainty. The institutional set-up provides a collective (social) knowledge. However, the fact that it is collective does not mean that it is infallible. In uncertain situations there is collective uncertainty, which reflects the extent to which the probable social knowledge provides a reliable guide to action.[96]

If we are able to accept the concept of collective uncertainty and social probable knowledge, the acceptance of the concept of social weight of argument becomes straightforward. The latter is understood as a degree of completeness of the social information set possessed by a social group. Thus, the probable social knowledge is related to the amount of relevant information (knowledge and ignorance) about a specific situation that is shared by a social group. It is the social weight of argument that will define the degree of collective uncertainty. One can say that, in the example above, the social weight of argument about the decision on how to improve the researcher's productivity is very high. The procedures for accessing the Internet are well known, as are the sources of data that are available on it and the outcomes that can be achieved with its use and so on. The relevant knowledge about this specific case is very widespread and, as the relevant ignorance is minimal, the social weight of argument is very high and the degree of collective uncertainty is low.

Summing up, my claim here is that in situations of uncertainty, whatever the degree attached to them, conventions emerge and are stable only if there is a social probable knowledge that allows the agent to have a shared understanding of the situation. Moreover, a pre-condition for the emergence of social probable knowledge is the existence of a social weight that defines the confidence regarding the convention. The higher is the social weight, the higher will be the stability of the convention.

[96] When acting, decision makers have to combine this probable social knowledge with their own probable knowledge to define a course of action.

III.2.3 The Diffusion of Technology

In this section we will discuss the diffusion of technology. On the one hand, we argue that the diffusion of technology is a good example of how human action draws upon social structure and, on the other hand, we show how the concepts of *social probable knowledge* and *social weight of argument* can help understand this process.

Until the beginning of the 1980's, the literature on diffusion of technology has been dominated by models of neoclassical flavour. These models can be classified in four types: epidemic; rank or probit, stock effect and order effect models.

Epidemic models (Griliches 1957) can be considered the starting point, and have their origins on the analysis of the spread of diseases (Karshena and Stoneman 1995: 270). The main point is the understanding of the diffusion process as an outcome of the spread of information. In its simplest representation, this approach argues that the number of agents aware of the new technology is the main constrain to its diffusion. However, as the experience of the users starts to spread the knowledge about the technology, non-users become users and the mechanism is itself reinforced. This process will show a sigmoid or S pattern, meaning that the number of users grows slowly at initial stages but at an increasing rate. After a point of inflection is reached, the growth of diffusion declines until a maximum point is achieved.

The main claim of rank models (David 1969; Davies 1979) is that they do not assume homogeneous potential users, but it argues that users will differ from each other in respect to some dimension like, for example, the rate of return. This heterogeneity allows the ranking of potential users according to the expected benefit that can be obtained from the adoption of the new technology.

Stock effects models (Reinganum 1981; Quirmbach 1986), in its turn, argue that the benefit from the introduction of an innovation is affected by the number of the users. The greater the number of adopters the smaller the benefits from the introduction. The behaviour of the price of final products is affected due an increase on supply or the effects on the price of inputs.

Finally, the order effects models (Fudenberg and Tirole 1985; Ireland and Stoneman 1985) claim that "firms' position in the adoption order determines its gross return from adoption" (Karshenas and Stoneman 1995: 274). In other words, the first adopters of a new technology will have greater returns than the latter ones. The reasons for that could be pre-emption, advantages to the acquisition of prime geographic sites or the acquisition of limited pools of skilled labour.

The models of Karshenas and Stoneman (1995) and Stoneman and Kwon (1994) incorporate all these approaches – epidemic, rank, stock and order. Formally, the rank effects are represented by a parameter that captures firm's characteristics. Variables tht measure the number of other users of technology and the number of users of specific technology are supposed to represent order and stock effects, respectively. This rank, stock and order effect model is used to explain the process of diffusion in both a situation where there exists only one technology and situations where there are multiple technologies.

The main criticism that can be made to this models is their complete disregard of factors like learning, uncertainty and imperfect knowledge. All firms are supposed to possess the capability to use the new technology, but will have different degrees of appropriability generated by factors like size (rank), total number of users (stock) and the readiness in adopt the new technology (order). Moreover, as pointed by Silverberg et all,

> Radical uncertainty is *de facto* eliminated and maximising behaviour is assumed. The analysis is often undertaken in terms of the existence and the properties of equilibria, while nothing is generally said about the adjustment processes. Information about the techno-economic characteristics of the technologies is generally assumed to be freely available to all agents. The nature of 'technology' is radically simplified and assumed to be embodied in given technical features of production inputs.
>
> (Silverberg et all 1988: 1033)[97]

By the end of the 1980's a literature on diffusion with an Evolutionary flavour began to gain more space in the economic debate. One of the first models is the model of diffusion developed by Petit and Tahar (1989) in which they argue that the concept of technological system has been incorporated. The authors claim that the diffusion of a new technology "follows from the general level of investment and the propensity of firms to modernise themselves, determined by individual product market conditions and histories" (Petit and Tahar 1989: 371). This study concentrates on aggregate variables and claims that the introduction of investment behaviour in the micro level can deal with the particularities of the technological system. The diffusion process is dependent on the degree of modernisation in the previous period, the overall investment/capital ratio and the probability that a traditional unit is modernised in the present period. The latter is determined by two factors: (i) market perspectives reflecting both the willingness to invest and the intensity of forthcoming competition, and (ii) the characteristics of the new equipment (profitability and learning process). The features of the technological system will be capture by the value of the probability of modernisation.

Despite the importance of introducing some features of technological systems into the model, Petit and Tahar fail to recognise other features like technological opportunities. The use of aggregate variables and of a general behavioural assumption for the adoption of a new technology overlook the important fact that both there is a key technology at the basis of a technological system and there are technological asymmetries among firms.

By the same time, Silverberg, Dosi and Orsenigo (1988) have developed a model of diffusion in which they incorporate the main features of the Evolutionary approach to technical change discussed on Chapter One. The model takes into account features like technological trajectories, technological opportunities, cumulativeness in patterns of innovations, tacitness of knowledge and technological asymmetries. Moreover, they acknowledge and try to incorporate learning mechanisms as an important element in both the spread of innovative/imitative capabilities among potential adopters and the reinforcement of the existent disparities via cumulative mechanism internal to the firm (Silverberg et all 1988: 1034). Taking all these features together, the authors have developed an evolutionary model where the process of diffusion is represented as a disequilibrium process in which uncertainty, bounded rationality and endogeneity of market structures play an important role.

A special feature of this model is that the study of diffusion is made through the analysis of the evolution of two competing technological trajectories, one of them superior (the new) to the other (the old). However, the productivities realised by the firms reflect not only the type of equipment in use, but also the development of the knowledge and the skills necessary to use an specific technology. This understanding has direct implications to investment decisions. In their words,

[97] Despite this quotation refers to rank, order and stock models that have been developed before 1988, its argument still valid for the models of Karshenas and Stoneman (1993) and Stoneman and Kwon (1994).

> Hence investment decisions are not merely a question of determining the best practice technology at a given time, but one of weighing the prospects for further development either by acquiring experience with it now to gain a jump on competitors or waiting for a more opportune moment and avoid possible development costs.
>
> (Silverberg at all 1988: 1041)

Moreover, there are some mechanisms by which the learning process that occurs inside the firm 'leak' out. These mechanisms can be the movement of skill labour and management between firms, trade organisations and publications, educational institutions among others. Thus, at any time there is a level of public skill, which, however, lags behind the average level of internal skills of the firm. "Firms profit from this learning externality because they 'float' on the rising general skill level even if they are not yet employing the new technology" (Silverberg et all 1988: 1042).

The understanding that a technological trajectory is in a constant development is an essential factor in this model. This understanding is reflected on the decision about whether to change to the new technology. Firms have to take into account not only the imminent gains in productivity they realise after the introduction of the new technology, but also the possible advantage of attaining early proficiency in its use. This decision will depend on both the expectations about both potential future developments of the technology and the extent in which the advantages of being first can be retained. The latter is dependent upon the relative rates of internal and external learning.

All the features that have been discussed above are integrated into a so-called self-organisation model of diffusion of innovation, which is

> a model whereby relatively ordered path of change emerges as the (partly) unintentional outcome of the dynamic interactions between individual agents and the changing characteristics of the technology.
>
> (Silverberg at all 1988: 1033)

Finally, more recently Antonelli (1995) has developed a model in which the concept of technological system plays a central role. He discusses the factors that affect productivity growth and relates the latter with the diffusion of a specific type of technology. He starts his argument showing the limitations in both new growth models of neoclassical flavour and Kaldor (Post Keynesian) models. In relation to the formers, he has noted that they concentrate their attention to the generation of new technologies rather than their diffusion in the productive process. Growth is the direct outcome of the introduction of new technologies. Antonelli argues that these models are not able to recognise that the process of diffusion of innovation has a particular and much more important role than the role of generation of new technology.[98] Similarly, the author criticises Kaldor's approach arguing that "it overlooks the role of adoption choices and equates diffusion to the outcome of the process of capital accumulation and investment" (Antonelli 1995: 5).

To stress the role of diffusion, as distinct from the generation, of innovation in the growth process, Antonelli opens "the black box of the technology" and emphasises some features of technical change that he judges to be important to the understanding of the diffusion process. These features are: (i) technological opportunities, which accounts for the fact that the scope for potential innovations varies across technologies; (ii) technological convergence: it refers to the possibility of different sectors sharing the same technology and it is triggered by the introduction of a radical innovation; (iii) technological complementarities: the overall level of productivity of a system depends on the degree of complementarity among different technologies of this system. "Only when an appropriate mix of complementary innovation is available, full effects in terms of increasing returns and externalities can be achieved" (Antonelli 1995: 7-8); and finally (iv) technological spillover, which refers to the fact that, due to the appropriability conditions, the externalities generated by innovations vary across sectors.

These features of technologies are used to define a *technological system*. In his words,

> A technological system is characterised by high levels of complementarity and interrelatedness among different technologies that are at the same time product innovations as well as process innovations, organisational innovations and more broadly innovations that change the production mix of firms and their market.
>
> (Antonelli 1995: 8)

The strong complementarity that characterises these technological innovations affects the productivity levels of the whole system. When a technological system emerges, the introduction of complementary technologies generates a cumulative process, which affects the overall productivity level. However, it must be kept in mind that the emergence of a technological system is a lagged process. It can be said that it has a particular life-cycle: it starts slowly; it is implemented and enriched; it declines and finally it is superseded by another one.

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[98] The same problem happens to occur in the so-called epidemic models (Griliches 1957; Mansfield 1961).

The central conclusion of this approach is that the study of the relation between technical change and growth should concentrate its attention on the analysis of key-technologies that are able to spread high levels of externalities throughout the economy due their technological opportunities, complementarity, convergence and spillover. According to Antonelli,

> We suggest that a better indicator of the factors leasing to effective increase of efficiency and hence to the increase of the total factor productivity is given by the rates and levels of diffusion of new key-technologies.
>
> (Antonelli 1995: 9).

The author concludes with a model in which the levels of labour productivity are explained by the capital stock and by effective levels of penetration of key technological innovation. Thus, productivity is explained not only by the growth of the capital stock, as in Kaldor's model, but also by the rates of diffusion.

From the brief review made above, two points deserves clarification before we continue. First, it is necessary to make a distinction between the *adoption* of an innovation and its *diffusion*. Theoretically, the analysis of adoption is concerned with a decision-making process. It is concerned with decision taken by agents to incorporate an innovation (new technology) into their activities. On the other hand, the analysis of diffusion is concerned with the change in the economic relevance of a new technology through time (Metcalfe 1988). Despite this difference, the two concepts are strongly related as it is through the adoption of an innovation by more and more agents throughout time that it becomes economically relevant. In this sense, the study of the mechanisms that facilitate the adoption of an innovation is itself an analysis of the process of diffusion.[99]

> Diffusion will be understood here as the process by which an innovation is communicated through certain channels over[100] time among the members of a social system.
>
> (Rogers 1983: 5)

Second, the process of diffusion of technology implies two complementary kinds of diffusion: the spread of the technological knowledge necessary to adopt the innovation, and the diffusion of the new equipment itself; that is, the diffusion of disembodied and embodied technology respectively. My concern here is the former kind of diffusion -

[99] Accordingly, throughout the dissertation the words adoption and diffusion will be used interchangeably. When the innovation is adopted for the first time, the term *introduction* of an innovation will be used.

[100] Communication is a process in which participants create and share information with one another in order to reach a mutual understanding (Rogers 1983: 5).

technological knowledge - mainly because it is a pre-requisite for the second kind of diffusion to take place. Let us take a further look at this kind of diffusion.

The first point that should be addressed is why firms look for new technologies. Just to remember, we are assuming in this dissertation that the inducement to introduce a new technology is related to the inadequacy of the old technology to solve technological problems - from the economic and/or technical point of view - faced by the firm. This inadequacy creates uncertainty for the firm in that it has to search for alternatives which the firm is not, initially, acquainted with.[101] To deal with this uncertainty the firm has to develop a learning process about the alternatives.

The features of this learning process are directly related to the different kinds of knowledge necessary to the adoption of an innovation. According to Dosi (1988a: 224), various sorts of pieces of not mutually exclusive knowledge are used in the solution of most technological problems: universal versus specific; articulated versus tacit; public versus private.

Universal knowledge means that knowledge that has a large applicable understanding, which is based on principles that are well known and pervasive, while specific knowledge means a special 'way of doing things'. Moreover, there are some sorts of knowledge that are well articulated and that are for the most part written down in manuals, books and so on. In contrast, there is also that kind of knowledge that is tacit, meaning that it comes from experience and practice. Important processes for the acquisition of tacit knowledge are 'learning-by-doing' and 'learning-by-using'. The latter implies that this knowledge is not a public good to be freely and easily adopted by all potential users, but rather that the cost of exploiting and developing new or borrowed technology depends on the availability of technical and social capabilities.[102] Finally, there is that knowledge that is public in the sense that it is available in scientific and technical publications. On the opposite side, there is that knowledge that is private either because it is protected by law (patents) and/or because it is tacit.

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[101] It should be made clear that diffusion here is not only related to the diffusion of specific knowledge of a specific artefact. It is also related to the spread of the knowledge of technological principles which can be used in different ways in different equipment. This differentiation is important for after the acquisition of the technology many incremental innovations can be made at the firm level as these general principles combine with the tacit knowledge specific to each firm.

[102] As pointed out by Dosi and Orsenigo, technology

> involves specific, often idiosyncratic, partly appropriable knowledge which is accumulated over time through equally specific learning processes, whose directions partly depend on firm-specific knowledge and on the technologies already in use.

For the present discussion we will take into consideration that kind of knowledge that is universal, articulated and public. This does not mean that the *absorptive capability*, i.e. the capabilities of the firm to use technology developed elsewhere, is not important. Tacit knowledge is an important concept to explain not only technological asymmetries, but also the differing performance of firms. However, to understand the diffusion of a specific technology it is necessary to have a previous understanding of the research spillovers of this technology.

> To understand the features of the kind of knowledge we are concerned with (universal, articulated and public) we have to look at the learning process inherent to the system of innovation as a social activity, which involves interaction between people.
>
> (Lundval 1992: 2)

Moreover, this process of learning is influenced, in regard to its content, rate and direction, by the institutional set-up of the economy. Put in another way, to overcome the inadequacy of the old technology, agents will draw upon the social structure to act. It is through the latter that society accumulates, reproduces and transforms knowledge. Learning is a social process that is hardly ever done individually without some kind of social interaction. Learning depends on the social structure and in turn will reflect the social structure.

It is within this framework that the diffusion of disembodied technology must be analysed. What will be learned is a shared understanding about how to overcome the inadequacy of the present technology. In other words, what will be learned is the 'technological' social knowledge. However, the latter is related to the solution of a technological problem, and it is well known that uncertainty is an important feature of the innovative process that is always present and impossible to be reduced to some kind of probabilistic knowledge (Freeman and Soete 1997, Dosi and Egidi, 1991). According to our previous discussion, the 'technological' social knowledge is better described as *probable social knowledge*, as there is an uncertain component in this knowledge. In this sense, it reflects the degree of 'collective' uncertainty about the technology itself.

The emergence of 'technological' probable social knowledge depends basically on the following aspects of the social structure. First, a fundamental element is the technological paradigm in which the agent is immersed. As we have seen in Chapter I,

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(Dosi and Orsenigo 1988: 16)

at every moment in time there is a technological paradigm related to a specific activity. This means not only that the heuristics of the search for technological solutions to supersede the old technology are constrained by the TP but also that this constraint is faced by the whole community that works under the TP. This is a strong mechanism that generates a uniform direction of search among the actors in a specific activity.

Secondly, part of the knowledge produced under the umbrella of the TP is codified (articulated). This means that this knowledge is available in a compact and standardised form, which facilitates and reduces the cost of acquiring it.

Thirdly, there are the *positions* and their relations. More specifically, the "informal and formal communication links between the population of potential adopters and between them and suppliers of the innovation" (Metcalfe 1988: 567).

These three elements are fundamental aspects of the social structure that allow the emergence of a 'technological' probable social knowledge. However, there is another element that interacts with the previous three: the conventional behaviour of the agents. As noted before, in situations of uncertainty it is rational to fall back onto convention to act. Here the understanding of convention as a structure of interdependent judgement is very helpful. Drawing upon the three previous elements of the social structure reduces but does not eliminate the uncertainty. Thus, using Keynes's words, the agents "endeavour to fall back on the judgement of the rest of the world which is perhaps better informed" (*C.W.* XIV: 114). According to Rogers, various studies have shown that

> Most people depend mainly upon a subjective evaluation of an innovation that is conveyed to them from other individuals like themselves who have previously adopted the innovation.
>
> (Rogers 1983: 18)

Therefore, one can say that the agent will adopt a specific innovation not only because previous adopters have been successful but also because they believe that other competitors will also adopt the innovation. It is the interaction between the agents that creates the conventional behaviour of adopting a specific innovation. This explains what has been called 'bandwagon effects' in the literature about diffusion (see Metcalfe 1988). So, the very act of adopting an innovation contributes both to reproducing and to transforming the social structure.

What is interesting to note here is the interaction between human action and social structure. An innovation is adopted by agents drawing upon the social structure (TP; codified knowledge; positional relationship and conventions). In this sense the human action contributes to reproducing the social structure. However, the process does not stop with the adoption of the innovation. The latter generates a process of learning which itself increases and modifies the codified knowledge and the conventions. Information changes because of the diffusion of a technique (Metcalfe 1988).

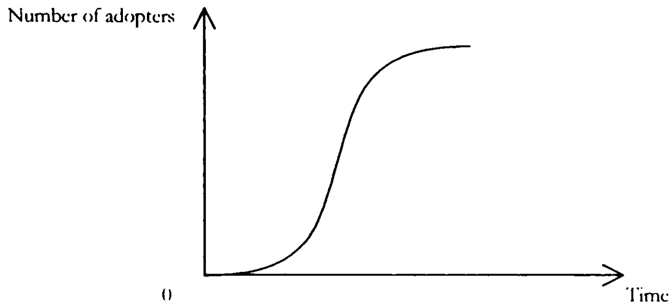
The process of diffusion of technological knowledge shows a very similar pattern to the process analysed in the first section of this chapter. At the beginning only the innovator has the knowledge about the specific innovation, and the understanding about that specific technology that allows him to have a probable knowledge about the success of the introduction of that innovation. At this moment, the *probable social knowledge* about the innovation is very low as the *social weight* is also very low (the *relevant social ignorance* about the technology is high). After the introduction, and supposing that it has been successfully introduced, the interaction between individuals, whether being through formal or informal institutions, starts to produce a better understanding of the new technological knowledge, increasing the *social weight of argument* related to the introduction of that innovation.[103] As Freeman and Soete point out,

> When a product or process is first introduced it is almost inevitably in a relatively primitive form and is submitted to successive incremental improvements which ... increase its quality, performance, reliability or whatever other aspect is important to the users or can contribute to enlarge the market. ... This means that the imitator does not always enter the 'same' technology as the innovator. Nor do later imitators enter at the same point in the technology's evolution or trajectory as earlier ones. All these improvements have a cost and they all imply the generation of additional innovation-bound knowledge and experience.
>
> (Freeman and Soete 1997: 357)

As *social weight* increases the *confidence* increases and the diffusion speeds up, meaning that the introduction of this technology becomes a conventional process. Finally, two last remarks deserve attention, both related to the role of the conventional behaviour in this process. First, it is reasonable to claim some connection between the well-known S-shaped diffusion curve and the conventional behaviour in adopting a

[103] There are several channels through which knowledge can be transmitted. Some examples are: reverse engineering; publications, catalogues or patent applications; conferences and seminars; human capital that moves among firms; inter-firm co-operation.

Figure III.3: *S* - Shaped Diffusion Curve



specific innovation. Figure III.2 depicts the S-shaped diffusion curve. It shows that as time goes by the number of users of a specific innovation grows slowly at the beginning, increases exponentially after some period and, finally, grows at a decreasing rate. This pattern, we believe, presents a strong relationship with the conventional behaviour described above. After an initial period, where everybody is looking at what others are doing, a convention is established through a process of convergence, and so the diffusion accelerated. "The more who congregate in a vicinity, the more who join them" (Littleboy 1990: 33).

Second, the discussion of conventions can also shed light on the establishment of a technological paradigm. When a technological paradigm experience a crisis, in the sense that it fails to give answers to actual technological problems, the community of engineers and researchers starts to look for alternatives. Everybody is trying, not only to find their own answers, but also to look at what others are doing. This process ofinteraction tends to produce a mutual understanding of the best approach to inquiry for the solution of technological problem. In Andrade's words,

> As interactions tend to increase over time, a mutual understanding about what is the most adequate way of doing things emerges. This collective involvement engenders useful information concerning preferred courses of action and enables agents to continue to perform their current and future activities.
>
> (Andrade 1998: 139).

It is interesting to compare the above quotation with our own quotation from Chapter I about the definition of a technological paradigm:

> The concept of TP implies a set of *heuristics* - e.g., Where do we go from here? Where should we search? What sort of knowledge should we draw on? (cf. Dosi 1988b:1127) - and a prescription of *directions* of technical change to pursue and those to neglect and these *heuristics* and *directions* are shared by the community of practitioners in each particular activity.
>
> (Chapter I: 36)

Thus, as one can see, the above discussion gives support to the claim that there is a strong relationship between the emergence and the establishment of a technological paradigm and conventional behaviour.

III.3 Conclusion

The ideas outlined above could represent a possible link between the EI approach to technical change and Keynes's theory of probability. First, the EI approach to innovation stresses the importance of uncertainty as a feature always present in the innovative activity, which can never be eliminated. To deal with this uncertainty EI theorists developed the concept of routines.

Moreover, the concept of technology used by this approach sheds light on features such as cumulativeness, appropriability and knowledge base, which are incorporated in the concepts of technological paradigm and technological trajectory. These factors shape the routines that are used by the firms.

However, as the uncertainty is never eliminated, routines themselves are not sufficient to explain the decision-making process during the introduction of an innovation. They explain the use of the premises used in this process, but they do not explain the logical development of this choice. A decision remains to be made: whether to introduce an innovation or not.

At this point, we have tried to show that Keynes's theory of probability can complete the set of tools required to understand that process. From the use of Keynes's probability it is clear that this process can be seen as rational, despite the fact that one may never know for certain whether the innovation will be a success. The concepts of probable knowledge and weight of argument are the key factors in the understanding of the rationality that is behind the development of a technological trajectory. Routines embody the knowledge accumulated, and they are constrained by the TP. The learning process that occurs during the continuous innovative activity weakens the influence of some sources of the uncertainty related to the investment process. The basis on which successive decisions to introduce innovation is founded becomes more grounded as both weight of argument (state of confidence) and the probable knowledge increase, driving the formation of the expectation in the same direction.

Thus, one can say that routines form the premises (*h*) upon which the decision is taken. Based on these routines, a probable knowledge of the success of the introduction of the innovation can be established, and as new routines are developed, as a result of the innovative process, the weight of argument changes.[104]

Moreover, we have tried to expand this understanding of the introduction of an innovation to the analysis of the process of diffusion of a new technology. In doing this, I have shown that it can be understood as a conventional process, in which the concepts of *social probable knowledge and social weight of argument* are useful tools.

The approach described above does not exhaust the analysis of the diffusion of technology. There are many aspects that have not been analysed here. For example, the differences between technologies (appropriability, cumulativeness, etc.) and its effects on the speed of diffusion; the expectations of future technological development; etc. However, we think that the analysis of these aspects does not change what was argued above. Our concern here is to provide an understanding of the process of diffusion of technological knowledge in a broader sense in which the interaction between human action and social structure is the central element.

[104] Vromen'a (1995) concept of *conditional rules* provides some insights on this point. According to him *conditional rule* "discriminates between different environmental conditions that may obtain and relates these to possibly different things to do under these different conditions" (Vromen 1995: 81). The important point to be stressed here is that the adherence to a conditional rule may result in flexible responses to alterations in surrounding conditions. In turn, the process through which these responses are achieved is determined by what Vromen calls "high-order routines". These routines are triggered by changes on the environment that make first-order routines ineffective, and produce news and more effective ones. Applying this point to the present discussion, one can say that the way by which the weight is translated into action could be represented by a conditional rule, in a sense that when weight varies according previous failure or success, some *conditional rule* comes to place to decide what actions to follow. The only reservation to be made to this use of *conditional rule* to our discussion is that weight can vary according to both internal and external factors.

CHAPTER IV

THE DYNAMICS OF EXPECTATIONS WITH CONTINUOUS INNOVATIONS

Introduction

In the previous chapter we saw that the introduction of an innovation can be explained with the concepts of probable knowledge and weight of argument. In this chapter we will discuss the implications for the formation of expectations when this particular understanding of technical change is taken into account. In doing so, we claim that a new type of expectations should be developed and introduced into the framework: medium-period expectations. The chapter is developed as follows. First we discuss the formation of expectations in Keynes's approach. In Section II we reiterate some elements of the technological approach used in the thesis. The impact of this approach on the formation of expectations is analysed in the third section. Finally, some conclusions are drawn from the analysis.

IV.1 Expectations in Keynes's Approach

In the *General Theory* Keynes explains the importance of expectations in the determination of the level of employment and output. He defines two types of expectations: short- and long-period expectations (SPE and LPE respectively). The former are responsible for the determination of 'daily'[105] output. These are expectations about both the cost of production and sales proceeds. Its main feature is the fact that the stock of capital is taken as given. They define the volume of production and employment provided by firms.

The second type of expectations (long-period) refer to the expected proceeds from the sales of a good produced with new equipment. In other words, these are *investment expectations.*

[105] Keynes uses the expression 'daily' to refer to "the shortest interval after which the firm is free to revise its decision as to how much employment to offer" (*C.W.* VII: 47 n1)

There are two important distinctions between these types of expectations. The first one is the period of time related to each one. The formation of short-period expectations involves a period of time considerably shorter than long-period expectations, making easier the calculation of expected proceeds. There is no doubt that it is far simpler to guess about the sales in the next month (supposing that production decisions are made on a monthly basis) than to imagine what will be the proceeds from sales in the next 10 years (supposing 10 years as the life time of the new equipment). Secondly, the amount of monetary resources involved in each decision is considerably different, being smaller in the short period. Indeed, in the latter, the payment of 'prime cost' may come out of the proceeds of the last period's sales making borrowing less important than it would be in the case of the investment decision.

Taken together, these two features - the period of time and the amount of resources involved in these decisions – suggest that the consequence of a miscalculation of the prospective yields in both types of decision will be very different. A miscalculation by the entrepreneur in terms of production expectations can be corrected within a short time and, as the amount of resources involved are relatively small, the consequences are minimal. Accordingly, Keynes pointed out that,

> It will often be safe to omit express reference to *short-term* expectation, in view of the fact that in practice the process of revision of short-term expectation is a gradual and continuous one, carried on largely in the light of realised results, so that expected and realised results run into and overlap one another in their influence.
>
> (Keynes *C.W.* VII: 50-51)

However, if one takes in consideration both the period of time and the amount of monetary resources involved in an investment decision, it is easy to appreciate that a miscalculation of the prospective yields implies a significant loss for the entrepreneur. This feature of the investment decision makes the formation of long-period expectations a very important aspect of Keynes's theory.

Another important difference between these types of expectations is related to how easily they can be revised. As Keynes noted, SPE can be modified gradually and continuously, based upon the knowledge of the outcome of *productions decisions* (Chick 1983). In contrast, LPE embraces a much longer period of time and so, "they cannot be checked at short intervals in the light of realised results" (Keynes, *C.W.* VII: 51). Moreover, previous and present LPE are treated as being independent of each other. This is due to the fact that the time lag between these two moments is so long that the conditions upon which previous LPE were formed bear no relation with those observed when present LPE are formed. In this sense, the fulfilment or not of previous LPE does not influence the formation of the present LPE.

The relationship between these two types of expectations has been discussed extensively in the Keynesian literature. In an insightful paper, Kregel (1976) shows that the methodology used by Keynes implies the use of three distinct models related to expectational factors. What differentiates them are the assumptions regarding the fulfilment of expectations and their interactions.

The first model, presented by Keynes in his 1937 lecture notes, assumes that long-period expectations are constant and that the short-period expectations are always and instantaneously met. Given these assumptions, the system automatically rests at the *point of effective demand*. What Keynes wants to stress with this model is that an unemployment equilibrium can be achieved "irrespective of the process by which the system reacted to disappointed expectations" (Kregel 1976: 214; also Davidson 1978: 374-75).[106] Keynes uses this model to emphasise that unemployment is not essentially a short-period disequilibrium phenomena. This model was labelled by Kregel as the "static model".

The second model, which is used in the first eighteen chapters of the *General Theory*, assumes that SPE can be disappointed without any effect on LPE. Keynes uses this model to demonstrate the role of the principle of effective demand as the main determinant of the level of employment (Kregel 1976: 215). This model is called stationary equilibrium. The disappointment of short-period expectations from suppliers of consumption goods does not affect their demand for capital goods. As Torr (1988: 49) pointed out, this model assumes an apparently stable demand for consumption goods, although their producers have to find this out by trial and error. This model is today the most common interpretation of Keynes's work.

There is little discussion in the *G.T.* of the process of forming LPE, let alone the process by which they may change. It is clear that they cannot be based on the success or failure of previous LPE, for the time to accumulate such information is too long. Moreover, in both the static and the stationary equilibrium model there is no connection between validations of one kind of expectation and the formation of the other type. Using Hick's (1939) concept of elasticity of expectations (E_e), defined as the ratio of the

[106] In Keynes's words: "For the theory of effective demand is substantially the same if we assume that short-period expectations are always fulfilled" (*C.W.* XIV: 181).

proportionate change in the expected future values of x to the proportionate change in the current realised value of x vis-à-vis the previous expected value of current x, one can say that in both the static and stationary equilibrium models the E_e for long-period expectations is equal to zero (Davidson, 1978).

In this model the process of formation of long-period expectations takes into consideration only aspects related to the future. In other words, nothing that has been done in the past by the firm affects its expectations about future investment. To understand this point we have to bear in mind that Keynes treats 'time' as historical. This means that time is irreversible and decisions are irrevocable. Moreover, the past is unrepeatable and the future is unknown and unknowable. Today's decisions cannot be made using the past as a perfect image[107] of the future and the complete consequences of today's decisions can only be known in the future. Thus, this conception of time is strongly connected with uncertainty. Accordingly, when forming long-term expectations, investors cannot deduce from existing data what the future course of events will be. As we have seen in Chapter III, the social process is not an ergodic process (cf. Davidson, 1982-83), that is, the average calculated from past observation is different from the average of future outcomes (cf. Davidson, 1991). Thus, there is no replicability and the economic process is time-dependent.

However, the existence of uncertainty, and thereby the impossibility of making use of frequency distributions, does not imply some kind of nihilism[108]. What is wrong with this interpretation is that it implies that expectations are only formed based on some kind of demonstrative logic amenable to formal representation (cf. Dow, 1996a).

Kregel's last model - the model of shifting equilibrium - assumes that the disappointment of short-period expectations can affect long-period expectations.[109]

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[107] The past could be used as a basis for action but this does not mean that the future is a mirror of the past.

[108] According to Keynes, the *animal spirits* - a characteristic of human nature - makes nihilism an impossibility. In an environment of true uncertainty, what makes the difference in the decision process is exactly this characteristic of human behaviour. As Keynes points out,

> Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be taken as a result of animal spirits - of a spontaneous urge to action rather then inaction, and not as the outcome of weighted average of quantitative benefits multiplied by quantitative probabilities.
>
> (Keynes *C.W.* VII: 161)

[109] **There is no consensus on economic literature in relation to this interpretation of Keynes's shifting equilibrium. Setterfield (1999: 484) agrees, arguing not only that in a shifting equilibrium model short- and long-period expectations are interdependent, but also that the direction of this interdependence goes from SPE to LPE. In your turn, Chick (1983: 129, 263) is well clear about the exogeneity of the formation of LPE. Davidson's (1978) interpretation encompasses the two situations. He argues that two dynamic models can be found in Keynes's theory:**

This means that the system will be in equilibrium only if, by chance, the point of effective demand is achieved at the beginning of the process. If not, there will be a shift of the aggregate demand and supply curves, "since their underlying determinants (propensity to consume, liquidity preference, marginal efficiency of capital) will be readjusting to disappointment and this is in addition to any shift which is independent of these factors" (Kregel 1976: 215). This shifting of aggregate demand and supply curves makes the economic system function as a process of chasing an ever changing equilibrium point, and there is no guarantee that it will be caught.[110]

Therefore, according to Kregel's interpretation of shifting equilibrium,[111] the stability of the system will be defined by the extent of the change in long-period expectations due to the disappointment of short-period expectations. In other words, if $0 < E_e < 1$, the system could be at a shifting but stable equilibrium (Davidson, 1978: 380). Keynes assumed that this was the normal condition of the economic system.[112] When $E_e > 1$, the system becomes unstable.[113]

Since the focus of Keynes's analysis was the determination of the level of employment and output, he chooses to use two methodological devices to carry the investigation.

> dynamic model IA, where there are autonomous changes in expectations occurring whether current expectations are met or not and dynamic model IB, where there are no autonomous change on expectations but discrepancies between expectations and realisation induce changes in expectations about the future vis-a-vis *previous expectations* about the same future dates.
>
> (Davidson 1978: 376)

Some quotations from Keynes do not help resolve the matter. In his words,

> … we might make our line of division between the theory of stationary equilibrium and the theory of shifting equilibrium – meaning by the latter the theory of a system in which changing views about the future are capable of influencing the present situation.
>
> (Keynes *C.W.* VII: 293)

It is clear in this quotation that shifting equilibrium implies the impact on SPE due to modifications of LPE. The only consensus that I can observe is that all scholars are considering shifting equilibrium as a situation where LPE is allowed to change. Whether this change is autonomous or induced by changes in short-period expectations is a matter of disagreement. Despite the fact that Kregel's paper has been written more than two decades ago, there are no references in economic literature about these different interpretations.

[110] For a further discussion about the model of shifting equilibrium see Davidson (1978) and Setterfield (1999). For a comparison of the classical view of instability and the Post-Keynesian approach see Deprez and Dalendina (1994).

[111] See footnote 97.

[112] "Keynes recognised there was nothing in the logic of the analysis that required $E_e < 1$; nevertheless the real world was not violently unstable. Hence Keynes was continuously searching for conditions which are capable of causing the $E_e < 1$ (cf. *General Theory*, p. 250)" (Davidson 1978: 380 n1).

[113] Shackle uses similar definitions to distinguish disappointments:

> Counter-expected event: an hypothesis which has been considered and to which as a consequence of this examination a high degree of potential surprise has been assigned. Unexpected event: a contingency which has entirely escaped attention, which has never entered the individual's mind, and has formed no part of any hypothesis.
>
> (Shackle 1952: 73n)

Carvalho (1990: 29) argues that, in the case of a counter-expected event, Hicks's elasticity of expectations would be less than one, whereas in the case of an unexpected event E_e would be much higher than one.

The first one is the use of the static model, where short-period expectations are always fulfilled. The second one, is to explain effective demand allowing the independence between SPE and LPE, although SPE may not be fulfilled. In other words, the methodological devices were used to explain effective demand without the use of the shifting model. With these devices he was able to study the determination of the levels of employment assuming as given the following factors:

> the existing skill and quantity of available labour, the existing quality and quantity of available equipment, the existing technique, the degree of competition, the tastes and habits of the consumer, the disutility of different intensities of labour and the activities of supervision and organisation, as well as the social structure including the forces, other than our variables set forth below, which determine the distribution of the national income.
>
> (Keynes *C.W.* VII: 245)

The issue we shall analyse here is what happens with this framework if we assume that technical change is continuous. The question is whether or not the methodological artifices used by Keynes can be sustained when technical change is not only included but assumed to be continuous. We believe that the discussion about probable knowledge and technical change made in the previous chapter can clarify this matter and adds new elements to the discussion of the formation of expectations

IV.2 Reviewing some concepts of technical change

To make clear the contrast with the assumptions in the *General Theory*, let us recapitulate some important elements of technical change discussed in this thesis. In the Keynesian tradition, as we have seen in Chapter I, technical change is treated as exogenous to the economic system. Despite minor differences among them, Keynesian authors assume that there is always a blue-print of techniques at the disposal of investors, which are sometimes subject to financial restrictions (whether or not the investor will have the money to 'buy' the technology). While this approach could be appropriate to the study of the effects of technical change on income distribution, it is doubtful if it is useful for understanding the impact of technical change on the formation of expectations. Following the discussions in Chapters I and III, the approach adopted in our analysis comes from the studies of the Neo-Schumpeterians/Institutionalists.

What makes this approach distinctive from the traditional Keynesian point of view is that technological knowledge is not a free good that any investor can pick up off the shelf whenever he wants. There are features of the knowledge base used in every activity that make the diffusion of technological knowledge more difficult in some cases than in others. The access to the blue-print does not guarantee access to the knowledge necessary to use a technology. There is thus a clear distinction between information and knowledge. As Fransman writes,

> While processed information may be an important input into the knowledge-creation process, the creation of knowledge involves more than processing of information. ... Knowledge is always in a process of becoming, extending beyond itself. The firm's knowledge, therefore (that is the knowledge of its decision makers including the knowledge of those who create the firm's knowledge) must be conceived as being open-ended.
>
> (Fransman 1998: 151)

The firm is viewed as a repository of knowledge which is contingent on the firm's past history. The size and composition of this stock of knowledge differentiates firms and inhibits the free transfer of technological knowledge among them. The firm must therefore be seen as a collection of physical and human resources which may be developed in a variety of ways to supply a diversity of services (cf. Penrose, 1995[1959]). As Richardson points out,

> It is convenient to think of industry as carrying out an indefinitely large number of *activities*, activities related to the discovery and estimation of future wants, to research, development, and design, to the execution and co-ordination of processes of physical transformation, the marketing of goods, and so on. And we have to recognise that these activities have to be carried out by organizations with appropriate *capabilities*, or, in other words, with appropriate knowledge, experience and skills.
>
> (Richardson 1972: 888; 1990: 231)

As point by Fransman (1998: 181) these capabilities are not only inherited from the past, but they are constrained by the past. They are the effect of learning, technological opportunities and the selection process. Moreover, capabilities are stuck in the sense that they cannot be removed or acquired easily and with low cost. [114]

Together with this conception of the firm, the concepts of technological paradigm and technological trajectory are important to the understanding of the relations between technical change and expectations. As shown in Chapter I, these concepts shed light on special features of innovative activity, entailing a representation of technologies centred on the cognitive procedures which they involve (cf. Cimoli and Dosi 1995: 244).

[114] For a discussion of the firm's capabilities, see Penrose (1995[1959]) and Teece et al (1990). For a quick review of theories of the firm, see Fransman (1998). For a wide discussion about the implications of technical change for the theory of the firm, competitiveness and market organisation, see Dosi et al (1998).

In summation, we are assuming a conception of firm as a repository of knowledge which is expressed through its capabilities. Firms use their capabilities to increase their market power and their profitability. Metcalfe writes,

> The essence of dynamic competition is that firms differ in their profitability, that their different rates of return are translated into different rates of accumulation and that firms deliberately seek to create profitability differentials through the acquisition of privileged knowledge. ... Competition in this sense means rivalry, not passive acceptance of given market conditions. It is important to recognise the significance of knowledge generating activities to the dynamic process.
>
> (Metcalfe 1985: 92)

Moreover, a fundamental aspect of this dynamic competition is the introduction of innovations, either of the products produced by the firm or in its productive processes. Thus, a firm could be seen as developing a technological trajectory as a mechanism to increase its competitive power.

A final element to stress is the claim that, conceptually speaking, the decision to introduce an innovation has the same features as an investment decision (the decision of buying a capital asset), no matter to what kind of innovation we are referring. The difference between these kinds of decisions is not a theoretical one, but only a matter of degree.

Investment in capital assets has peculiar characteristics that make it very distinctive from the decision to buy any other type of asset:

i. Investors in capital goods are not interested in titles to capital goods as a store of wealth, but rather in the prospective yields of the services of the capital. They are interested in the sales of the products produced with the help of the capital good;

ii. The secondary market for capital goods is completely different from the secondary market for other assets, implying a very small liquidity premium. Because of this, the recovery of resources spent on the acquisition of a capital good, through reselling it, is very uncertain;

iii. These two features create a very high degree of irreversibility in the investment decision.

These characteristics of the investment process can also be found in innovative activity. When someone decides to invest in the development of a new technology, one is not interested in the innovation itself, but in the proceeds of the sales of the product that carries the innovation, or the proceeds of sales of the good that will be produced with the equipment which carries the innovation. The innovation itself does not function as a store of wealth. When a firm decides to invest in the research and development (R&D hereafter) of an innovation to be introduced into an already existing product (for example, the development of a new remote control for a television), what the firm is looking for is the revenue of the sales of the television with the new remote control.

Moreover, similarly capital assets, the existence of a secondary market for technological knowledge is very limited. The tacit characteristic of the knowledge produced during the R&D process makes this knowledge very difficult, and in some situations impossible, to be 'sold' in a secondary market.[115] This knowledge expresses itself through the capabilities of the firm, and, as we saw before, the capabilities are stuck onto the firm.

These features of the innovative activity make the decision to develop and introduce an innovation conceptually similar to the acquisition of a capital good and conceptually distinct from a production decision.

IV.3 Technical Change and Expectations

The question now becomes whether the acceptance of this understanding of technical change implies some modification on the way Post-Keynesians address the process of formation of expectations. In other words, we are interested in investigating to what extent the concepts of short- and long-period expectations are capable of dealing with technical change. To make the argument clearer, we distinguish the impact of the introduction of product innovation from the impact of the introduction of process innovation on the formation of expectations.

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[115] According to Patel and Pavitt

> Tacit knowledge - underlying the ability to cope with complexity - is acquired essentially through experience, and trial and error. It is misleading to assume that such trial and error is either random, or a purely costless by-product of other activities like 'learning by doing' or 'learning by using'. Tacit (and other forms of) knowledge are increasingly acquired within firms through deliberately planned and funded activities in the form of product design, production engineering, quality control, education and staff training, research, or the development and testing of prototypes and pilot plant.
>
> (Patel and Pavitt 1998: 290)

IV.3.1 Product Innovation

To facilitate the analysis let us divide the present discussion in two parts: the study of product innovation with the same capital good and then inquire into the impact of product innovation on LPE.

IV.3.1.1 Product Innovation and Medium-Period Expectations

Let us begin by recapitulating two important assumptions that we are working with. First, the concept of technical change assumed here denies the possibility of firms obtaining the new technology freely. It is assumed that to introduce a new product innovation a firm must develop it by itself. Secondly, we assume, for the moment, that we are not dealing with radical product innovations that signify a completely new set-up of the process of production.

The importance of product innovation to the behaviour of the firm has been studied for a long time in economic literature. Scherer and Ross (1990: 630) estimate that for each dollar spent on internal process R&D roughly three are spent on product innovation. It "is usually viewed as tapping into a market with some potential for earning profits". This fundamental role played by product innovation imposes that it should receive a theoretical treatment distinct from that one given to the production of a standard product.

In Chapter III, we demonstrated that the weight of argument related to the introduction of an innovation changes at each stage of the development of a TT. In these situations one can argue that there is a link between the outcome of the introduction of a previous innovation and the expectations about the prospective yield of the next innovation. What makes the connection is the development of the technological trajectory. If the past product innovations were successful in terms of market acceptance and technological performance, the weight of argument related to the introduction of the new innovation increases as the relevant knowledge about both market conditions and technology increases.

However, this process entails expectations that do not fit comfortably within the dichotomy of short- and long-period expectations. The central point is that the introduction of a product innovation is a decision process located between the production decision and the traditional investment decision.[116] First, the expectations

[116] The term 'traditional investment' will be used here as to investment without technical change.

involved in the introduction of a product innovation and what Keynes calls 'short-term expectations' are different. Despite the fact that in both cases the stock of capital is given, the decision to introduce a product innovation is different from the decision about how much to produce of a specific product. The variables that should be taken into consideration in these decisions are different. In the case of a production decision, the entrepreneur is concerned with the recovery of the cost of *one production period.* On the other hand, in the case of a product innovation, the firm is concerned with the recovery of the money spent on the development of its new product through the revenues of *many production periods.* Thus, it is a decision process that implies a different process of expectation formation from the process related to a production decision.

Secondly, despite being similar, the introduction of a new product and the acquisition of a new capital asset will differ in relation to the period of time considered and the amount of monetary resource involved. The calculation of the prospective yields from the acquisition of a physical capital good is much more complicated due to the length of time involved. On the other hand, the number of periods of production that have to be taken into consideration is shorter in the case of a product innovation. Moreover, because of the amount of monetary resources involved, the consequences of a miscalculation of the prospective yields from a traditional investment decision will be more damaging to the firm than a miscalculation arising from the introduction of a product innovation. Thus, one can say that despite being theoretically similar, these two types of decision possess properties that make their respective processes of expectation formation different.

Thus, there emerges the necessity of elaborating a new class of expectation to deal with the introduction of a product innovation. We will call this class of expectations *'medium-period expectation'* or *'single-product expectation'*. It will be defined as the expectations concerning the *quasi-rents* arising from the introduction of a new product. It involves many production decisions, although it also involves a shorter perspective of time and less monetary resources than the acquisition of a capital good.

We will now turn to the factors that affect the formation of medium-period expectations. As noted earlier, Keynes believed that short-period expectations encompass both a brief period of time and a limited amount of monetary resources, which make their disappointment less serious. They can be adjusted without significant costs. As demand is relatively stable in the short-period, it is relatively easy for the producer to adjust his expectations. The main factor affecting the ongoing formation of expectations is whether or not the previous expectations were disappointed. On the other hand, Keynes assumes that the LPE have to be based not only on the 'rational calculations' but also on animal spirits and convention. The fulfilment or not of previous long-period expectations does not affect the formation of the expectations for the next period (Keynes *C.W.* VII: Chapters 5 and 12; Chick 1983: Chapter 2; Davidson 1978: Chapter 16 and Kregel 1976).

What are the main factors affecting the formation of medium-period expectations? Are these factors conventions or the realisation of the last expectation? We think that an intermediate position between short- and long-period expectations formation provides the most satisfactory grounds on which to address this issue.

The fulfilment or not of previous expectations certainly will affect the expectations about the next product innovation.[117] In this sense, there are similarities with the formation of short-period expectations. However, there are two important differences. First, short-period expectations are about the demand for a standard product. When a producer has to decide how much to produce, there is nothing that he can do to affect the demand.[118] He has to guess the relatively stable demand. In this context, matching the demand means equilibrium (given the LPE). This is why Keynes said that equilibrium could be achieved through a process of trial and error. In this case, a vital element of the formation of the expectation is the degree of mismatch between previous expectations and realised outcomes. If the mismatch is positive (i.e. the outcome exceeds expectations) the next expectation will be increased, and expectations will be lowered if the outcome disappoints (the mismatch is negative) .

Medium-period expectations are concerned with a new product that is, at the same time, a development of the previous one. Holding everything else constant, this means that a firm can affect its own demand by launching a new product in the market. The main implication of this special feature is that there is no one-to-one relationship between the mismatch of previous expectations and the formation of the next one, as is the case in short-period expectations. The disappointment of previous expectations does not necessarily imply a negative revision of expectations for the new product. As the latter has some element of novelty, there is a possibility that the firm's demand will be positively affected. Of course, if the disappointment is large the expectations will have

[117] Remember that we are assuming, as we saw in Chapter III, that each firm has a place along a specific technological trajectory.
[118] For simplicity we are excluding marketing efforts from the analysis.

to be revised.

The key element in this discussion is that the firm's demand cannot be considered stable when product innovation is considered. Product innovation implies that a firm cannot be seen as passive in relation to its own demand. As we saw before, the concept of competition used here means rivalry, which, in turn, implies an active behaviour by the firm in relation to the market conditions.

By the same token, in the case of medium-period expectations, the match of previous expectations and realised outcomes does not necessarily produce an equilibrium that equates the prospective yields of sequential products. As we are dealing with a new product, a successful prediction of the prospective yields of a previous product can positively affect the expectations for the next ones. What is behind this analysis is both the discussion made in Chapter III about the development of a technological trajectory and its relation to the weight of argument. The success or failure of the introduction of an innovation changes the weight of argument in relation to the introduction of the next innovation. In situations where the previous product innovation has been successfully introduced (expectations were confirmed), there is an increase in the weight of argument related to the introduction of the new one, and so, there is an increase in confidence allowing for an increase in the expectations for the next product.

One must bear in mind that the approach adopted here presupposes two leads: one external, i.e. market response and one internal, i.e. R&D inside the firm. The market lead expresses itself through the validation or not of previous single-product expectations. In its own turn, the internal lead (R&D) operates through changes in firm's capabilities. The decision to launch a new product and the expectations about it are affected by both internal and external leads. A firm has to balance the influence of both aspects when making its own MPE.

The particularity of the approach used here is that both elements are captured in the weight of argument related to the decision about whether or not to launch a new product. The disappointment of previous medium-period expectations will not determine a negative revision of the formation of present MPE whenever the R&D generates an increase in the relevant knowledge about firm's technological trajectory. In situations like this, the negative influence on the weight of argument due to disappointment of previous expectations[119] is counterbalanced by the increase in the

[119] The disappointment implies an increase in the relevant ignorance of market conditions.

relevant knowledge in relation to the technology that is being used. Thus, the weight related to the introduction of the next product increases and, consequently, confidence increases. This process explains why the expectations about the new product are not negatively revised in relation to the previous expectations despite the invalidation of the latter. A similar argument can be used to explain why the validation of previous expectations can positively affect the formation of expectations about the next product.

However, there is another element that also plays a role in this process, that is *conventional behaviour*. As we have seen in Chapter III, the diffusion of an innovation can be explained by conventional behaviour. We can say that a convention related to a product innovation also affects the formation of medium-period expectations. Take for example a firm that produces televisions. If its competitors have introduced remote control and have been successful, there is an incentive for the firm to adopt this conventional behaviour[120] and introduce its own remote control device.[121] Despite the outcome of previous expectations, the convention gives rise to positive expectations about the new product. In this sense, the process of medium-period expectations formation resembles the formation of long-period expectations.

To sum up, the process of formation of medium-period expectations could be seen as a balance between the elements that are involved in the formation of short- and long-period expectations. Because they concern a new product that belongs to a specific technological trajectory, mismatches of medium-period expectations cannot be 'solved' by trial and error like in the case of SPE. However, the period of time elapsed since the last product decision is shorter than the time elapsed between investment decisions, in a way that demands that the compatibility between previous expectations and realised outcomes should be taken into consideration. Although mismatches play a relevant role in this process, there is not a direct relationship between these mismatches and the direction in which expectation must be revised. Moreover, because of the similarities to the investment decision, the introduction of a product innovation will also be affected by the conventions related to technical change.

The point that will be addressed now concerns the relationship between medium and long-period expectations. The main issue here is to analyse whether it is possible to assume, as a methodological device, as Keynes did in relation to short- and long-period

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[120] As pointed out by Littleboy (1992: 33) "imitation and faith in the views of the others can spontaneously give rise to conventions."
[121] Supposing that the firm has the technological capacity to develop its own remote control.

expectations, that these kinds of expectations are independent. To answer this question it is necessary to analyse investment decisions with continuous product innovation.

IV.3.1.2 Investment decision with continuous product innovation

The question to be answered is the following: what will happen with the investment decision in the Post-Keynesian approach if product innovation is allowed. In other words, we have to analyse what the impact on LPE will be if we assume that there will be future developments in the firm's product.

When deciding about an investment in physical capital, Keynes points out that a firm takes into consideration the expectations about prospective yields from the sales of its products. Allowing continuous product innovation implies that the calculation of prospective yields has to take into account not the expected sales of a unique product, but rather of several products with different technologies. The problem here is that the product innovations that will be introduced in the future are not known at the time of the investment decision. The future behaviour of the firm's demand will also depend on the future developments of the technological trajectory of the firm's product.

From what has been said above, one can conclude that the basis upon which the investor has to make the calculation of prospective yields becomes weaker if one assumes the prospect of continuous product innovation. From this point of view, the introduction of technological change in the investment decision reinforces the claims made by Keynes and the Post-Keynesians about the precariousness of the basis upon which investment decisions are made, as it seems to increase the uncertainty.

However, as Keynes has already pointed out,

> It would be foolish, in forming our expectations, to attach great weight to matters which are very uncertain. It is reasonable, therefore, to be guided to a considerable degree by the facts about which we feel somewhat confident, even though they may be less decisively relevant to the issue than other facts about which our knowledge is vague and scanty. For this reason the facts of the existing situation enter, in a sense disproportionately, into the formation of our long-term expectations; our usual practices being to take the existing situation and to project it into the future, modified only to the extent that we have more or less definite reasons for expecting a change.
>
> (Keynes *C.W.* VII: 148)

According to the quotation above, one has to be guided by the facts of the present situation when deciding whether to invest or not. The usual approach in this case is to introduce into the framework the conventions that are held by investors at the moment of the decision. While this cannot be denied, our previous discussion of technological trajectories suggested that another element can be introduced into this framework.

Applying Keynes's framework mentioned above to the problem in question, it can be seen that when an investor makes a prospect of future receipts from the sales of the products produced by the capital asset that is now being bought, he attaches great weight to the prospective yields from the product that will be produced ***immediately*** by the new equipment.

Although the firm knows little about the products that will be produced by this new capital good in a more distant future, it knows that the immediate products to be produced usually represent a stage on a technological trajectory that has been developed by the firm. Unless the first type of product to be produced by the new capital good is a completely new product (a change of the technological trajectory), there will be strong connections between the latest products produced with the old capital asset and the first products to be produced with the new capital asset. As we showed before, if the latest innovations have been introduced successfully, the confidence about the introduction of the new product innovation increases along with the weight related to this decision increases. Thus, the expectation of prospective yields from the first types of products to be produced with the new capital asset are strongly affected by the outcomes obtained by the latest types of products produced with the old equipment.

The main point here is to show that when one tries to analyse the firm's investment decision, one has to acknowledge that the firm has been developing a technological trajectory. This feature implies a dual impact on the formation of long-period expectations. First, technical change weakens the grounds on which the formation of expectations is based as the agent has to try to calculate the prospective yield of different types of products, some of which are largely unknown. Secondly, because of some features of the technological knowledge possessed by the firm (tacitness, cumulativeness, etc.), the formation of expectations can be made on stronger grounds as the immediate past outcomes obtained by the firm strongly affect the formation of expectations about the immediate future, even when these expectations are about an investment in a new plant.

A similar point was made by Kaldor and Mirrlees:

> ... under conditions of continuing technical progress, the expectations concerning the more distant future ... are regarded as far more hazardous or uncertain than the expectations for the near future, where the incidence of unforeseeable major inventions or discoveries is less significant. Hence investment projects which qualify for adoption must pass a further test – apart from the test of earning a satisfactory rate of profit – and that is the gross profit earned in the first *h* years of its operation must be sufficient to repay the cost of investment.
>
> (Kaldor and Mirrlees 1962: 178)[122]

It must be emphasised that what has been argued here is completely different from the rational expectations approach. The latter assumes that the *'entire'* past results of the firm are a reliable guide to the possible future outcomes and determine the formation of investment expectations. The point that has been argued here is that *only the latest* outcomes are important in the formation of the expectations about the future yields. As pointed out by Keynes, recent facts are "a more serviceable guide to the future than a candid examination of past experience would show it to have been hitherto" (*C.W.* XIV: 114). Moreover, as the new capital asset will produce several products in its whole economic life, the increased confidence on the prospective yields refers to the *immediate products* that will be produced by the firm, and not to the prospective yields of the capital asset during its whole life.

The discussion of technological trajectories supplies a further reason to assume the conventional behaviour of supposing "that the existing state of affairs will continue indefinitely, except in so far as we have specific reasons to expect a change". This is a point which Meeks (1991) and Runde (1991) have both noted:

> But once the convention of assuming continuity is accepted, past evidence will frequently support *some* (sometimes considerable) degree of belief in propositions about the future - especially about the *near* future.
>
> (Meeks 1991: 154)

and

> For all practical purposes investors 'simply do not know' about things such as the price of copper ten years hence. Nevertheless, they may on occasion be able to judge some projects more 'probable' than others over the *near future*, even though they do not know what the more distant future will bring.
>
> (Runde 1991: 134 - italics added)

[122] Anderson and Goldsmith (1997) test a model, with good results, in which investment is explained as a function of the business executives' forecast (six months ahead) and the weight (or confidence) of this forecast (whether the previous forecast was attained or not).

The element that has not been taken into consideration either by Keynes or by the Post-Keynesians is the link between the fulfilment of the product expectations (medium-period) of the latest products produced by the firm with the old capital asset[123] with the expectations of prospective yields from the immediate products produced by the firm with the new capital good. The interpretation suggested here can help explain a question posed by Meeks concerning contradictory suggestions from Keynes, such as:

> "We simply do not know" when a new invention will become obsolete or what the rate of interest will be twenty years from now (XIV, pp. 113-14) ... and "the entrepreneur is supposed by Keynes to enjoy an 'element of real knowledge' (based on 'special knowledge of the circumstances, either actual or prospective, of the business in question') about the value of investment he undertakes.
>
> (Meeks 1991: 154-55)

This supposed contradiction disappears when one takes into consideration the concept of technological trajectory. Both statements are correct in the sense that uncertainty is never eliminated in an innovative activity. It is impossible to have perfect foresight of future technological developments, despite the fact that the acknowledgement by the investor of his position in a technological trajectory allows him to have an "element of real knowledge" about part of the prospective yields from the investment now being undertaken.

From what has been said, it is possible to argue that both the introduction of a product innovation and the recognition of the weight of argument as an important element in the development of a technological trajectory bring into the process of the formation of LPE a new element which has not been taken into account by Post-Keynesian economists, that is the interaction between the validation or not of MPE and its impact on the formation of LPE. One can safely say that LPE become *partially endogenised* when MPE are brought into account. Moreover, even from a methodological point of view, the complete separation of these two kinds of expectations cannot be made as this procedure implies the exclusion of an important element of the process of expectation formation, that is the fact that a firm is always producing a product that belongs to a technological trajectory.

Another aspect that deserves attention is related to the volatility of long-period expectations. The Keynesian literature is full of references to the flimsy foundations on

[123] Whether or not the expectation has been fulfilled determines the success or failure of the technological trajectory that has been developed by the firm.

which long-period expectations are based. However, despite the possibility of sudden instability arising from changes outside the system, Keynes himself noted that, as a norm, the economic system is not very unstable.[124] According to him, to understand this feature it is necessary to suppose that the environment and the psychological propensities of the world are able to produce this stability. Among the Post-Keynesians there have been intense discussions about the institutional conditions that generate this stability (Davidson 1978: Chapter 16; Crotty 1994). Examples of these institutions are spot and forward markets; money and forward contracts; institutions and practices that regulate competition[125]; the institutionalisation of decision making[126]; and government regulation of the macroeconomy. These institutions can help to reduce uncertainty by delimiting – however imperfectly - likely future outcomes.

In the light of our previous discussion, it can be strongly argued that technological trajectories and technological paradigms can be added to this list.

> Both the technological and institutional knowledge of *how and what people learn, what are their beliefs and how they change* [features that are strongly shaped by the technological paradigm] … are factors of *behavioural order* which contribute to explain coordination and consistency in uncertain, complex and changing environments.
>
> (Dosi and Orsenigo 1988: 19)

Moreover, if we take into account the concept of techno-economic paradigm (Perez, 1985) in which there is a "change in the basic approach and 'common-sense' of designers, engineers and managers which is so pervasive that it affects almost all industries and sectors of the economy" (Freeman 1994: 487), the propensity towards stability in the system is strongly reinforced.

The concepts of technological trajectory and technological paradigm are important elements in the formation and in the linking of medium- and long-period expectations. They also reinforce the bounds in which the formation of expectations take place. This mechanism strongly contributes to overcoming the volatile conditions under which long-period expectations are formed.

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[124] In Keynes's words:

> … it is an outstanding characteristic of the economic system in which we live that, whilst it is subject to severe fluctuations in respect of output and employment, it is not violently unstable.
>
> (Keynes *C.W.* VII: 249)

[125] **"Through cooperative interfirm relations such as oligopolistic structures, trade associations, mergers, enterprise-bank groupings, and so forth, firms have historically attempt to limit the damage done by anarchistic competition" (Crotty 1994: 133)**

[126] **Examples include rules of thumb, routinized behaviour, heuristics fixed by law, formal policy, etc.**

A last scenario should be discussed. That is, what happens with the formation of expectations when the product innovation is a breakthrough, a radical innovation, so that a completely new capital good is required, due to the enormous differences between the technical requirements for the production of the old product and the technical specifications for the production of the new product. Usually, this situation implies a change in the technological trajectory of the firm.

The introduction of a radical product innovation resembles the traditional investment decision. As the new TT of the firm is at its initial stages, the partial endogeneity that operates on the formation of MPE and LPE is decisively weakened. Thus, conventional behaviour and animal spirits will be the most important elements on the formation of expectations.

IV.3.1.3 A Summing Up

From the foregoing discussion, we may now advance the following taxonomy of expectations:

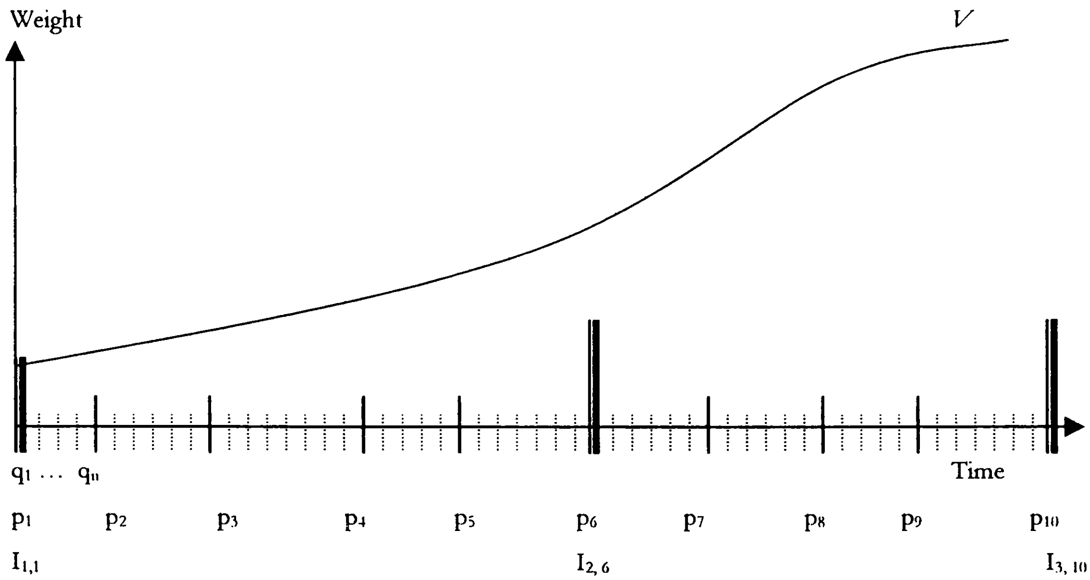
Short-period expectations: these are the traditional expectation as defined by Keynes. They encompass 'daily' decisions about how much to produce of a standard product;

Medium-period expectations (*single-product expectations*): expectations about the proceeds over the life cycle of a new product;

Long-period expectations (*investment expectations*): expectations about the acquisition of a capital good. However, now one has to take into account that the capital good that has been bought will have to produce different products during its life. Thus, these expectations involve prospective yields from different products.

The figure below can help to understand the relationship among them. Figure IV.1 represents the sequential decisions made by an entrepreneur during a successful development of a technological trajectory. The marks on the horizontal axis represent the three types of decision we have discussed in this chapter and the *V* curve represents the weight curve discussed in Chapter III. $I_{1,1}$ represents the first investment decision (i=1) and the fact that the new equipment will start, producing the good with technological age 1 (j=1). $I_{2,6}$ is the second investment decision (i=2), where the equipment will initially produce the good with technological age 6 (j=6). The distance between $I_{1,1}$ and $I_{2,6}$ represents the life time of the capital asset that has been acquired after the first investment decision.

Figure IV. 1 : Time Horizon for Investment, Product and Production Decision and Evolution of Weight of a Successful Trajectory



where $I_{i,j}$ (‖) is the point at which an investment decision is made (based on long-period expectations);

p_j (|) is the point at which a product decision is made (based on medium-period expectations);

q_n (⁞) is the point at which a production decision is made (based on short-period expectation).

During the life time of a capital good, different products with different technologies will be produced using the same stock of capital. p_j represents the decision to invest in a new product. Thus, in our example, the capital asset I_1 will produce five different types of good during its life time. Between the introduction of two different products, many production decisions (q_n) are made. For each type of decision a different type of expectations is involved. Long-period expectations are related to decisions $I_{1,1}$ $I_{2,6}$ and $I_{3,10}$. Product expectations come to deal with decisions p_j, while q_n represents production decisions.

In this example we are dealing with a successful technological trajectory, and thus we can see that the weight of argument related to the introduction of a new product is increasing at each product decision.[127] The fulfilment of the set of production expectations between p_1 and p_2, for example, is important to determine the expected yields from the introduction of p_2. In the same way, the fulfilment of the set of production expectations between p_5 and p_6 will produce an increase of the weight related to the formation of the expectations related to the new capital's prospective yields ($I_{2,6}$). This could improve the long-period expectations and induce an increase in the amount of resources allocated to the acquisition of the new capital good. This is represented in the figure by an increase in the height of the mark that represents the investment decision. Moreover, in the calculation of these prospective yields, the expected yields from the production of the good with technological age six will also enter into the calculation with a higher weight than the goods with technological ages of seven, eight, nine and ten.

Figure IV.1, also helps us to understand the dual impact of product innovation on the formation of LPE. At point $I_{2,6}$ the investor does not know for sure how many products it may be produced with the new equipment. Products p_7, p_8 and p_9 will be known only in the future. This makes the estimation of prospective yields from the use of the capital good much more difficult than in the traditional case in which a given equipment produces a uniform product. On the other hand, at point $I_{2,6}$, the investor knows whether the product expectation in relation to p_5 has been realised or not. Based on this he can have greater confidence in the expectations about p_6. This means that two types (p_5 and p_6 in the figure) of expectations enter into the formation of long-period expectations disproportionately. In Keynes's words,

> Accordingly it is sensible for producers to base their expectations on the assumption that the most recently realised results will continue, except in so far as there are definite reasons for expecting a change.
>
> (Keynes *C.W.* VII: 51)

Although the above quotation is related to short-term expectations, the discussion of technological trajectories in Chapter III allows us to extend it to the relation between medium-period and long-period expectations.

Moreover, this analysis is also compatible with two out of the three techniques Keynes suggests when discussing conventions (*C.W.* XIV: 114).[128]

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127 Notice that the weight curve intercepts the vertical axis above its minimal point. This is because a new product is only launched into the market after some fundamental research has been made. This research creates a little amount of weight.

128 See the discussion of conventions in Chapter III.

We can claim that the introduction of the technological element into the formation of expectations does not change the core of Keynes's approach. According to O'Donnell, Keynes developed important insights concerning expectation formation, both related to the choice of the appropriate levels of abstraction and realism.

> The first is that only a part of existing knowledge will commonly be used in the inductive projection, namely, knowledge of the present and recent past [...] The second idea is that the reliability of induction as a guide to the economic future decays rapidly when expectations are pushed beyond the immediate horizon.
>
> (O'Donnell 1989: 252)

The next two figures below (IV.2 and IV.3) represent the development of a technological trajectory with a failure occurring with the product with technological age five. One can see, in this example, that the market failure implies a decrease in the weight related to the next product. However, the reaction to this failure will vary according to the comparison between the decrease on the weight of the existent trajectory and the weight of the alternative trajectory as already shown in Figure III.2. In Figure IV.2, the lack of success does not imply a change of trajectory. This is represented by the continuity of the *V* curve. The decrease in the weight affects the investment decision $I_{2,6}$ by reducing the amount of resources allocated to this decision.

Figure IV.3, in turn, shows a situation in which failure results in a change of the technological trajectory. The effect on the weight due to the disappointment of the product expectations about p_5 is so great that the weight in relation to the expectations about the next product (p_6) becomes lower than the weight related to a new product in a completely different trajectory (p^1). Thus, using the *principle of maximum weight* discussed in Chapter III, it is rational for the investor to change the technological trajectory he is traversing.

Figure IV. 2: Time Horizon for Investment, Product and Production and Evolution of Weight of a Trajectory with Failure

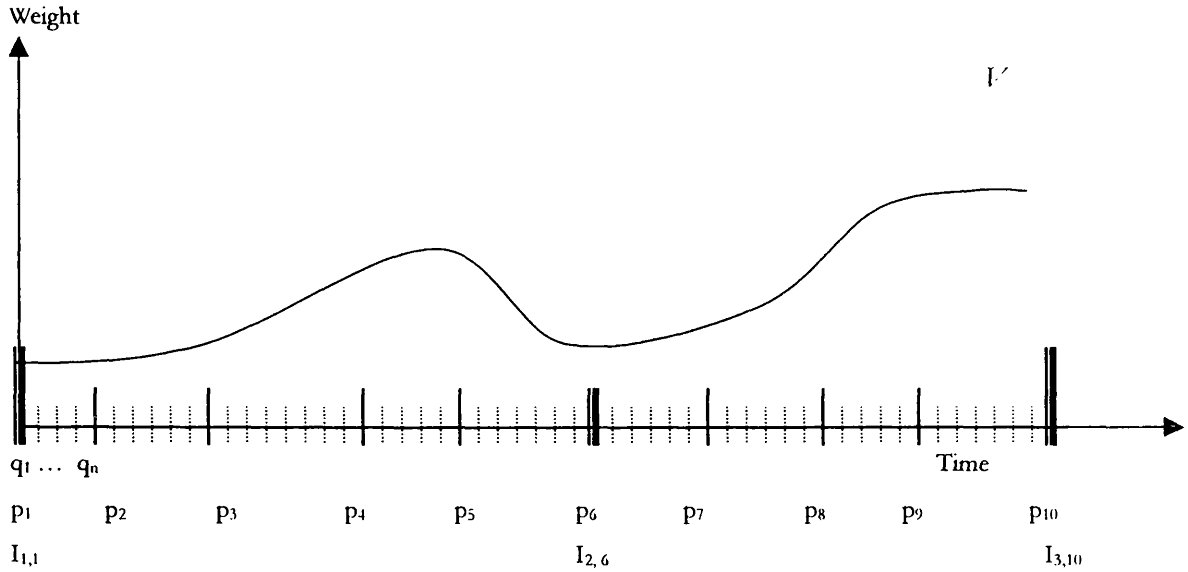
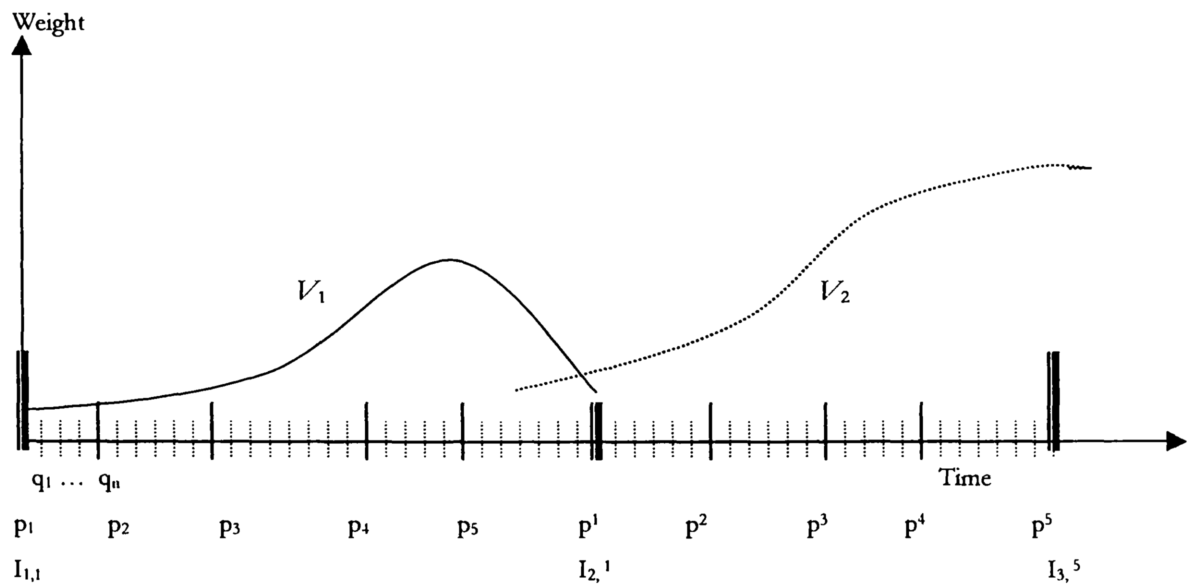


Figure IV. 3: Time Horizon for Investment, Product and Production Decisions and Evolution of Weight with a change of Trajectory



where V_1 is the weight related to the first technological trajectory (which fails at p_5);
V_2 is the weight related to the second technological trajectory;
p^i is the product decision inside the second technological trajectory and;
I_t^j is the investment decision related to the second technological trajectory.

IV.3.2 Process Innovation

This discussion can be framed as follows: What is the impact of a process innovation on the formation of short- and long-period expectations? To clarify the analysis let us take up each of these two kinds of expectations, in turn.

Starting with short-period expectations, it is necessary to remember that process innovations can only be brought into the productive process by adding a new capital good to the firm's stock of capital, which is a decision process related to long-period expectations. This implies that there will be no significant impact on the formation of short-period expectations. The latter take the stock of capital as given. Therefore, with respect to process innovations, there is no need to modify Keynes's analysis.

However, for the case of LPE the analysis is different. To illustrate the point, we will assume a situation which all process innovations are produced outside the firm.[129] In other words, we are assuming an economy with two sectors: capital and consumer goods sectors.

The first aspect to be noted is that the equipment that embodies the process innovation generated in the capital goods sector is a product innovation from the point of view of this sector. In other words, in relation to process innovation there are two dimensions that work simultaneously. One is related to its impact on the formation of LPE from the point of view of the 'consumers' of the process innovation. The other one is related to the 'producers' of the process innovation and is related to the development of the capital equipment technological trajectory. As we shall see, both processes present some degree of interdependence.

To elucidate the discussion let us analyse these two processes separately.

IV.3.2.1 Process Innovation and 'Consumers' of Capital Goods

The question here is: what is the impact of this kind of externally-generated technological change on the formation of long-period expectations from the point of view of the buyers of capital goods.

An aspect that should be analysed refers to what Rosenberg (1982) has called technological expectations. In other words, the impact on the formation of LPE when

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[129] It is known that process innovation can be generated inside the firm. However, these types of innovations can be characterised as incremental to a major innovation that has been produced in the capital goods sector. Thus, for simplicity, we will take into account only process innovations that are generated outside the firm and are internalised through the acquisition of a new type of capital good.

there are expectations of future improvements on the process of production. First, let us discuss the acquisition of a capital good related to an increase on the productive capacity. In this case, positive technological expectations will decrease the marginal efficiency of capital (*mec*) of the new capital asset. This situation was described by Keynes when he wrote that,

> The output from equipment produced to-day will have to compete, in the course of its life, with the output from equipment produced subsequently, ..., perhaps by an improved technique, which is content with a lower price for its output and will be increased in quantity until the price of its output has fallen to lower price with which it is content. ... In so far as such developments are foreseen as probable, or even as possible, the marginal efficiency of capital produced to-day is appropriately diminished.
>
> (Keynes *C.W.* VII: 141)

However, this adverse impact on investment expectations will depend on how developed the capital asset's technological trajectory is. When the new capital asset represents a major innovation, meaning that the exploration of its technological trajectory is in its early stages, one could argue that it is more appropriate for an investor to delay his investment. As Rosenberg points out,

> ...there may be situations where large-scale improvements are confidently expected *after* the introduction of some major innovation. In such cases these expectations may lead to a surprising result of making rational a delay in the widespread diffusion of the innovation.
>
> (Rosenberg 1982: 106)

From a Keynesian point of view, what this means is that the relevant knowledge about the technology is low and the relevant ignorance high, which implies a low weight related to the investment decision. Thus, the degree of uncertainty related to this decision is high and there is a negative impact on expectations as the relevant knowledge pertaining to this decision is not reliable. Thus, in this situation the expected rate of technical change can work to decrease the volume of investment.

However, this argument loses relevance when the process innovation represents a later development of its TT. The main point here is the impact of the technology on the costs of production. Despite the fact that the product that will be produced with the capital asset that is now being bought has to compete in the future with products produced with better technology - if continuous technical change is assumed - the impact of this on the cost of production will vary depending on the stage of development of the technological trajectory of the capital asset. It can be assumed that in the early stages of this development, the increase in the productivity due to a new innovation is larger than that of innovations at a later stage of the development of a TT. Thus, if an innovation is late in the development of a TT, the impact of expected improvements in the technology on expectations is weak, and consequently, the negative impact on the amount of investment is small.

Another effect on the formation of LPE due to the assumption of continuous technical change is related to the calculations of expected quasi-rents. The latter is calculated as the prospective yields minus the prime costs, which are composed by the factor cost plus user cost. However, the value of the user cost is influenced by the optimum level of maintenance of the equipment. This level of maintenance, in turn, depends on both the expected behaviour of demand and the expectations about technological change, which will affect the expectations about the life-time horizon of the capital good now being bought. Thus, expectations about improvements on the capital good will imply a reduction on the user cost as the life expectation of the equipment will be reduced.[130] As a consequence, the expected quasi-rent will increase. As it might be expected, the marginal efficiency of capital also augments.

The last point to be mentioned in relation to the 'consumers' of capital goods is associated with the decision to invest aiming at increasing the productivity, without adding new productive capacity (i.e. stable demand). In this case, the decision to introduce a process innovation is driven by developments that occur on the technological trajectory of the capital good. These developments reduce the cost of production and, so, create the possibility of the firm increasing either its market share (if this reduction is translated into prices cut) or its rate of profits, or both. The point here is to acknowledge that even in situations where there is a stationary demand for firm's product, there will be an incentive to invest, at least to protect firm's market share. This feature has some implications for the effective demand that will be explored in the next chapter.

IV.3.2.2 Process Innovation and 'Producers' of Capital Goods

It remains to be discussed the implications of the assumption of continuous process innovations from the point of view of the 'producers' of capital goods. The whole discussion that has been made about product innovation applies to this case. As said

[130] For a discussion about user cost see Chick (1983: Chapter 3); Torr (1992, 1997) and Gossling (1969).

before, a capital good is a product that has its own technological trajectory and its own weight of argument. However, there is an important element that creates a particularity on the development of the TT of a capital good that is not present on the TT of a final consumer good.

There are studies (Rosenberg 1976, Fransman 1986) that show that the efficiency of the capital goods sector is dependent upon the level of demand for capital goods. This argument refers to Smith's division of labour and its impacts on productivity. According to Adam Smith the division of labour is limited by the extension of the market. Accordingly, the bigger the market, the greater the specialisation of capital goods sector and the greater its technological development. According to Rosenberg,

> The economies of specialization referred to derive not from the production of a homogeneous product but from the concentration upon a relatively narrow (heterogeneous) product range which in turn requires a relatively homogeneous collection of resources in their production. ... This highly developed facility in the designing and production of specialized machinery is, perhaps, the most important single characteristic of a well-organized capital goods industry and constitutes an external economy of enormous importance to other sectors of the economy.
>
> (Rosenberg 1976: 144)

Taking into account the concepts that have been used in this dissertation, one can say that the development of the technological trajectory of a capital goods sector is heavily affected by its own degree of specialisation, which is, in turn, dependent on the size of its demand.

Moreover, the development of the productive process of the capital goods sector has itself an important impact on the whole economy. Any cost reduction in this sector is capital-saving for the whole economy, regardless whether the innovation is of labour-saving or capital-saving nature,

Rosenberg synthesises this point as follows,

> Currently developed economies, then, have gone through the following historical sequence: with the growth in the demand for machinery the capital goods industry became gradually more and more highly specialized and subdivided in order to undertake the production of machines, the cost of producing was thereby sharply reduced, and as a result capital-saving for the economy as a whole was achieved.
>
> (Rosenberg 1976: 147)[131]

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[131] The policy implications from this conclusion are straightforward:

IV.4 Conclusions

It has been shown that Keynes in his writings uses a methodology that allows him to analyse the interactions between short- and long-term expectations in three different ways, depending on what he wants to explain. In two of these models (the stationary and the static) there is no interdependency between disappointment of short-period expectations and the formation of long-period expectations. In the third (shifting equilibrium model) these types of expectations are interdependent, according to Kregel's interpretation.

However, the main feature of these three models is that technology is taken as given. The claim made here is that this latter assumption is fundamental to the formation of expectations. If the concepts of technological paradigm and technological trajectory are incorporated, not only must a new kind of expectations be brought into the picture (medium-period expectations) but the methodological device used by Keynes, of assuming the independence of different types of expectations, cannot be used. The formation of long-period expectations *must* take into account whether or not the previous medium-period expectations were fulfilled. This does not mean that uncertainty about the future disappears, but rather that the formation of long-period expectation has one component that is *partially* endogenous.

Moreover, the assumption of continuous process innovation sheds light on two processes. From the 'consumers' point of view, the acknowledgement of the existence of a TT in the capital goods sector is an inducement to invest, affecting the formation of LPE due to its impact on the user cost. However, from the 'producers' point of view, the level of demand is an important element on the development of the capital good's TT as it opens the possibility of specialisation. It is a cumulative process where the TT stimulates investment decisions in the 'consumer' sector, and the demand for capital goods facilitates the technological progress.

> **... underdeveloped countries with little or no organized domestic capital goods sector simply have not had the opportunity to make capital-saving innovations because they have not had the capital goods industry necessary to them. Under these circumstances, such countries have typically imported their capital goods from abroad, but this has meant that they have not developed the technological base of skills, knowledge, facilities and organization upon which further technical progress so largely depends.**
>
> **(Rosenberg 1976: 147)**

CHAPTER V

CONSTANTLY EVOLVING EXPECTATIONS AND EFFECTIVE DEMAND

Introduction

As seen elsewhere, we believe that it is impossible to elaborate at a macro level capturing all features of the micro level. This point has been made by some scholars like Kirman (1989), Lavoie (1992), Rizvi (1994) and Chick (1997). Perhaps the most strong argument against the microfoundations project has been made by Rizvi(1994). In this article he strongly challenges that it is possible, even in a general equilibrium approach, to explain the macroeconomic level according strict microeconomic foundations. He argues that the microfoundations approach "stands on the twin beliefs that macro-phenomena must be reduced to micro-principles, and that this reduction occurs with the use of the General Equilibrium Theory [general equilibrium theory of the Walrasian Arrow-Debreu-McKenzie type] model" (Rizvi 1994: 361).

He uses the Sonnenschein-Mantel-Debreu (SMD) theorem to show that the individual rationality's hypothesis at the micro-level provides no guidance to the study of macro-level phenomena. Basically, the SMD theorem shows that the excess demand functions satisfying Walra's law can take almost any form. This is devastating to the GET model as it argues that due the primitives of the model excess demand functions would always be downward-sloping. The rejection of this latter claim means that the uniqueness or stability of the equilibrium in GET model is no more guaranteed. Rizvi concludes his argument pointing out that

> [...] the fact that AED [Aggregate Excess Demand function] is essentially arbitrary, and that no reasonable assumptions at the level of individuals remove this indeterminacy, means that the era of strict microfoundations has come to an end. This arbitrariness specifically means that attempts to give strict microfoundations and completeness found in the treatment of competitive Walrasian general equilibrium, are not generally valid.
>
> (Rizvi 1994: 373)

Taking the discussion above into account, we share the understanding of Chick (1997: 1), that the move from microeconomics to macroeconomics will inevitably entail compromise of some sort.

This caution is required as the aim of this chapter is to draw some implications for the discussion of effective demand from the analysis that was undertaken in the previous chapter. In other words, we now are going to move from the micro level (the formation of expectations) to the macro level (its implications for effective demand). In order better to understand this move, "compromise of some sort" is warranted. By making abstractions of some microeconomic feature of the approach to technical change used here, we believe we can contribute to the understanding of the macroeconomic implications of our analysis. The procedure of abstraction can be understood as

> ..the process of individuating and focusing on an aspect or aspects of some concrete phenomenon of interest, with the aim of concentrating attention on factors that are considered essential to it, for a particular purpose or from a particular point of view, while temporarily relegating factors that are deemed inessential into the background.
>
> (Runde 1997b: 17)[132]

For example, as in this chapter we are concerned with the level of employment, we will not take into account modifications of market share among existing firms. We know that this is an important characteristic of the economy when firms and technical change are treated as they have been in this dissertation. However, as we shall see later, for the discussion of the effective demand this feature can be put aside; we shall assume a constant distribution of labour among firms. Other features, such as the fact that firms use their capabilities to compete and the fact that the technological knowledge used to generate a new product is built inside the firm, will be taken into account.

Bearing in mind these caveats, the investigation will be carried out separating two aspects of effective demand. The first we call the supply dimension, even though it takes into account expected values of demand. These expectations, which exist in the minds of entrepreneurs, play a determining role in defining output and employment at any specific time. The second dimension, which we call the demand side, deals with actual values. As we will see, the main concern of this approach is the study of the final

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[132] He goes on, contrasting abstraction and idealisation. The latter

> tends to take the form of postulating limit or ideal types and/or analysing economic phenomena as if they or their component parts exist and operate in isolation from the involvement or interference of aspects of the situation in which they arise.

equilibrium position.[133] As there has been extensive discussion on effective demand in the economic literature, the aim of the next section is merely the presentation of its main features.[134]

V.1 The Supply Side of Effective Demand

To facilitate the analysis let us divide the discussion in two subsections. First, we will recapitulate the discussion in Keynes's terms, recalling that in the *G.T.* there is no technical change. Then, we will investigate the implications of the introduction of technical change, and consequently medium-period expectations (MPE), into the framework.

V.1.1 Keynes's Point of Effective Demand

The supply version of Effective Demand is developed by Keynes in Chapter 3 of the *General Theory*. His main argument is that the levels of employment and output are determined by producers' expectations. These levels of output and employment are determined by the use of two functions: *Aggregate Supply* and *Expected Aggregate Demand Functions*. According to Keynes, these two functions are defined as follows:

> Let Z be the aggregate supply price of the output from employing N men, the relation between Z and N being written $Z = \phi(N)$, which can be called the *aggregate supply function*. Similarly, let D be the proceeds which entrepreneurs expect to receive from the employment of N men, the relationship between D and N being written $D = f(N)$, which can be called [expected] *aggregate demand function*.
>
> (Keynes *C.W.* VII: 25)

Let us take a closer look at these two functions. Starting with the aggregate supply function, it should be noticed that it does not represent a relationship between the unitary price and the unitary cost of production, as the classical supply function does, but rather a relationship between the total proceeds originating from a specific amount of production and the level of employment necessary to produce that specific amount

(Runde 1997b: 17)

[133] This distinction between supply and demand side of effective demand follows from Amadeo (1989).
[134] For a complete discussion on the topic see Davidson (1978), Chick (1983), Torr (1988), Kregel (1988) and Amadeo (1989) among others.

of output. Assuming profit maximisation, the supply price will be given by the formula[135]

$$[K_n / K_n - 1] \; MC_n O_n \qquad (5.1)^{136}$$

where K_n is the elasticity of demand,

MC_n is the marginal cost, and

O_n is the volume of production.

This equation comprises the profit maximisation procedure where MC is equated with the marginal revenue. Moreover, it opens the possibility of incorporation of imperfect competition through the value of K, which captures the degree of market power of the firm. What the above equation tells us is the expected proceeds that would lead an individual firm to produce the output O_n (Tarshis 1979: 366). It will not produce as much as O_n if the expected proceeds are less than the amount determined by the formula 5.1.

The *Aggregate Supply Function* is obtained through the aggregation of the supply curve of the existing firms. This implies that the amount required to convince each firm to produce its own contribution to the total output has to be added. As noted by Tarshis (1979: 371), if this aggregation is made by adding required sales receipts, a "double counting" procedure will happen, as the sales required by the producer of the final goods will be added to the sales required by the producer of inputs. For example, the sales required by the producer of steel would be added to the sales required by the producer of automobiles, who uses steel as input. To avoid this problem, the supply curve of each firm should be derived on a "value-added basis" (Tarshis 1979).[137]

Taking this caveat into account, the aggregate supply price of an volume of output O_t will be defined as:

$$\sum_{n=1}^{n=M} \left[\frac{K_n}{K_n - 1} MC_n O_n \right] \qquad (5.2)$$

[135] This formalization follows Tarshis (1979).

[136] The format of the supply curve does not alter if we assume any other procedure to decide the level of production. For a derivation of the supply curve assuming Full-Cost approach see Weintraub (1958).

[137] According to Tarshis,

> that was Keynes's intention when instead of defining the aggregate supply function in terms of expectation of sales receipts needed to persuade entrepreneurs to hire any particular number of employees, he defined it in terms of the expectations of 'proceeds' required to provide such an inducement. In fact, his concept of 'user cost' was designed to permit the conversion of 'sales receipts' to 'value added'.
>
> (Tarshis 1979: 371)

which is the total proceeds that will induce M firms to produce the amount MO_n[138] of the output.

The expected aggregate demand function is also obtained through the aggregation of the estimates of expected aggregate demand of the existing firms. An important assumption is made by Keynes when constructing a firm's demand curve: the decision about how much labour a firm will hire is related to its expectations about the aggregate level of expenditure (consumption and investment). In his words,

> the volume of employment which maximises [the entrepreneur's expected] profit depends on the [expected] aggregate demand function given by his expectations of the sum of the proceeds resulting from consumption and investment respectively on various hypotheses.
>
> (Keynes *C.W.* VII: 77)

In the *G.T.* discussion about the point of effective demand, the volume of investment is taken as exogenous, which implies that it is the behaviour of consumption demand that explains the shape of Expected Aggregate Demand function (D^e)[139]. Accordingly, D^e will have a concave shape reflecting the following hypothesis: (i) given the investment, consumption will vary directly with the level of employment and, (ii) as income increases, the marginal propensity to consume decreases (Chick 1983: 67-70).

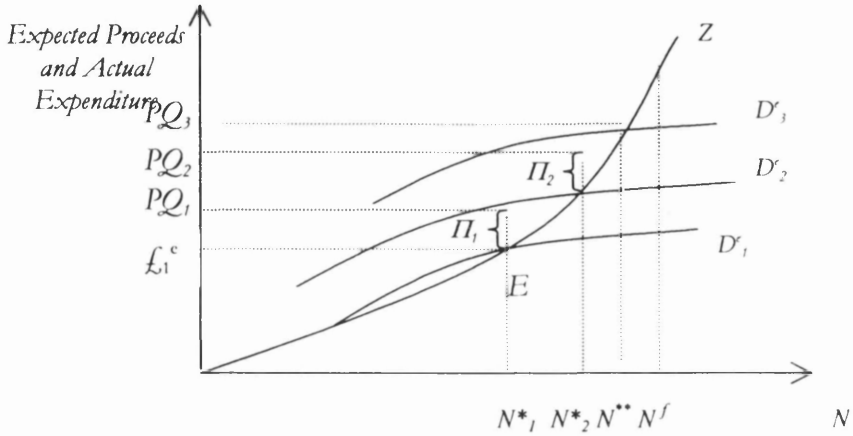
It is important to note that the expected aggregate demand function, when the discussion is made from the supply side perspective, is not a real one. It exists only on the entrepreneur's mind. Whether this expected aggregate demand will coincide with the actual aggregate demand is another matter. The key feature of this approach is that the level of employment and output will be defined based on this expected demand function. Therefore, for a particular production period the level of employment and output will be defined by the intersection between the demand and supply functions. In Keynes's words,

> the volume of employment is given by the point of intersection between the [expected] aggregate demand function and the aggregate supply function; for it is at this point that the entrepreneurs' expectation of profits will be maximised. The value of D at the point of the [expected] aggregate demand function, where it is intersected by the aggregate supply function, will be called *the effective demand*. . . .
>
> (Keynes *C.W.* VII: 25).

[138] For the determination of the aggregate supply curve it is not necessary O_n be the same for every firm, although it is necessary that the distribution of the production among firm be constant.

[139] In contrast with Keynes's notation (D), we are representing the Aggregate Demand Function as D^e as it is a function that refers to expected values. This representation follows Chick (1983).

Figure V. 1: The Determination of the Point of Effective Demand and the Path Towards the Short-Period Equilibrium



where: Π_t is unexpected (actual) profit at time t;

D'_t is the expected aggregate demand at time t;

P is the price;

Q is the quantity;

N^*_t is the level of employment at time t;

N^{**} is the level of employment at short-period equilibrium;

N^f is the level of full employment;

$£_t^e$ is the expected proceeds at time t.

Figure V.1 above shows the determination of the point of effective demand. The point E is the point of effective demand at time 1. Based on the entrepreneurs' expectations ($£_1^e$),[140] the amount of employment will be N_1^*. Given their expectations, there is no incentive for firms to expand employment further, as this would imply a reduction of the profits of firms. Moreover, there is no mechanism that can ensure that N_1^* will represent full employment (N^f), or that it will be achieved. As Chick points out,

> There is no presumption that N^* is a point of full employment; it can just as well be a level of employment which will not fully satisfy the demands for jobs. The mere existence of unemployment does not itself provide a reason for firms to expand output further. If demand as estimated is not adequate to compensate for the extra costs involved in producing more than the output which N^* labour-hours can produce with the existing capital equipment and employment, that is the end of the matter.
>
> (Chick 1983: 64)

[140] As we are following Tarshis's approach, where the supply price is derived on a value-added basis, we have decide to avoid traditional notations as *PQ* (price times quantity) *or Y* (national income) to represent expected proceeds.

Moreover, the definition of point E as the point of effective demand has been made taking into account two functions that are determined by the entrepreneurs. The whole process has been developed in the supply side of the economy.

It should be noticed that all the discussion about the point of effective demand is related to the production period. At the beginning of the production period, entrepreneurs form their expectations and, given the stock of capital, the amount of employment and output will be defined (N^*_1). If the actual level of expenditure at the end of the production period turns out to be greater (less) than expected, then unexpected profits (losses) will appear and a process of revision of expectations for the next production period takes place and a new point of effective demand will be achieved (N^*_2). The actual demand curve, which determines sales and profits, is not shown on the graph, to reduce complexity. This process continues until the point of effective demand coincides with the point of equilibrium defined by the actual aggregate demand, which in a short period is defined by a given amount of investment. In this situation we have what Keynes called short-period equilibrium (N^{**}). This process is shown in Figure V.1. As we have seen in Chapter IV, the definition of the short-period equilibrium was made assuming that short-period outcomes do not affect LPE. This is the way the short-period equilibrium can be achieved by a process of trial and error.

As Keynes's discussion abstracts from the subject of product or process innovation, he may portray the firm as producing the same type of product throughout its life. Moreover, all firms are represented as having the same capabilities, and all the working force is treated as being homogeneous in their skills. These assumptions combine to form the foundations of the production period, in which the firm produces a standard product throughout and therefore is only concerned with finding the right level of output. The effective homogeneity of labour and absence of tacit knowledge imply that the firm can hire and dismiss labour without any impact on its cost structure but only on the total amount of its costs. These features are the most important in the institutional set-up within which competition takes place in Keynes's framework.

V.1.2 Medium-Period Expectations and the Point of Effective Demand

V.1.2.1 A New Institutional Set-up

The approach to technical change that has been used in this dissertation has some implications for the institutional set-up upon which the expected aggregate demand and supply functions are based. The most important of these implications is the understanding of a firm as a repository of knowledge. The capabilities of the firm are the most important instrument in the competition and they will be determinant to the firm's performance. These capabilities incorporate the firm's knowledge and are determined, among other things, by the way the components of the firm (sectors and people) interact among each other. One special feature of the knowledge possessed by the firm is tacit knowledge.

An important implication of this approach is related to the firm's ease of hiring and dismissing labour force. A new employee does not automatically integrate with other components of the firm. He has to be trained and this represents a cost to the firm. Moreover, when an employee is dismissed, the firm gives up not only a unit of labour force, but also part of the firm's tacit knowledge. This latter cannot be replaced by the employment of another worker. As Nelson (1992: 178) points out, "modern production is a team activity, and team skills are involved in its undertakings". As he argues, the capabilities of the firm are not decomposable into the capabilities of the managers and individual workers, but involve teamwork that must be coordinated and practised. These features imply that there is a cost involved in the process of dismissing and hiring labour force. Even if the same person that is being dismissed is re-hired in the future some cost will be involved. As a consequence, a firm becomes much more cautious when dealing with its labour force, as individual and organisational skills acquired in the learning process demand time and are costly. Hence, these costs become an important element when a firm has to decide about its optimal level of employment.

A second important element to take into account is the fact that firms, according to the approach used here, can interfere with their own demand. As we are dealing with product innovation, firms know that there is a possibility for the increase of their market share due to the novelty of the product. Moreover, it is well recognised that every new product has a life cycle. The latter evolves along the following pattern. In the initial stages, the acceptance by the market of a new product increases at a very low rate. After some period, the sales of this new product show an increase in growing rates. Finally, when the product achieves its maturity, the sales start presenting decreasing rates of growth. Despite minor differences, this is a pattern that is observed among the majority of new products.

From what has been said, it is possible to argue that every firm expects that whenever it launches a new product into the market, the demand for its product will show oscillations similar to those predicted by the product cycle theory.

From a theoretical point of view, the above discussion sheds light on the question of whether or not, according to this approach, it is still acceptable to assume that a firm varies the amount of its labour force every time its production expectations are not validated. In other words, in the case of considering an institutional framework where the firm regards its capabilities as a valuable asset, is an invalidation of the firm's production expectations sufficient to alter the level of employment it offers?

The claim made here is a negative answer to the last question. To support this claim, let us summarise the foregoing discussion into two assumptions that emerge from the approach used here: (i) a firm knows that it will face a variable demand through the life cycle of its products and, (ii) a firm tries to keep its capabilities as long as possible. The immediate consequence of these assumptions is that firms will define the amount of labour force to hire according to expectations related to the whole life cycle of its products. The implication for the discussion of this chapter from these conclusions is that production-period expectations should be replaced by medium-period expectations in the enquiry of the point of effective demand. In other words, we are claiming that the level of employment at a specific point of time is defined by the medium-period expectations, given the total level of investment. Let us develop the argument.

To simplify the exposition we should add another assumption to the two described above: (iii) we assume that the volume of employment offered by a firm, during the life cycle of a product, is defined as if the expected demand for the new product will be equally distributed throughout the cycle. This means that at initial stages either a firm will produce more than will be demanded (increasing the stocks) or part of the work force will be used as spare capacity (they are paid but are not used in production). Thus, based on its medium–period (single-product) expectations, a firm will hire the amount of labour that it thinks will be necessary to match the entire demand for the new product. It will change this amount of employment only at the end of the life cycle of the new product.

It should be noticed that the use of medium-period expectations instead of short-period expectations relies implicitly on the assumption that the 'costs' involved in both the continuous revision of SPE and the process of hiring and dismissing labour force is higher than the 'costs' involved in keeping inventories or having idle labour force as it happens when MPE takes the place of SPE. However, it has to be made it clear that the costs involved in revisions of SPE are higher not only due to the amount of monetary resources that are committed but also, and most important, due the costs – non pecuniary but very real - of acquiring and losing tacit knowledge. This is not a monetary cost itself, but it will be reflected in the capabilities of the firm.

V.1.2.2 Medium-Period Supply and Demand Functions

The above discussion determines that the definitions of expected aggregate demand and aggregate supply functions should be modified to incorporate these new behavioural relations. A firm's demand function will be the expected demand during the product's period of life. As in Keynes's formulation, it will reflect the expectations about the aggregate consumption behaviour, taking as given the aggregate level of investment. The aggregation can be made as in Keynes's case. Let us call this new function *the medium-period (single-product) expected aggregate demand function.* It will be labelled $\overline{D^e}$. Turning to the supply price, we can see that it now has to do with the amount of proceeds that a firm expects to receive during the life cycle of a new product, which induces it to produce that new good. Formally the new supply price can be expressed as,

$$\sum_{t=1}^{L}[K_n / K_n - 1]\ MC_{nt}\overline{O}_n \qquad (5.3)$$

where: L is the number of production periods that a firm expects to go through during the lifetime of its product;

$\overline{O}_n$ is the average level of production related to the whole life cycle of the product.

Taking all firms together, the new medium-period aggregate supply function ($\overline{Z}$) will be expressed as

$$\sum_{t=1}^{L}\sum_{n=1}^{M}\left[\frac{K_{nt}}{K_{nt}-1}MC_{nt}\overline{O_{nt}}\right] \qquad (5.4)$$

It will be "the proceeds which will just make it worth the while of entrepreneurs to employ" a certain number of men during the medium period.

The point of effective demand is the intersection between these two curves and will determine the volume of employment that will be offered at any point in time. It is important to note that, despite the fact that both curves have been constructed in relation to medium-period expectations, they define the amount of employment at each period of production encompassed by those expectations.

If we compare Keynes's definition of the point of effective demand, the incorporation of technical change implies a similar process of determination of employment. Despite being related to different kinds of expectations, the medium-period expected aggregate demand and supply function present the same shape as Keynes's definition. However, there are two main differences: the dynamics of the process (which will be examined in the next section) and the length of time involved. As a firm will change its own level of employment only at the end of the medium period, the level of employment at any moment in time is more stable than in Keynes's approach. This conclusion holds even when there is a mismatch between expected demand and actual level of expenditure in the production period.

Therefore, at this point we can stress the first major consequence for the discussion of effective demand from the introduction of the assumption of continuous technical change. The approach to technical change that has been used in this dissertation implies a new institutional set-up. Due to the latter, it is necessary to use MPE instead of SPE as the expectations that, together with LPE, determine the level of employment. At any specific point of time, both the process and the period of time involved on the formation of MPE determine a level of employment that will be more stable than the level of employment in Keynes's approach. This conclusion holds whether or not the system is in equilibrium, i.e. whether or not the state of expectations are corrected. It is interesting to note that, contrary to conventional understanding, at a first glance, the introduction of the assumption of continuous technological change decreases the volatility of the economic system. This can only happen because of the particular understanding of technical change that has been assumed in this thesis.

V.1.2.3 Point of Effective Demand and the Formation of Medium-Period Expectations

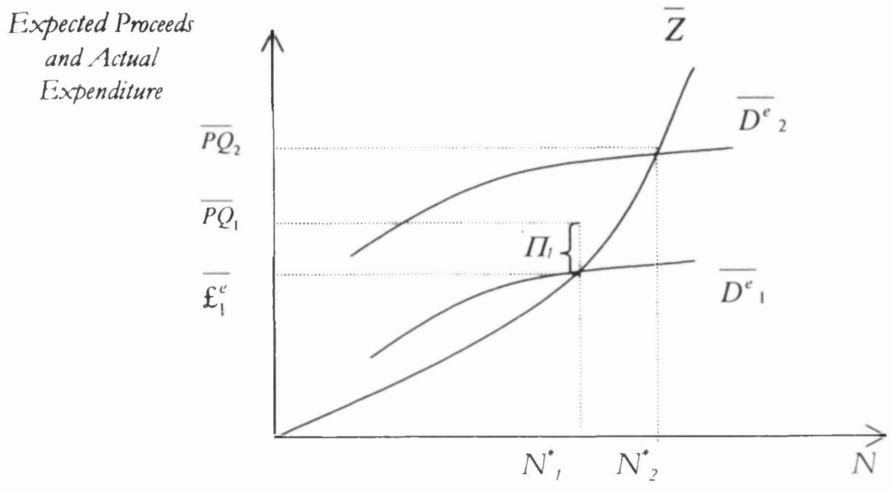
To analyse the behaviour of the medium-period aggregate functions we have to incorporate into the discussion the analysis that was made in Chapter IV. Two important conclusions emerge from that chapter. First, it has been shown that the formation of present single-product expectations is related to the validation of previous expectations. However, due to the possibility of product innovation, there is not an one-to-one relationship between the confirmation of previous and the formation of present expectations. Second, it has been shown that the fulfilment of MPE will have some impact on LPE. To be more didactical, let us analyse separately both conclusions. In this section we will regard the level of investment as given and exogenous, meaning that we will not consider the interactions between MPE and LPE. In the following section the latter assumption will be relinquished.

Figure V.2 below shows the adjustment process due to a positive mismatch between $\overline{D^e}_1$ and $\overline{PQ}_1$. At time 1, firms have already formed their product expectations and based on these they generate the medium-period expected aggregate demand $\overline{D^e}_1$. At the end of this medium period the actual level of expenditure ($\overline{PQ}_1$) is revealed to be higher than previously expected ($\overline{£_1^e}$). This implies an increase in the weight of argument of the firms and so expectations for the next single-product period are increased. In Figure V.2 this is shown through the shift from $\overline{D^e}_1$ to $\overline{D^e}_2$. This means that the level of employment offered during the life cycle of the next product will be increased (from N^*_1 to N^*_2).[141]

The discussion will be a little different when the actual level of expenditure turns out to be lower than previously assumed by the firms. As Figure V.3 below shows, there is a negative mismatch between the expectations of the entrepreneurs ($\overline{£_1^e}$) and the actual level of expenditure at the end of period 1 ($\overline{PQ}_1$). According to the argument that was developed in Chapter IV, this situation will not necessarily means a negative revision of the expectations for the next single-product period. As the next product has some kind of novelty, there is always a possibility of the firms positively affecting their own demand. This allows them to avoid a reduction in their levels of employment. In this case, the medium-period expected aggregate demand function for the next period ($\overline{D^e}_2$) will remain the same as the previous one ($\overline{D^e}_1$).

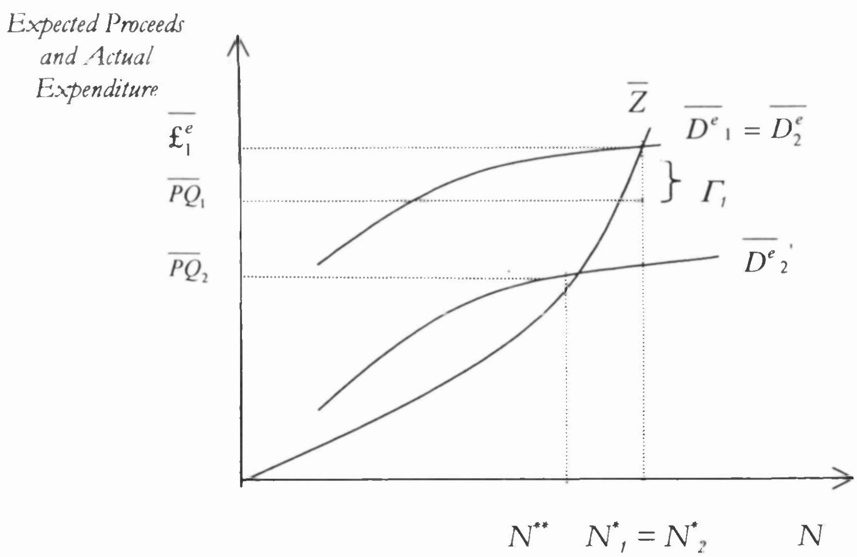
[141] Recall that by defining the firm as a repository of knowledge, we are assuming that the knowledge acquired in the introduction and commercialisation of former products provides useful guidance to the introduction and commercialisation of new products. The development of the technological trajectory also underpins the confidence of firms in the success or not of their new products.

Figure V. 2: Adjustment of $\overline{D^e}_1$ due to a Positive Mismatch



where: $\overline{£^e_1}$ is the expected proceeds at time t.

Figure V. 3: Adjustment of $\overline{D^e}_1$ due to a Negative Mismatch



where: Γ_t is the unexpected loss at time t.

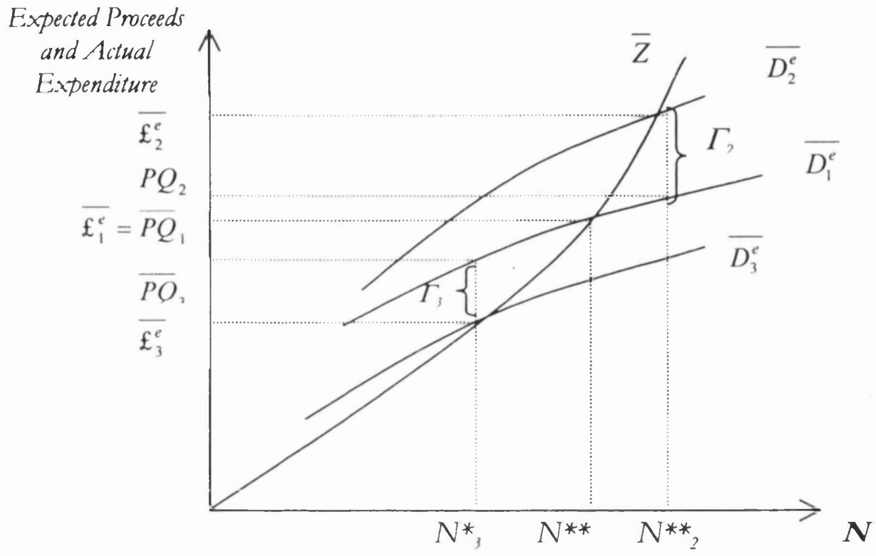
However, if the mismatch is large enough, the impact on the weight of argument related to the next single-product expectation can decrease in such a way that $\overline{D^{e'}}_2$ is defined with lower expectations than $\overline{D^e}_1$. We can argue that there will be a threshold value for the loss that will be acceptable to the firm. Any losses less than this threshold will not generate a negative revision of expectations. The value of this threshold depends on many institutional aspects, such as the degree of competition, the structure of product and financial markets, the technological trajectory and even some conventional behaviour. It should be noticed that a continuous disappointment of expectations will have some impact on the development of the technological trajectory and its weight, which will entail a reduction of the threshold mark. This means that the stability of the level of employment cannot be sustained by continuous disappointment of expectations.

Finally, an interesting point to consider is what happens when the medium-period expectations are fulfilled. In the discussion set out by Keynes, who has in mind production expectations about a standard product, the short-period equilibrium is established when short-period expectations are fulfilled and there is no incentive to the entrepreneurs to change their expectations. In the case of medium-period expectations, however, their very process of formation generates a mechanism that works against the system achieving a stable equilibrium when there is a validation of expectations. This situation is described in the Figure V.4 below. The fulfilment of previous expectations works to increase the weight of argument for the next period-expectations. As we have shown in foregoing chapters, positive changes in the weight works to increase the expectations about the proceeds from the next product, and so, the next single-product expected aggregate demand function will be shifted upwards ($\overline{D^e}_1$ to $\overline{D^e}_2$).

However, as at this stage we are assuming that the level of investment is given, the medium-period expectation in the next period will be disappointed (Γ_2). If the difference is very large, the expectation at the end of time 2 will be revised, shifting downwards the expected aggregate demand function ($\overline{D^e}_3$).

What is important to note is that there will be a benchmark for the level of employment defined by the level of investment (N**), i.e. as, for the moment, MPE are not affecting LPE there is a level of employment, defined by the level of investment, around which the actual level of employment will be moving. The point is that there is an element of

Figure V. 4: Adjustment of $\overline{D^e}$ due to a Fulfilment of Expectations



instability that is generated by the way MPE are formed. A comparison with Keynes will be helpful.

The instability in Keynes happens when either SPE and LPE are interrelated or when LPE is allowed to shift exogenously or both. In the approach used here, even when MPE and LPE are not related and LPE remains constant, which, as we have seen[142], are unrealistic assumptions, the instability will happen due to the particular way technical change has been characterised. This characterisation implies the incorporation into the analysis of the TT and the development of its weight plus a special form of competition in which the introduction of an innovation is a key element.

These are the factors that make the process of formation of MPE distinctive from SPE determining behavioural assumptions on the formation of the medium-period expected aggregate demand curve that will make a stable equilibrium position unattainable. The system will become unstable, moving around the benchmark level of employment. This implies that a new theoretical definition is needed for the term unemployment equilibrium.

The understanding that it is possible for a situation to exist where there is no mechanism that automatically generates full employment remains. If the term 'equilibrium' is used to represent this absence of automatic mechanism, so the term unemployment equilibrium can be used to incorporate the new understanding to the

[142] See footnote 97 in Chapter IV.

point of effective demand. Notwithstanding, the expression 'unstable' should be added to capture the fact that there will not be a unique level of unemployment equilibrium, but a domain of levels of unemployment moving around the quantity determined by the amount of investment.

Summing up, we can argue that the inclusion of single-product expectations into the framework brings two distinctive features to the discussion of the point of effective demand. The first one is a particular set of behavioural assumptions in relation to the validation of previous medium-period expectations. These behavioural assumptions can be synthesised as follows:

$$\overline{£_t^e} = \overline{PQ_{t-1}} + v_t \qquad (5.5)$$

where $\overline{£_t^e}$ is the medium-period expected proceeds at time t ;

$\overline{PQ_{t-1}}$ is the actual medium-period level of expenditure at time t-1;

v_t is the "shift parameter" which captures the impact on present medium-period expected aggregate demand function due to the validation or not of previous expectations.

The evolution of v_t may be described as follows:

$$v_t \begin{cases} > 0 \text{ if } \overline{PQ_{t-1}} - \overline{£_{t-1}^e} \geq 0; \\ = 0 \text{ if } 0 > \overline{PQ_{t-1}} - \overline{£_{t-1}^e} \geq \rho; \\ < 0 \text{ if } \overline{PQ_{t-1}} - \overline{£_{t-1}^e} < \rho. \end{cases} \qquad (5.6)$$

where ρ is the threshold loss that is acceptable to the firm, without reversing its present expectations in relation to the previous one.

This pattern of behaviour determines the second special feature of medium-period analysis, that is the instability of unemployment equilibrium.

V.2 The Expenditure Dimension of Effective Demand

So far, our discussion in this chapter has emphasised the supply side of the effective demand, i.e., the level of output being defined by the expectations of entrepreneurs. However, as one can observe from the discussion above, the final level of unstable equilibrium is bounded by the actual level of expenditure. This means that despite the behaviour of the expectations, the final configuration is constrained by the level of expenditure. This conclusion is similar to Keynes's argument when he shows that the fulfilment of production expectations are unimportant for the determination of final level of equilibrium, which is determined by the autonomous level of investment. According to Amadeo,

> ...as he worked towards the final version of the work Keynes gradually abandoned dynamic analysis and substituted expected for realized functions and magnitudes; in particular, the notions of expected sale proceeds and effective demand were gradually replaced by the notions of (actual) aggregate demand function and income, respectively.
>
> (Amadeo 1989: 107)

It should be noticed that Keynes's movement from the supply to the expenditure dimension of effective demand can only be made due the fact that in Keynes's approach there exists no relation between SPE and LPE. As the fulfilment or not of SPE does not interfere with the formation of LPE, the process of adjustment of SPE to the actual outcomes becomes irrelevant for the definition of the equilibrium level of employment. However, as we have shown in Chapter IV, the introduction of continuous technical change demands the formation of LPE be taken into account whether MPE were validated or not.[143]

Therefore, the point to be addressed now refers to the components of (actual) aggregate demand, that is consumption and investment taking into account the assumption of continuous technical change. The scrutiny that has been made shows that the introduction of technical change does not alter Keynes's approach to consumption, and so, it will continue to be considered as a function of the level of income. However, the same is not true for investment. To analyse this problem, let us first inquiry into the determinants of investment in Keynes's approach.

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[143] Indeed, Keynes's claim about the independence between SPE and LPE is also sustained by his conception of technical change. As we have seen, Keynes completely agrees with Schumpeter (Keynes, *C.W.* VI: 85-86), who considers technical change completely exogenous (Schumpeter 1934).

V.2.1 The investment decision: the Keynes approach

Keynes's analysis of the investment decision is set out in Chapters 11 and 12 of *G.T.*. In the former chapter, he analyses the concept of Marginal Efficiency of Capital (*mec*) and in the latter he explains long-period expectations. The two chapters must be analysed together to maintain the correct understanding of Keynes's theory.

In Chapter 11, as a first step in the construction of a theory of investment, the amount of investment at any period of time is related to the marginal efficiency of capital, *d*, and the interest rate, *r*. That is:

$$I = f(r, d) \qquad (5.7)$$

Keynes defines *mec* as the rate of discount that makes the prospective returns obtained from the selling of the outputs from investment (prospective yield) equal to the supply-price (P_k) of a capital good.

The *mec* will be a rate of discount, *d*, "which will equate P_k with the present value of the profit stream" (Chick, 1983: 120):

$$P_k = \sum_{t=1}^{n} \pi_t (1+d)^{-t} \qquad (5.9)$$

where : π_t is the expected profit at time t.

In other words, the marginal efficiency of capital is equal to the solution of (5.9) for *d*.

The value of the *mec* is then compared with the current interest rate.

> If [*mec*] is greater than the rate of interest, the return from investing in the machine is greater than the return from lending out an equivalent sum at the current rate of interest, so the producer decides in favour of the machine.
>
> (Chick 1983: 120-121)

The concept of marginal efficiency of capital has a central role in Keynes's theory of investment. It is the connection between the profits expected to accrue in the future and the cost that has to be handled in the present. Therefore the investment decision has the key function of linking the present to the future.

The discussion of the long-term expectations set out in Chapter 12 completes the understanding of the investment decision, and the introduction of the concept of *animal spirits* into the framework of this kind of decision renders Keynes's approach more comprehensive and realistic. In Chick's words (1983: 121), "it was Keynes's view that *animal spirits* substantially dominated the investment decision," and the influence of the *mec* on investment "is merely that *part* of the decision which is amenable to economic analysis."[144]

Chapter 12 is certainly one of the most important chapters of the whole *GT*. A thorough reading of it reveals to the reader the most important concepts in Keynes's work. In that chapter, Keynes discusses how long-period expectations are formed. As we have seen in the discussion of the *mec*, when an investor has to decide how much to invest in a new capital good, he makes assumptions about its prospective yields. However, the distinctive element of Keynes's analysis is the basis on which these expectations are grounded. Due to uncertainty, long-term expectations are formed based on convention, qualitative judgement and intuition. These non-formalised elements together with the elements discussed in Chapter 11 provide the basis for action in Keynes's theory.

V.2.2 Investment Decision with Continuous Technical Change

In Chapter IV, we saw that the introduction of product and process innovations into the analysis implies that there are two elements that have not been taken into account in the foregoing approach to the investment decision: (i) the interaction between MPE and LPE and, (ii) the impact on the formation of the *mec* due to the development of a technological trajectory in the capital goods sector. In what follows we will discuss the implications of these elements for the determination of the level of employment.

Let us recall first an important argument discussed in the previous chapter. The fact that at any point in time every firm is developing a technological trajectory creates a dual consequence for the formation of LPE: first, it becomes more difficult to make the calculation of the prospective yields of a new capital good, as this good will produce different types of product during its life; and, second, it makes it easier to have greater confidence in the calculation of the prospective yields of the immediate product that will be produced with the new capital good. The second impact, as we have seen, will have a great influence on the decision about the acquisition of the new capital good.

Regarding process innovation, the discussion in the previous chapter showed that the development of the capital goods technological trajectory (V_c hereafter),[145] is itself an

[144] For a further discussion on animal spirits and rationality see Dow and Dow (1985).
[145] The symbol V_c has been chosen to represent the development of the capital goods technological trajectory because this development can be captured by the evolution of the weight of argument of that specific TT.

element that induces the acquisition of a new equipment. The latter proposition will be true even in situations where the demand for the consumer sector is stable.

One should note that the influence of both the MPE and the capital goods TT on LPE will be expressed in the expected quasi-rents that enter into the calculation of the *mec*. The MPE will affect the expected demand of the firm and V_c will influence the cost of production. An important distinction between these elements is that one (MPE) is endogenous to the dynamics of the economic system, and the other (V_c) is exogenous to the consumer goods sector.

Therefore, the amount of investment at any period of time will be determined according the equation 5.9,

$$I_t = f\left(r^*, d_t\left(\delta_t, V_{ct}, \varsigma_t, \chi_t\right)\right) \qquad (5.9)$$

where: r^* is the interest rate, which, for our discussion is taken as given and constant;

d_t is the marginal efficiency of capital at time t;

δ_t is the impact on *mec* due to the validation or not of MPE at time t;

V_{ct} is the impact on *mec* due to the evolution of the capital goods TT at time t;

ς_t is the impact on the formation of LPE due to the *Convention* that exists at time t; and

χ_t is animal spirits.

As the *mec* can vary according to four influences, we decide to make these sources explicit in order to facilitate the identification of the factors that affect the calculation of the *mec*.

The parameter δ_t will be defined according to the following behavioural rules:

$$\delta_t = \begin{cases} \delta_{t-1} + \varphi_t & \text{if} \quad \sum_{i=1}^{t-1} \gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^e_{t=i}}\right) \geq 0, \quad 0 > \gamma > 1; \\ \delta_{t-1} - \varphi_t & \text{if} \quad \sum_{i=1}^{t-1} \gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^e_{t=i}}\right) < 0 \end{cases} \qquad (5.10).$$

where $\overline{PQ_t}$ is the actual level of expenditure at period t;

$\overline{£^e_t}$ is the expected proceeds associated with single-product expectations at time t;

φ_t is a shift parameter.[146]

The expression $\sum_{i=1}^{t-1}\gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^{e}_{t=i}}\right)$ captures the evolution of one component (market response) of the weight of argument of a firm's TT. The parameter γ, being greater than zero and less than one, guarantees that the validation of the last single-product expectation will have a bigger impact on the evolution of the parameter δ_t than the expectations about products that had been developed at the beginning of the firm's technological trajectory.

Equation 5.9 elaborates on the discussion made in Chapter IV about the partial endogeneity of investment decisions. Three of the four factors affecting the *mec* are exogenous to the firm: the evolution of the technological trajectory of the capital goods sector (ν_{ct}); the conventions about the LPE (ς_t) and the animal spirits (χ_t). Only the fourth, δ_t, is endogenous. It should be noticed that interaction between MPE and LPE implied by this exogeneity is different from the interaction between SPE and LPE proposed by some models that use the 'accelerator principle', as example Harrod (1939). In the latter expected future outcomes are the simple replication of actual outcomes. It is like as LPE are formed only taking into account the past or the present. In our approach the interaction between MPE and LPE is more elaborated. The validation or not of previous MPE affects the weight of the firm's TT, which in turn, affects the formation of LPE. The passage from previous medium-period outcomes and the formation of LPE carries a transformational mechanism that avoids the mere replication of these previous outcomes. Moreover, the formation of LPE continues to be liable to exogenous influences.[147]

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[146] $\varphi_t \sim \left(\mu_{\varphi_t}, \sigma^2_{\varphi_t}\right)$, $\varphi_t > 0$. This specification of the shift parameter follows Setterfield (1999: 490-1). Accordingly, φ_t can be considered to be a convention, meaning a normal response to the evolution of the firm's TT. Being a conventional value, it is subject to variations over time, implying that its moments are time variant:

> This is important, because it means that the characteristics of [φ_t] at any point in time cannot be deduced from the characteristics of the time series of past observations of [φ_t]. Agents cannot, therefore, learn from experience about the structure of [φ_t] in such a way that allows them to forecast its future values with absolute confidence based on the calculation of mathematical expectations (Setterfield, 1999: 491).

[147] Shackle (1967) has also criticised the fact that Harrod does not take into account these exogenous factors. In his words,

> **By sticking to the observable and measurable external aspect of things which *have happened*, by accepting as real only the *ex-post*, we turn our eyes away from that disorder and keep them fixed on what become, at any rate, a single narrative instead of a multiplicity of conjectures.**
>
> **(Shackle 1967:258)**

This means that the analysis that has been made here does not invalidate Keynes's analysis. It only claims that there is an element, derived from the assumption of continuous technical change, that works partially to endogenise the formation of the LPE. The above discussion gives rise to two important points: the inducement to invest due to the development of the capital goods TT; and the extent to which the analysis of the point of effective demand can be made assuming a given volume of investment. Let us further develop these points.

V.2.2.1 Technological Development in the Capital Goods Sector

Two elements should be addressed in relation to the technological development in the capital goods sector. The first one refers to the inducement that generates an increase in the level of investment – and thus an increase in the level of income – that is not related to expected change in demand. Everything else remaining constant, the assumption of continuous technical change generates, *per se*, a level of investment which is greater than the level which is supposed to occur if this assumption is not taken into account, as in Keynes's approach.

The second aspect to be analysed is that, despite being exogenous from the point of view of the firm, the development of the TT of the capital goods sector is endogenous to the functioning of the whole economic system. Being more precise, the speed of technological development in the capital goods sector is directly related to the level of demand in this sector, which in a closed economy, is related to the aggregate level of investment. Recall that in Chapter IV we briefly discussed the importance of the level of aggregate demand in the consumer sector for the development of the capital goods technological trajectory. The main argument was related to the degree of specialization that is allowed by the size of the aggregate demand. It was argued that economies with continuously high levels of demand for domestically produced capital goods will have higher levels of specialization in this sector, which in turn boosts the productivity of the whole economy. This process can be captured by the study of the V_{ct}, as it is this variable that captures the evolution of the technological trajectory in the capital goods sector. If the TT has been successfully developed then V_{ct} will rise continuously, affecting positively the level of investment of the consumer sector. In the reverse

By 'disorder' Shackle means the fact that decisions are made based on uncoordinated and uncoordinable thoughts based upon insufficient evidence, which interpretation will produce incongruent expectations.

situation, the impact on the productivity of the economy will be diminished. Algebraically we have

$$V_{ct} = \beta_t + \vartheta \sum_{i=1}^{t} \theta^i I_i, \quad 0 < \theta < 1, \text{ and } \vartheta > 0 \qquad (5.11)$$

where: V_{ct} is the weight of argument of the TT of the capital goods sector at time t;

β_t is the parameter that captures the evolution of the scientific knowledge outside the capital goods sector at time t;

ϑ is the parameter that captures the influence of the aggregate level of investment (I_i) on the development of the weight.

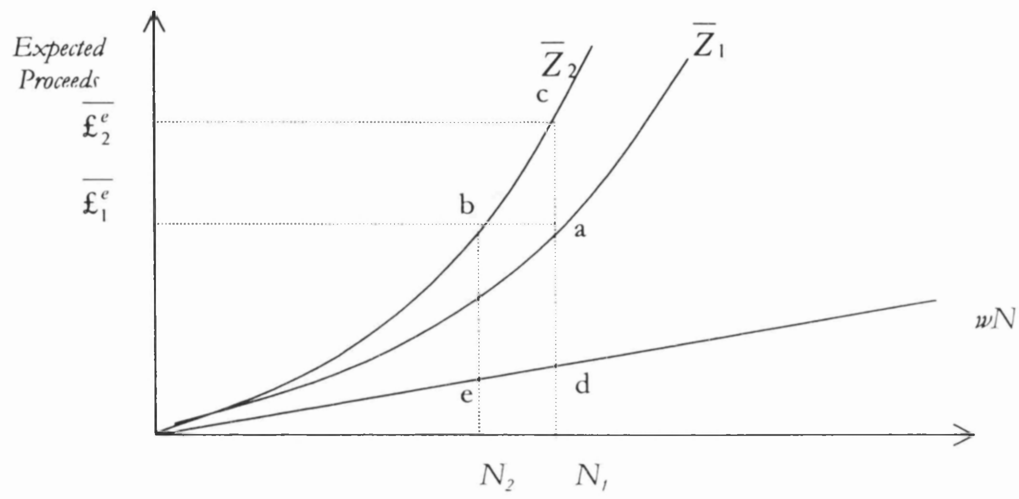
As θ^i is greater than zero and less than one, the latest level of aggregate investment will have a greater impact on the evolution of the weight than previous ones.

In the present formulation there is a cumulative causation effect on the investment decision. A higher level of aggregate investment speeds up the consequent evolution of the TT in the capital goods sector. This generates an inducement to further investment as the firm can improve its own position in the market with better equipment. This process sheds light on the relevance for policy of the technological development in the capital goods sector, as it affects the general performance of the whole economy. Investment is important not only to increase effective demand, but also to create conditions to endogenise further investment and so to sustain a higher level of effective demand through the influence of the generation of technical change on the investment decision. Moreover, when the acquisition of the capital good is made abroad, what is being exported is not only some amount of employment, but also the conditions for a sustainable growth.

It is interesting to note that despite being partially endogenised through the expression $\vartheta \sum_{i=1}^{t} \theta^i I_i$, the evolution of weight of the TT of the capital goods sector will depend on the value of the parameter ϑ. It is greater than zero as the level of aggregate investment has a direct impact on the evolution of the weight. However, whether it will be greater or less than one will depend on institutional aspects, such as the stage of development of the TT, the configuration of the national system of innovation[148] among other things. This means that, for the moment, the only thing can be said is that ϑ is greater than zero. For each particular situation the institutional set-up will determine its final value.

[148] For a discussion about national system of innovation see Nelson (1993) and Edquist (1997).

Figure V. 5: Shift in Supply Curve due to Evolution of the Capital Goods Technological Trajectory



The consequences of technical change in the capital goods sector for the consumer goods sector can be analysed with the help of Figure V.5 above.

Any point in the $\overline{Z}_t$ curve represents the total expected proceeds (value added) that motivate a firm to hire a specific amount of labour force. In Figure V.5, $\overline{£}^{e}_{1}$ is the expected proceeds needed by the economy to employ N_1 workers. Moreover, for every point of $\overline{Z}$ there exists an unique income distribution (Chick 1983: 96). This feature is represented in Figure V.5 with the help of the wage bill curve *wN*, where *w* is exogenously determined by bargaining or any other wage settlement. With the initial supply curve $\overline{Z}_1$ the value added corresponds to the distance aN_1, with the wage share being equal to dN_1 and the distance *ad* being the gross profit (residual) share. A change in the volume of investment due to the development of the technological trajectory in the capital goods sector (V_{ct}), will shift the position of $\overline{Z}_t$ to the left.

As Weintraub points out, in the case of labour-saving innovations,

> ... if for the same amount of output more equipment and less labour is used, for a given amount of employment the stock of capital will be larger and presumably the marginal product of labour will be greater. Manifestly, these changes in productive techniques will not be undertaken unless the capital share can be widened. The effect of labour-saving inventions, therefore, is to lift *Z* relative to [*wN*], to the *relative* income detriment of labour at each employment position.
>
> (Weintraub 1958: 83)

This movement is depicted in Figure V.5 through the shift of $\overline{Z}_1$ to $\overline{Z}_2$. Due to the technological development of the new equipment, the same amount of expected proceeds (value added) can be obtained with a lower level of labour force, N_2. Moreover, with the new technology the gross profit share of the firm when employing N_2 workers (*be*) is greater than the previous one (*ad*). A firm will continue to demand the same amount of workers as before, only if the introduction of the technical change comes together with a change on the expectations of proceeds.

If the innovation is capital-saving the medium-period supply curve will shift to the right as less capital is using with the same amount of labour. With this new combination the same amount of expected proceeds now can stimulate a firm to hire more for less capital is using. However, as this kind of innovation has been very unusual we will concentrate the analysis only on labour-saving innovation.

V.2.2.2 The interaction between MPE and LPE: constantly evolving expectations

According to equation 5.10 the interaction between MPE and LPE is determined by the behaviour of the parameter δ_t. According to the formulation presented here the parameter δ_t will be in constant modification. The reason for this is related to the type of decision we are dealing with and to the expression $\sum_{i=1}^{t-1} \gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^e_{t=i}}\right)$. The latter captures the development of the whole TT of the firm and will influence investment decision (I). When the expression $\sum_{i=1}^{t-1} \gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^e_{t=i}}\right)$ is equal to or greater than zero, the TT is successful. This increases the confidence related to the future development of the TT that will be undertaken with the new capital good that is being bought. As the confidence increases the volume of investment goes in the same direction.

However, the confidence in future development of the TT will be eroded if the actual evolution of the TT is a failure ($\sum_{i=1}^{t-1} \gamma^{t-i}\left(\overline{PQ_{t=i}} - \overline{£^e_{t=i}}\right) < 0$). It should be noticed that the behavioural assumptions related to the investment decision do not allow the entrepreneurs to take as acceptable a threshold loss in the development of the TT as is the case with the formation of MPE. The explanation for this is related to the different amount of money and time involved in each kind of expectations.

What is important to note is that the assumption of continuous technical change introduces an element of endogeneity in the process of investment decision, and the analysis of the effective demand should take this into account. In other words, the partial endogeneity implies that a model of constant evolving expectations must be used in the analysis of effective demand.

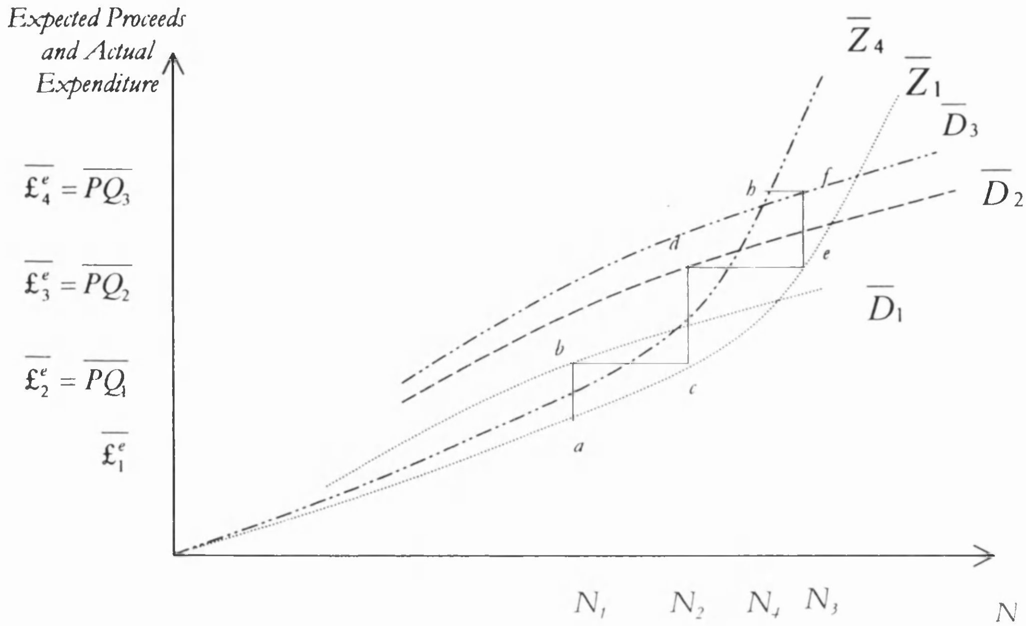
Let us re-examine the discussion of effective demand, but now assuming both the impact of the development of capital good TT and the partial endogeneity of LPE due to single-product expectations. Figure V.6 below will help us. As we are dealing with the expenditure side of the principle of effective demand, we depicted in the figure the actual level of expenditure ($\overline{D}_1$) instead of the expected value ($\overline{D^e}_1$). Moreover, to facilitate the analysis let us make two additional assumptions: (i) new equipment with new technology is available every time a firm decides to invest (i.e., the cost structure of the economy varies every time the level of investment changes); and (ii) there will be a temporal gap between the investment decision and the beginning of the operation of the new equipment. For the purpose of our example this gap will be of two units of time.

At time 1 the two actual aggregate curves are $\overline{D}_1$ and $\overline{Z}_1$. Suppose that firms have an expected proceeds of $\overline{£_1^e}$, hiring altogether N_1 (point *a*). However, for this level of employment the actual level of expenditure will be $\overline{PQ}_1$, implying an excess of proceeds in the amount of the distance between $\overline{£_1^e}$ and $\overline{PQ_1}$ (*ab*). These unexpected profits will induce firms to expand their production and their level of investment according to equation (5.10).

Thus, at time 2 there will be an upward shift of the demand curve ($\overline{D}_1$ to $\overline{D}_2$). Assuming that firms have taken the previous level of expenditure as the expected demand at time 2, they will employ N_2 workers (point *c*).

According to the scenario described in Figure V.6, at the end of time 2 another positive mismatch between expected and actual aggregate demand will happen (points *c* and *d* respectively) implying another increase in the levels of output and investment at time 3 (shift of $\overline{D}_2$ to $\overline{D}_3$), giving rise to another unexpected profits (*ef*).

Figure V. 6: Effective Demand and Constantly Evolving Expectations System



However, now (at time 3) the investment that had been induced by the unexpected profits at time 1 becomes operative. This means that at time 4 not only does a new demand curve appears but also a new supply curve ($\overline{Z}_4$).[149] Despite the realisation of unexpected profits at the end of time 3 (*ef*), the level of employment will be reduced at the beginning of time 4, as the same expected proceeds at the end of time 4 (which are equal to the actual expenditure at the end of time 3) can be obtained with a smaller amount of labour force.

What is important to be noticed is that the technological development in the capital goods sector generates an improvement in the techniques that causes a reduction in the level of employment that compensates for the positive effects due to an increase on the level of investment. In Figure V.6 this can be visualised by the difference between points *h* and *f*.

What will happen at the end of time 4 will depend on the behaviour of aggregate demand. Recall that at the end of time 3 an unexpected profit was realized and this improved LPE. If this improvement will be sufficient to compensate the reduction of the level of employment due to the new supply curve, an unexpected profit will occur again. If not, there will be a negative revision of expectations at the end of time 4 due

[149] Time 4 is not depicted in Figure V.6 to avoid an overload on the graph.

to unexpected losses, implying a subsequent reduction in the level of investment, thereby shifting $\overline{D}_t$ downwards. The difference now is that, as the effective demand is decreasing, the impact on the development of the technological trajectory in the capital goods sector will be negative. This means that the shift in the aggregate supply curve when the level of investment is decreasing will be smaller than when the level of effective demand is increasing.

Therefore, the system becomes completely unstable and the key aspect to the path of the economy is the comparison between the increase in the productivity and the variations of the level of investment due to the validation of the technological trajectory of the economy. The system will be in disequilibrium – meaning that there are some mechanisms that stimulate agents to change their positions – even if the expected demand coincides with the actual demand at the beginning of the process (see equation 5.10).

What is important to note is that in a model with continuous technical change and with investment being partially endogenised there is no mechanism that guarantees that an equilibrium will be obtained. This is true even when there is a fulfilment of expectations due to both the way MPE are formed and to the partial endogenisation of LPE.

Moreover, the system possesses some elements whose behaviour cannot be completely determined by the past performance of the economy. Although one of them, the evolution of the weight of the TT of capital goods sector, has been endogenised, it is impossible to control the movement of the aggregate supply that it generates as there is no well defined relationship between the aggregate investment and the generation of a process innovation. As we have seen, the only thing that it is possible to say is that this relationship is positive. However, due to the characteristic of the R&D activity it is impossible to know precisely how much investment is necessary to produce an innovation. The two exogenous elements of LPE, animal spirits and conventions, will affect the behaviour of the medium-period aggregate demand.

Therefore, endogenous and exogenous factors work together to prevent the system reaching a position where there is no incentive for the agents to change their expectations. In other words, the system will be constantly out of equilibrium due to the constant evolvement of the expectations.

V.3 Conclusion

Summing up, we can argue that an evolving expectations model, where LPE are partially endogenised, is the only one that can capture all effects that the assumption of continuous technical change brings into the discussion of the effective demand. As we have shown, product innovations will affect the behaviour of the aggregate demand function due to the particular process of formation of MPE. In its own turn, process innovation will affect both aggregate supply and demand functions. However, in both types of innovations, their consequences for the determination of the level of employment have a similar origin, that is, the understanding that every economy, in a broad sense, is developing a technological trajectory. The latter, through the role of weight of argument, affects the process of formation of MPE and LPE in a particular way, implying a process of determination of employment very distinctive from that originally formulated by Keynes. We think that the main new feature revealed by the investigation carried out in this dissertation is the partial endogenisation of the formation of the LPE.

This partial endogenisation of the LPE should be stressed and well understood. Among the elements that affect the investment decision two (the previous development of the TT in both consumer and capital goods sectors) are endogenised, the others are exogenous. The exogeneity of conventions and animal spirits, for example, implies that the path of an economy can be different from what has been discussed if there is a sudden and great change in these factors. The claim here is that the variations in the level of investment and, as a consequence, in the effective demand, can be partially explained through the interactions between MPE and LPE. This is true despite the fact that this interaction generates an instability. In other words, the introduction of continuous technical change gives rise to two complementary phenomena: it partially endogenises the variation of the level of investment and it transforms the system into an evolving expectations model, where the shifts are not completely exogenous but part of the evolution of the system.

CONCLUSION

As we have said in the Introduction, this dissertation should be viewed as an initial exercise in trying to incorporate some of the richness of the Evolutionary and Institutional approach to technical change into the macroeconomic framework of Post-Keynesians. The development of this task has been carried out according to the following steps. In Chapter I we have discussed the approach to technical change in accordance with three schools of thought: Keynes/Post-Keynesians; Neoclassicals and Neo–Schumpeterian/Institutionalist. The analyses brought us to the conclusion that the latter approach provides an insightful contribution to the understanding of technical change, as it manages to capture essential features of this phenomenon, usually overlooked by the other two schools of thought. These features, such as cumulativeness, learning, tacitness of knowledge, technological trajectory and technological paradigm, allow the characterisation of technical change as an ordered pattern of change based in an invariant, although augmenting, knowledge base. Sometimes this process can be intertwined by major discontinuities which produce changes in both the source of knowledge and in the direction of change.

Moreover, the EI approach gives a great deal of attention to a very special feature of the innovative activity, that is, its surrounding uncertainty. This uncertainty is defined as true (strong) in the same sense as Knight/Keynes, meaning that it is considered as not numerically measurable. Moreover, the EI approach also acknowledges that there exist different degrees of uncertainty related to different kinds of innovations. However, this latter claim has not been completely theorised by this school of thought. The alleged sources of uncertainty – incompleteness of the information set and knowledge incompleteness – and the general agreement with Knight/Keynes distinction between risk and uncertainty are not, *per se*, sufficient to sustain theoretically the claim that there exist different degrees of uncertainty. Thus, despite having, in our view, the most comprehensive understanding of technical change, the EI approach lacks a definition of uncertainty capable of supporting their case of different degrees of uncertainty attached to different kinds of innovations.

At this point we built a bridge between the EI and Keynes/Post-Keynesian approaches. As Post-Keynesian, are well known by the relevance they give to strong uncertainty in economic analyses we were led to cross the bridge to the Post-Keynesian side and temporarily leave the discussion of technical change.

The economic literature is replete with papers and quotations from Keynes and Post-Keynesians arguing that traditional ways to represent uncertainty, like SEU, do not capture the organicity, openness and complexity of the economic environment. At a first glance, there seems to be a great deal of agreement between both EI and Keynes/Post-Keynesian understanding of uncertainty, as both accept uncertainty as a phenomenon which is not measurable. However, the issue about the existence of degrees of uncertainty is subject to dispute among Post-Keynesians. As, in this matter, we share the same point of view of EI, we have dedicated Chapter II to elaborating a definition of uncertainty that would be capable of being ranked (i.e. encompassing the EI understanding of uncertainty) and compatible with the concepts of non-ergodicity and crucial decisions. In doing so, the concepts of probable knowledge and weight of argument, drawn from Keynes's theory of probability, emerge as key elements to explain qualitative degrees of strong (true) uncertainty.

In possession of this definition of uncertainty we could cross again the bridge to the EI side and explain the process of introduction of an innovation, bringing together the concepts of technological paradigm, technological trajectory, probable knowledge and weight of argument. This was the subject of Chapter III. The main conclusion of this process of integration is the claim that the development of a technological trajectory can be explained by the evolution of the weight of argument. In other words, every time an investor has to decide whether or not to introduce an innovation, he confronts a degree of uncertainty and confidence. These are an expression of the relevant knowledge and ignorance related to the specific stage of development of the technological trajectory with which he is dealing. These pieces of relevant knowledge and ignorance are associated to all aspects that are involved in an investment decision, be they technological or economic. As we have seen, a successful development of a technological trajectory works to increase the weight of argument related to the next innovation, and so increases the confidence in the next development. It is the evolution of the weight of argument related to a trajectory that gives theoretical support to the claim that there are qualitatively distinct degrees of uncertainty associated with different kinds of innovation.

Moreover, we also maintained that the diffusion of a technology can be understood as conventional behaviour. In doing so, we expand the concepts of probable knowledge and weight of argument, claiming that they can be used in a social context. Thus, the process of diffusion of a technology can be explained by the evolution of the *social* probable knowledge and *social* weight of argument.

Having done the integration between Keynesian uncertainty and the development of a technological trajectory, we could cross again the bridge to the Keynes/Post-Keynesian side to analyse the consequences of this understanding of technical change to the process of formation of expectations. We found that the traditional taxonomy of expectations between short and long period is not capable of explaining the process of the introduction of a product innovation. To deal with this essential feature of a modern economy a new kind of expectation had to be formulated. Medium-Period Expectations, which refers to the expected period for which a given product will be produced, was the answer to this challenge. The main features of MPE are related to their process of formation – which, despite taking into account previous expectations, does not show an one-to-one match with their validation or disagreement -, and their interaction with LPE. This interaction reveals the dual impact of technical change on the formation of investment expectations. On the one hand, it increases the uncertainty, as the calculation of prospective yields has to take into account future performance not only of one product, but of a series of different products belonging to the same technological trajectory. On the other hand, the calculation of the prospective yields of the immediate products to be produced with the new equipment can be done with more confidence if the previous MPE are confirmed. The main conclusion is that the process of formation of the LPE has to be changed to incorporate the outcomes of MPE. In other words, the introduction of continuous technical change, framed with the concepts of technological trajectory and weight of argument, has generated a partial endogeneity of the formation of LPE.

This endogeneity is not a trivial outcome for the Keynes/Post-Keynesian approach. It represents a significant departure from Keynes's assumptions. Furthermore, technical change is understood by Post-Keynesians as an additional reason for the exogeneity of LPE. However, surprising as it may seem to some Post-Keynesians, technical change in the model of this dissertation is the factor that generates partial endogeneity of LPE. This result depends on the particular type of technical change assumed along with its institutional aspects (technological paradigms and trajectories for example). The way technical change is understood also affects the claims made by other schools of thought. As we have seen in Chapter I, the findings of the neoclassical New Endogenous

Growth theories are strongly related to the understanding of technical change as a blueprint available in the shelf, in which there is no space for tacit knowledge.

Staying on the Post-Keynesian side of the bridge, we conclude the dissertation by applying the implications of this new taxonomy of expectations to the study of effective demand. So, we made the jump from the micro level to the macro level. With all caveats required by this movement, we have found some interesting results. One implication of tacit knowledge is that there will be a degree of stability in the level of employment, in order to protect that knowledge. Moreover, assuming continuos technical change, a firm sees itself both as producing different products during its life and as inside a technological trajectory. This acknowledgement implies that it is necessary to define a new unit of time for the analysis of effective demand capable of integrating the necessity of the firm to protect its capabilities; the market performance of different products and the development of its technological trajectory. The replacement of MPE for SPE was the answer to this challenge.

With the substitution of MPE for SPE, the point of effective demand will be more stable; this is not due to some equilibrium mechanism, but to the lengthening of the period of time between the formation of two MPE. However, the very process of formation of MPE implies the impossibility of a situation of stable position of effective demand as in Keynes's model. Despite being less volatile, the process of formation of MPE and the partial endogeneity of the investment decision generate a constantly evolving expectations model, where a state of rest, be it partial, final or provisional, cannot be achieved. Moreover, the development of the technological trajectory in the capital goods sector, with its impacts on both aggregate supply and demand functions, is a further element that prevents the equilibrium.

We have said in the Introduction that this dissertation should be viewed as a (modest) first step in a much broader research agenda that has the aim of incorporating a special approach to technical change in Post-Keynesian macroeconomics. We know that important elements were left out of our discussion, like the relation between money (finance, demand, liquidity, etc.) and technical change; the impact of R&D spending on effective demand, among others. These are themes for future research. However, we truly believe that this thesis have shown that fruitful outcomes can be achieved with further 'conversations' between Evolutionary and Institutional and Post-Keynesian schools of thought.

REFERENCES

Aghion, P. and Howitt, P. (1992) 'A Model of Growth Through Creative Destruction', *Econometrica* 60: 323-51.

Amadeo, E. (1989) *Keynes's Principle of Effective Demand,* Aldershot: Edward Elgar.

Anderson, M. and Goldsmith, A. (1997) 'A Direct Test of Keynes's Theory of Investment: assessing the role of profit expectations and weight', in Davidson, P. and Kregel, J. (eds.) *Improving the Global Economy,* Aldershot: Edward Elgar.

Andrade, R. (1997) *Theories of Uncertainty: Affinity and Uniqueness,* mimeo,

Andrade, R. (1998) *Dynamics of Conventions: a Post-Classical Analysis,* PhD. Dissertation, Department of Economics - UCL, University of London, London.

Arestis, P. and Dow, S. (eds.) (1992) *On Money, Method and Keynes: selected essays of Victoria Chick,* New York: St. Martin's Press Inc.

Arestis, P., Palma, G. and Sawyer, M. (eds.) (1997) *Markets, Unemployment and Economic Policy,* London: Routledge.

Arrow, K. (1962) 'The Economic Implications of Learning by Doing', *Review of Economic Studies* 29: 155-73.

Barrere, A. (ed.) (1988) *The Foundations of Keynesian Analysis,* London: Macmillan Press.

Barro, R. J. and Sala-I-Martin, X. (1995) *Economic Growth,* New York: McGraw-Hill.

Bateman, B. and Davis, J. (eds.) (1991) *Keynes and Philosophy,* Aldershot: Edward Elgar.

Boskin, M. (ed.) (1979) *Economics and Human Welfare: essays in honour of Tibor Scitovsky,* New York: Academic Press.

Camerer, C. and Weber, M. (1992) 'Recent Developments in Modelling Preferences: Uncertainty and Ambiguity', *Journal of Risk and Uncertainty* 5: 325-70.

Camic, C. (1986) 'The Matter of Habit', *American Journal of Sociology* 91: 1039-87.

Carabelli, A. (1985) 'Cause, Chance and Possibility', in Lawson, T. and Pesaran, H. (eds.) *Keynes's Economics: Methodological Issues,* London: Croom Helm.

__________ (1988) *On Keynes's Method,* London: Macmillan Press.

__________ (1992) 'Organic Interdependence and the Choice of Units in the *General Theory*', in Gerrard, B. and Hillard, J. (eds.) *The Philosophy and Economics of J. M. Keynes,* Aldershot: Edward Elgar.

__________ (1995) 'Uncertainty and Measurement in Keynes: Probability and Organicness', in Dow, S. and Hillard, J. (eds.) *Keynes, Knowledge and Uncertainty,* Aldershot: Edward Elgar.

__________ (1996) 'Speculation and Reasonableness', Second Conference on Keynes, Knowledge and Uncertainty, Leeds.

Carvalho, F. (1990) *Expectations and the Coordination of an Entrepreneurial Economy,* Discussion Paper - Fluminense Federal University, Departamento de Economia - UFF.

Chick, V. (1983) *Macroeconomics After Keynes: A Reconsideration of the General Theory,* Cambridge, Mass: The MIT Press.

________ (1992 [1983]) 'A Question of Relevance: The *General Theory* in Keynes's Time and Ours', in Arestis, P. and Dow, S. (eds.) *On Money, Method and Keynes*, New York: ST. Martins's Press Inc.

________ (1997) *Keynes's Theory of Investment and Necessary Compromise*, Discussion Paper, Department of Economics - UCL.

Choo, C. (1998) *Knowing Organization: How Organizations Use Information,* Oxford: Oxford University Press.

Cimoli, M. and Dosi, G. (1995) 'Technological Paradigms, Patterns of Learning and Development: an introductory roadmap', *Journal of Evolutionary Economics* 5: 243-68.

Crotty, J. (1994) 'Are Keynesian Uncertainty and Macrotheory Compatible? Conventional Decision Making, Institutional Structure, and Conditional Stability in Keynesian Macromodels', in Dymski, G. and Pollin, R. (eds.) *New Perspective in Monetary Macroeconomics*, Ann Arbor: The University of Michigan Press.

David, P. (1975) *Technical Choice, Innovation and Economic Growth,* Cambridge: Cambridge University Press.

________ (1969) *A Contribution to the Theory of Diffusion*, Center for Research in Economic Growth Research Memorandum, no. 71, Stanford University.

________ (1985) 'Clio and the economics of QWERTY', *American Economic Review* 75: 332-7.

Davidson, P. (1978) *Money and The Real World,* Houndmills: The Macmillan Press.

________ (1982/1983) 'Rational Expectations: a fallacious foundation for studying crucial decision-making processes', *Journal of Post-Kynesian Economics* 5: 182-98.

________ (1987) 'Sensible Expectations and the Long-Run Non-Neutrality of Money', *Journal of Post Keynesian Economics* X: 146-53.

________ (1991) 'Is Probability Theory Relevant for Uncertainty? A Post Keynesian Perspective', *Journal of Economic Perspective* 5: 129-43.

________ (1993) 'Austrians and Post Keynesians on Economic Reality: Rejoinder to Critics', *Critical Review* 7: 423-44.

________ (1995) 'Uncertainty in Economics', in Dow, S. and Hillard, J. (eds.) *Keynes, Knowledge and Uncertainty*, Aldershot: Edward Elgar.

Davidson, P. and Kregel, J. (eds.) (1997) *Improving the Global Economy,* Aldershot: Edward Elgar.

Davies, S. (1979) *The Diffusion of Process Innovations,* Cambridge: Cambridge University Press.

Davis, J. (ed.) (1994a) *The State of Interpretation of Keynes,* Boston/London: Kluwer Academic Publishers.

________ (1994b) 'Keynes's Philosophical Thinking', in Davis, J. (ed.) *The State of Interpretation of Keynes*, Boston/London: Kluwer Academic Publishers.

________ (1997) 'J. M. Keynes on History and Convention', in Harcourt, G. and Riach, P. (eds.) *A 'Second Edition' of The General Theory*, London: Routledge.

De Finetti, B. (1980 [1937]) 'Foresight: Its Logical Laves, Its Subjective Sources', in Kyburg, H. and Smokler, H. (eds.) *Studies in Subjective Probability*, New York: Robert E. Krieger Publishing Company.

Deprez, J. and Dalendina, P. (1994) 'The Monetary Determinants of (In)Stability: some contrasts of Dumenil/Levy and the Post Keynesians', *Review of Radical Political Economics* 26: 66-75.

Dequech, D. (1997) 'Uncertainty in Strong Sense: meaning and sources', *Economic Issues* 2: 21-43.

Dosi, G. (1982) 'Technological Paradigms and Technological Trajectories', *Research Policy* II: 147-62.

_______ (1988a) 'The Nature of the Innovative Process', in Dosi, G., et al. (eds.) *Technical Change and Economic Theory*, London: Pinter Publishers.

_______ (1988b) 'Sources, procedures and Microeconomic Effects of Innovation', *Journal of Economic Literature* XXVI: 1120-71, Reprinted in C. Freeman (ed.) (1990) The Economics of Innovation.

_______ (1997) 'Opportunities, Incentives and the Collective Patterns of Technological Change', *Economic Journal* 107: 1530-47.

Dosi, G. and Orsenigo, L. (1988) 'Coordination and transformation: an overview of structures, behaviours and change in evolutionary environments', in Dosi, G., et al. (eds.) *Technical Change and Economic Theory*, London: Pinter Publishers Ltd.

Dosi, G., et al. (eds.) (1988) *Technical Change and Economic Theory*, London: Pinter Publishers LTD.

Dosi, G. and Egidi, M. (1991) 'Substantive and Procedural Uncertainty', *Journal of Evolutionary Economics* 1: 145-68.

Dosi, G., Gianneti, P. and Toninelli, P. (eds.) (1992) *Technology and Enterprise in a Historical Perspective*, Oxford: Clarendon Press.

Dosi, G., Teece, D. and Chytry, J. (eds.) (1998) *Technology, Organization and Competitiveness: perspectives on industrial and corporate change*, Oxford: Oxford University Press.

Dow, S. (1995) 'Uncertainty about Uncertainty', in Dow, S. and Hillard, J. (eds.) *Keynes, Knowledge and Uncertainty*, Aldershot: Edward Elgar.

_______ (1996a) *Keynes, the Post Keynesians and Methodology*,

_______ (1996b) *The Methodology of Macroeconomic Thought: a conceptual analysis of schools of thought in economics*, Cheltenham, UK: Edward Elgar.

Dow, S. and Dow, A. (1985) 'Animal Spirits and Rationality', in Lawson, T. and Pesaran, H. (eds.) *Keynes's Economics: Methodological Issues*, London: Croom Helm.

Dow, S. and Hillard, J. (eds.) (1995) *Keynes, Knowledge and Uncertainty*, Aldershot: Edward Elgar.

Dymski, G. and Pollin, R. (eds.) (1994) *New Perspective in Monetary Economics: explorations in the tradition of Hyman Minsky*, Ann Arbor: The University of Michigan Press.

Edquist, C. (ed.) (1997) *Systems of Innovation: technologies, institutions and organizations*, London: Pinter.

Eichner, A. S. (1991) *The Macrodynamics of Advanced Market Economies*, London: M. E. Sharpe.

Farmer, M. (1995) 'Knowledgability, Actors and Uncertain Worlds', in Dow, S. and Hillard, J. (eds.) *Keynes, Knowledge and Uncertainty*, Aldershot: Edward Elgar.

Feiwel, G. (ed.) (1989) *Joan Robinson and Modern Economic Theory*, London: Macmillan.

Fitzgibbons, A. (1988) *Keynes's Vision*, Oxford: Clarendon Press.

Ford, J. (ed.) (1990) *Time, Expectations and Uncertainty in Economics: Selected Essays of G. L. S. Shackle*, Aldershot: Edward Elgar.

______ (1990) 'Shackle's Theory of Decision-Making Under Uncertainty: a brief exposition and critical assessment', in Frowen, F. (ed.) *Unknowledge and Choice in Economics*, London: Macmillan Press.

Fransman, M. (1986) 'Machinery and Economic Development', in Fransman, M. (ed.) *Machinery and Economic Development*, Houndmills: The Macmillan Press.

___________ (ed.) (1990) *Machinery and Economic Development*, Houndmills: The Macmillan Press.

__________ (1998) 'Information, Knowledge, Vision, and Theories of the Firm', in Dosi, G., Teece, D. and Chytry, J. (eds.) *Technology, Organization and Competitiveness*, Oxford: Oxford University Press.

Freeman, C. (ed.) (1990) *The Economics of Innovation*, Aldershot: Edward Elgar.

_________ (1994) 'The Economics of Technical Change', *Cambridge Journal of Economics* 18: 463-514.

Freeman, C., Clark, J. and Soete, L. (1982) *Unemployment and Technical Innovations: a study of long-waves and economic development*, London: Pinter.

Freeman, C. and Perez, C. (1988) 'Structural Crises of Adjustment: business cycles and investment behaviour', in Dosi, G., et al. (eds.) *Technical Change and Economic Theory*, London: Pinter Publisher Ltd.

Freeman, C. and Soete, L. (1997) *The Economics of Industrial Innovation*, London: Penguin Books.

Frisch, D. and Baron, J. (1988) 'Ambiguity and Rationality', *Journal of Behavioural Decision Making* 1: 149-57.

Frowen, G. (ed.) (1990) *Unknowledge and Choice in Economics*, London: Macmillan Press.

Fudenberg, D. and Tirole, J. (1985) 'Preemption and Rent Equalisation in the Adoption of New Technology', *Review of Economic Studies* 52: 383-401.

Gardenfors, P. and Sahlin, N. (eds.) (1988) *Decision, Probability and Utility: selected readings*, Cambridge: Cambridge University Press.

Gerrard, B. and Hillard, J. (eds.) (1992) *The Philosophy and Economics of J. M. Keynes*, Aldershot: Edward Elgar.

Giddens, A. (1982) *Profiles and Critiques*, London: Macmillan.

_________. (1984) *The Constitution of Social Theory*, London: Macmillan.

Gossling, W. (1969) 'A Note on User Cost', *Manchester School of Economics and Social Studies* 37: 259-61.

Griliches, Z. (1957) 'Hybrid Corn: An Exploration in the Economics of Technological Change', *Econometrica* 48: 501-22.

Grossman, G. and Helpman, E. (1989) 'Product Development and International Trade', *Journal of Political Economy* 97: 1261-83.

____________________ (1990) 'Comparative Advantage and Long Run Growth', *American Economic Review* 80: 796-815.

____________________ (1991) *Innovation and Growth in the Global Economy,* Cambridge, Mass: MIT Press.

____________________ (1994) 'Endogenous Innovations in the Theory of Growth', *Journal of Economic Perspectives* 8: 23-44.

Gruber, H., Terrel, G. and Wertheimer, M. (eds.) (1962) *Contemporary Approaches to Creative Thinking,* New York: Atherton Press.

Harcourt, G. (1982) 'Review article of W.E.G. Salter, *Productivity and Technical Change*', in Kerr, P. (ed.) *The Social Science Imperialists,* London: Routledge & Kegan Paul Ltd.

__________ (ed.) (1985) *Keynes's and His Contemporaries,* New York: St. Martin's Press.

Harcourt, G. and Riach, P. (eds.) (1997) *A 'Second Edition' of The General Theory,* London and New York: Routledge.

Harcourt, G. and Hamouda, O. (1992) 'Post-Keynesianism: from criticism to coherence?', in Sardoni, C. (ed.) *On Political Economist and Modern Political Economy,* London: Routledge.

Harrod, R. (1939) 'An Essay in Dynamic Theory', *Economic Journal* 49: 14-33.

Hicks, J. (1939) *Value and Capital,* Oxford: Oxford University Press.

Hodgson, G. (1988) *Economics and Institutions,* Oxford: Basil Blackwell.

__________ (1989) 'Institutional Rigidities and Economic Growth', *Cambridge Journal of Economics* 13: 79-101.

__________ (1994) 'Habits', in Hodgson, G., Samuels, W. and Tool, M. (eds.) *The Elgar Companion to Institutional and Evolutionary Economics (A-K),* Brookfield: Edward Elgar.

__________ (1998) *Notes on Reductionism and Emergence,* mimeo,

__________ (1999) *Evolution and Institutions,* Cheltenham: Edward Elgar.

Hodgson, G., Samuels, W. and Tool, M. (eds.) (1994) *The Elgar Companion to Institutional and Evolutionary Economics,* Brookfield-USA: Edward Elgar.

Ireland, N. and Stoneman, P. (1985) 'Order Effects, Perfect Foresight and Intertemporal Price Discrimination', *Recherché Economique de Louvain* 51: 7-20.

Kaldor, N. (1957) 'A Model of Economic Growth', *Economic Journal* 67: 591-624.

__________ (1989 [1958]) 'Capital Accumulation and Economic Growth', in Targetti, F. and Thirlwall, A. (eds.) *The Essential of Kaldor,* New York: Holmes and Meier Publishers, Inc.

Kaldor, N. and Mirrless, J. (1962) 'A New Model of Economic Growth', *Review of Economic Studies* 29: 174-92.

Karshenas, M. and Stoneman, P. (1995) 'Technological Diffusion', in Stoneman, P. (eds.) *Handbook of the Economics of Innovation and Technological Change,* Oxford-UK and Cambridge-USA: Blackwell.

Kay, N. (1979) *The Innovating Firm,* London: The Macmillan Press.

Keer, P. (ed.) (1982) *The Social Science Imperialist,* London: Routledge & Kegan Paul.

Kelsey, D. and Quiggin, J. (1992) 'Theories of Choice Under Ignorance and Uncertainty', *Journal of Economic Surveys* 6: 133-53.

Keynes, J. M. (1973a[1930]) 'A Treatise on Money', *2,* Moggridge, D. (ed.) *The Collected Writings of John Maynard Keynes,* London: Macmillan.

____________ (1973b[1936]) 'The General Theory of Employment, Interest and Money', Moggridge, D. (ed.) *The Collected Writings of John Maynard Keynes,* London: Macmillan Press.

____________ (1973c[1921]) 'A Treatise on Probability', Moggridge, D. (ed.) *The Collected Writings of John Maynard Keynes,* London: Macmillan Press.

____________ (1973d) 'Essays in Biography', Moggridge, D. (ed.) *The Collected Writings of John Maynard Keynes,* London: Macmillan Press.

____________ (1973e) 'The General Theory and After: Part II. Defence and Development', in Moggridge, D. (ed.) *The Collected Writings of John Maynard Keynes,* London: Macmillan Press.

Kirman, A. (1989) 'The Intrinsic Limits of Modern Economic Theory: The Emperor has no Closes', *Economic Journal* 99: 129-39.

Knight, F. (1921) *Risk, Uncertainty and Profit,* New York: Houghton Mifflin.

Koopman, B. (1940) 'The Axioms and Algebra of Intuitive Probability', *Annals of Mathematics* 41: 269-92.

Kregel, J. (1976) 'Economic Methodology in the Face of Uncertainty: The Modelling Methods of Keynes and the Post-Keynesians', *Economic Journal* 86: 209-25.

________ (1988) 'The Multiplier and Liquidity Preference: two sides of the Theory of Effective Demand', in Barrere, A. (ed.) *The Foundations of Keynesian Analysis,* London: Macmillan Press.

Kuhn, T. (1962) *The Structure of Scientific Revolution,* Chicago: University of Chicago Press.

Kurdas, C. (1994) *Theories of Technical Change and Investment,* London: St. Martin's Press.

Kyburg, H. and Smokler, H. (eds.) (1980) *Studies in Subjective Probability,* New York: Robert E. Krieger Publishing Company.

____________________ (1980) 'Introduction', in Kyburg, H. and Smokler, H. (eds.) *Studies in Subjective Probability,* New York: Robert E. Krieger Publishing Company.

Latsis, S. (ed.) (1976) *Methods and Appraisal in Economics,* Cambridge: Cambridge University Press.

Lavoie, M. (1992) *Foundations of Post-Keynesian Economic Analysis,* Aldershot: Edward Elgar.

Lawson, T. (1985) 'Uncertainty and Economic Analysis', *Economic Journal* 95: 909-27.

_________ (1987) 'The Relative/Absolute Nature of Knowledge and Economic Analysis', *The Economic Journal* 97: 951-70.

_________ (1988) 'Probability and Uncertainty in Economic Analysis', *Journal of Post Keynesian Economics* 11: 38-65.

_________ (1993) 'Keynes and Convention', *Review of Social Economy* 51: 174 - 200.

________ (1995) 'Economics and Expectations', in Dow, S. and Hillard, J. (eds.) *Keynes, Knowledge and Uncertainty*, Aldershot: Edward Elgar.

________ (1997a) *Economics and Reality,* London: Routledge.

________ (1997b) 'Situated Rationality', *Journal of Economic Methodology* 4: 101-25.

Lawson, T. and Pesaran, H. (eds.) (1985) *Keynes's Methodological Issues,* London: Croom Helm.

Littleboy, B. (1990) *On Interpreting Keynes: a study in reconciliation,* London: Routledge.

________ (1992) 'Keynes and Convention Equilibria', in Sebastiani, M. (ed.) *The Notion of Equilibrium in the General Theory*, New York: St. Martin Press.

Lucas, R. (1988) 'On the Mechanics of Economic Development', *Journal of Monetary Economics* 22: 3-42.

Lundvall, B. (ed.) (1992) *National Innovation Systems of Information: Towards a Theory of Innovation and Interactive Learning,* London: Pinter.

Mansfield, E. e. a. (1977) 'Social and Private Rates of Return from Industrial Innovation', *Quarterly Journal of Economics* 91: 221-40.

McCann, C. (1994) *Probability Foundations of Economic Theory,* London: Routledge.

Meeks, G. (1991) 'Keynes on the Rationality of Decision Procedures under Uncertainty: the investment decision', in Meeks, G. (ed.) *Thoughtful Economic Man*, Cambridge: Cambridge University Press.

________ (ed.) (1991) *Thoughtful Economic Man,* Cambridge: Cambridge University Press.

Metcalfe, S. (1985) 'Comments on Kregel's Harrod and Keynes: Increasing Returns, the Theory of Employment and Dynamic Economics', in Harcourt, G. C. (ed.) *Keynes and His Contemporaries*, New York: St. Martin Press.

Metcalfe, J. (1988) 'The Diffusion of Innovations: an interpretative survey', in Dosi, G. and al., e. (eds.) *Technical Change and Economic Theory*, London: Pinter Publishers.

Milberg, W. (ed.) (1992) *The Megacorp & Macrodynamics: Essays in Memory of Alfred Eichner,* London: M.E. Sharpe.

Milberg, W. and Elmslie, B. (1992) 'Technical Change in the Corporate Economy: A Vertically Integrated Approach', in Milberg, W. (ed.) *The Megacorp and Macrodynamics*, Armonk: M.E. Sharpe, Inc.

Mowery, D. and Rosenberg, N. (1979) 'The Influence of Market Demand upon Innovation: a critical review of some recent empirical studies', *Research Policy* 8: 102-50.

Nell, E. (1989) 'Accumulation and Capital Theory', in Feiwel, G. (ed.) *Joan Robinson and Modern Economics*, London: Macmillan.

Nelson, R. and Winter, S. (1977) 'In Search of Useful Theory of Innovation', *Research Policy* 6: 37-76.

________________ (1982) *An Evolutionary Theory of Economic Change,* Cambridge, Mass: Harvard University Press.

Nelson, R. (1992) 'The Role of Firms in Technical Advance: a perspective from an Evolutionary Theory', in Dosi, G., Giannetti, R. and Toninelli, P. (eds.) *Technology and Enterprise in an Historical Perspective*, Oxford: Clarendon Press.

________ (ed.) (1993) *National Innovation Systems,* New York: Oxford University Press.

Newell, A., Shaw, J. and Simon, H. (1962) 'The Process of Creative Thinking', in Gruber, H., Terrell, G. and Wertheimer, M. (eds.) *Contemporary Approaches to Creative Thinking*, New York: Atherton Press.

Nonaka, I. and Takeuchi, H. (1995) *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation,* Oxford and New York: Oxford University Press.

Nonaka, I. and Takeuchi, H. (1999) 'A Theory of the Firm's Knowledge-Creation Dynamics', in Chandler Jr., A., Hagström, P. and Sölvell, O. (eds.) *The Dynamic Firm*, Oxford: Oxford Press.

O'Donnell, R. (1989) *Keynes: Philosophy, Economics and Politics,* London: Macmillan.

__________ (1990) 'An Overview of Probability, Expectations, Uncertainty and Rationality in Keynes's Conceptual Framework', *Review of Political Economy* 2: 253-66.

__________ (ed.) (1991) *Keynes as a Philosopher-Economomist,* London: Macmillan.

__________ (1991a) 'Keynes on Probability, Expectations and Uncertainty', in O'Donnell, R. (ed.) *Keynes as Philosopher-Economist*, London: Macmillan.

__________ (1991b) 'Keynes's Weight of Argument and its Bearing on Rationality and Uncertainty', in Bateman, B. and Davis, J. (eds.) *Keynes and Philosophy*, Aldershot: Edward Elgar.

Pasinetti, L. (1981) *Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations,* Cambridge: Cambridge University Press.

Patel, P. and Pavitt, K. (1998) 'Uneven (and Divergent) Technological Accumulation Among Advanced Countries: evidence and a framework explanation' in Dosi, G., Teece, D. and Chytry, J. (eds.) *Technology, Organization and Competitiveness*, Oxford: Oxford University Press.

Penrose, E. (1995[1959]) *The Theory of the Growth of the Firm,* Oxford: Oxford University Press.

Perez, C. (1985) 'Microelectronics, Long Waves and World Structural Change: new perspectives for developing countries', *World Development* 13: 441-63. Reprinted in C. Freeman(ed.) (1990) The Economics of Innovation. Edward Elgar, Aldershot.

Petit, P. and Tahar, G. (1989) 'Dynamics of Technological Change and Schemes of Diffusion', *The Manchester School of Economics and Social Studies* 57: 370-86.

Phillips, A. (1971) *Technology and Market Structure,* Lexington: D. C. Heath.

Polanyi, M. (1958) *Personal Knowledge: Towards a Post-Critical Philosophy,* London: Routledge and Kegan Paul.

Polanyi, M. (1967) *The Tacit Dimension,* London: Routledge and Kegan Paul.

Quirmbach, H. (1986) 'The Diffusion on New Technology and the Market for Innovation', *The Rand Journal of Economics* 17: 33-47.

Ramsey, F. (1988 [1931]) 'Truth and Probability', in Gardenfors, P. and Sahlin, N. (eds.) *Decision, Probability and Utility: selected readings*, Cambridge: Cambridge University Press. Reprinted from The Foundations of Mathematics, ed. by R. Braithwaite (1931) Routledge and Kegan Paul, London.

Reinganum, J. (1981) 'Market Structure and the Diffusion of New Technology', *Bell Journal of Economics* 14: 57-69.

Richardson, G. (1990 [1972]) *Information and Investment: a study of the working of the competitive economy,* New York: Oxford University Press.

Rizvi, S. (1994) 'The Microfoundations Project in General Equilibrium Theory', *Cambridge Journal of Economics* 18: 357-77.

Robinson, J. (1965) *The Accumulation of Capital,* London: Macmillan.

Rogers, E. (1983) *Diffusion of Innovations,* New York: The Free Press.

Romer, P. (1986) 'Increasing Returns and Long-Run Growth', *Journal of Political Economy* 94: 1002-37.

________ (1987) 'Growth Based on Increasing Returns Due to Specialization', *American Economic Review* 77: 56-62.

________ (1990) 'Endogenous Technological Change', *Journal of Political Economy* 98: s71-s101.

________ (1994) 'The Origins of Endogenous Growth', *Journal of Economic Perspectives* 8: 3-22.

Rosenberg, N. (1976) *Perspectives on Technology,* Cambridge: Cambridge University Press.

__________ (1982) *Inside the Black Box: Technology and Economics,* Cambridge: Cambridge University Press.

__________ (1994) *Exploring the Black Box,* Cambridge: Cambridge University Press.

Rowthorn, R. (1975) 'What Remains of Kaldor's Law?', *Economic Journal* 85: 10-9.

Runde, J. (1990) 'Keynesian Uncertainty and Weight of Argument', *Economics and Philosophy* 6: 275-92.

________ (1991) 'Keynesian Uncertainty and Instability of Beliefs', *Review of Political Economy* 3: 125-45.

________ (1993) 'Paul Davidson and the Austrians: Reply to Davidson', *Critical Review* 7: 381-97.

________ (1994a) 'Keynesian Uncertainty and Liquidity Preference', *Cambridge Journal of Economics* 18: 129-44.

________ (1994b) 'Keynes After Ramsey: in defence of a Treatise on Probability', *Studies in History and Philosophy of Science* 25: 97-121.

________ (1994c) 'The Keynesian Probability-Relation: in Search of a Substitute', in Davis, J. (ed.) *The State of Interpretation of Keynes,* Boston/London: Kluwer Academic Publishers.

________ (1997a) 'Keynesian Methodology', in Harcourt, G. and Riach, P. (eds.) *A 'Second Edition' of The General Theory,* London and New York: Routledge.

_______ (1997b) 'Abstraction, Idealisation and Economic Theory', in Arestis, P., Palma, G. and Sawyer, M. (eds.) *Markets, Unemployment and Economic Policy: Essays in honour of Geoff Harcourt, Vol. two,* London: Routledge.

Rymes, T. (1971) *On Concepts of Capital and Technical Change,* Cambridge: Cambridge University Press.

Sahal, D. (1981) *Patterns of Technological innovation,* New York: Addison-Wesley.

Salter, W. (1960) *Productivity and Technical Change,* Cambridge: Cambridge University Press.

Sardoni, C. (ed.) (1992) *On Political Economist and Modern Political Economy,* London: Routledge.

Scherer, F. and Ross, D. (1990) *Industrial Market Structure and Economic Performance,* Boston: Houghton Mifflin Company.

Schomookler, J. (1966) *Invention and Economic Growth,* Cambridge, Mass: Harvard University Press.

Schumpeter, J. (1934) *The Theory of Economic Development,* Cambridge, Mass: Harvard University Press.

____________ (1942) *Capitalism, Socialism and Democracy,* New York: Harper and Row.

Sebastiani, M. (ed.) (1992) *The Notion of Equilibrium in the General Theory,* New York: St. Martin Press.

Setterfield, M. (1994) 'Recent developments in growth theory: a post Keynesian view', in Davidson, P. and Kregel, J. A. (eds.) *Employment, Growth and Finance: economic reality and economic growth,* Aldershot: Edward Elgar.

___________ (1999) 'Expectations, Path Dependence and Effective Demand: a macroeconomic model along Keynesian lines', *Journal of Post Keynesian Economics* 21: 479-501.

Shackle, G. (1943) 'The Expectational Dynamics of the Individual', *Economica* 10: 99-129.

_________ (1952/1953) 'On the Meaning and Measure of Uncertainty', *Metroeconomica* 4: 87-123.

_________ (1958) *Time in Economics,* Amsterdam: North-Holland Publishing Company.

_________ (1959) 'Time and Thought', *British Journal for the Philosophy of Science* 9: 285-98.

_________ (1967) *The Years of High Theory,* Cambridge: Cambridge University Press.

_________ (1970) *Expectation, Enterprise and Profit,* London: George Allen and Unwin Ltd.

_________ (1983) 'A Student's Pilgrimage', *Banca Nationale del Lavoro Quartely Review* 108-16.

________ (1990 [1956]) 'Expectation and Cardinality', in Ford, L. (ed.) *Time, Expectations and Uncertainty in Economics,* Aldershot: Edward Elgar.

Simon, H. (1976) 'From Substantive to Procedural Rationality', in Latsis, S. (ed.) *Methods and Appraisal in Economics,* Cambridge: Cambridge University Press.

Soete, L. and Dosi, G. (1983) *Technology and Employment in the Electronics Industry,* London: Francis Pinter.

Stoneman, P. and Kwon, M. (1994) 'The Diffusion of Multiple Process Technologies', *Economic Journal* 104: 420-31.

Stoneman, P. (ed.) (1995) *Handbook of the Economics of Innovation and Technological Change,* Oxford -UK and Cambridge-USA: Blackwell.

Targetti, F. and Thirlwall, A. (eds.) (1989) *The Essential of Kaldor,* New York: Holems and Meier Publishers, Inc.

Tarshis, L. (1979) 'The Aggregate Money Supply Function in Keynes's General Theory', in Boskin, M. (ed.) *Economics and Human Welfare: Essays in Honour of Tibor Scitovsky*, New York: Academic Press.

Teece, D., Pisano, G. and Shuen, A. (1990) *Firm Capabilities, Resources and the Concept of Strategy*, CCC Working Paper N. 90-8,

Torr, C. (1988) *Equilibrium, Expectations and Information*, Cambridge: Polity Press.

_____ (1992) 'The Dual Role of User Cost in the Derivation of Keynes's Aggregate Supply Function', *Review of Political Economy* 4: 1-17.

______ (1997) 'User Cost', in Harcourt, G. and Riach, P. (eds.) *The Second Edition of The General Theory*, London: Routledge.

Veblen, T. (1899) *The Theory of the Leisure Class: An Economic Study in the Evolution of Institutions*, New York: Macmillan.

Vercelli, A. (1995) 'From Soft Uncertainty to Hard Environmental Uncertainty', *Economie Appliquee* XLVIII: 251- 69.

Verspagen (1992) 'Endogenous Innovation in Neoclassical Growth Models: a survey', *Journal of Macroeconomics* 14: 631-62.

Vromen, J. (1995) *Economic Evolution: An Enquiry into the Foundations of New Institutional Economics*, London: Routledge.

Weick, K. (1995) *Sensemaking in Organizations*, Sage: Tnousand Oaks.

Weintraub, S. (1958) *An Approach to the Theory of Income Distribution*, Westport: Greenwood Press.

Winter, S. (1984) 'Schumpeterian Competition in Alternative Technological Regimes', *Journal of Economic Behavior and Organization* 5: 287-320.

Young, A. (1993) 'Invention and Bounded Learning by Doing', *Journal of Political Economy* 101: 443-72.