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The Relationship Between Technological Change and Economic Development

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Abstract: This Discussion Paper arises as a background paper to a research project currently involved in testing whether technological change is a necessary condition for economic development - believed to be the basis for economically sustainable growth in the Philippines. The starting point of this paper is that economic development embodies technical, organisational and institutional changes in the way that output is produced. Section II, using examples from far-from-equilibrium physical and biological systems, suggests that the behavioural properties of transformations in the structure of the system itself, are quite different from those arising from relational responses, such as are associated with the functioning of the market mechanism. This raises the question of the relative importance of market adaptation and technological change in determining the pattern of development: an issue which is examined in the context of organisational change. A comparison is made between elements of the new theory of the firm and Chandler's historical analysis of organisational change. Attempts are then made to see Chandler's argument appears to be invalidated in any fundamental way by subsequent events and this is found not to be the case. Policy implication both general and for the Philippines - are then briefly outlined.

Keywords: Economic Development, Economic Growth, Evolution, Market Adaptation, Mutation, Natural Selection, Technological Change.

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The Relationship Between Technological Change and Economic Development

I. Economic Growth, Development and Change: An Introduction.

When examining the relationship between technological change and economic development one is inevitably involved in understanding the nature of economic change. Unfortunately, economic change is subject which is virtually taken for granted in much of economic theory: in neo-classical growth theory for example the long term growth effects of capital formation, labour force expansion and technological change are assumed to take place under conditions of competitive equilibrium. Any movement of resources is considered to be unimportant because the market will ensure that labour and capital will produce equal marginal returns in all uses. Growth can therefore be measured in terms of a single variable, such as per capita output, regardless of any change in the composition of that output. In contra-distinction, other economists preferred to focus on the differential growth rates of the sectors making up that output. Change is seen to be associated with growth, but only as an outcome of growth itself -

> ".... the set of changes in the composition of demand, trade, production and factor use as per capita income increases." (Chenery, 1988, pp.31-32).

Finally, there are those who see growth in terms of a change in the structure of the economic system itself. This conceptualisation is captured in the Kindleberger and Herrick's (1977) distinction between growth and development: -

> "Economic growth means more output, while economic development implies both more output and changes in the *technical and institutional* arrangements by which it is produced and distributed ..... development draws attention to changes in *functional capacities*." (p.3, my emphasis).

These particular ways of perceiving the relationships between growth and change have been far from universally accepted. Criticism has been expressed of the way excessive aggregation and abstract generality conceal,

> "... all the drama of the events - the rise and fall of products, technologies and industries, and the accompanying transformation of the spatial and occupational distribution of the population.." (Nordhaus and Tobin, 1972, p.2).

They go on to express their belief in an alternative vision of capitalist development presented by Schumpeter, as well as to invoking a plague on both your Cambridges (although not quite in those words)! Also, not all development economists have emphasised Kindleberger and Herrick's distinction between growth and development - especially the concept of development embodying both technical and institutional change. Sen's (1988) distinction between development and growth embodies 5 factors which tend to reflect the incompleteness of market criteria in traditional models of economic growth but don't explain what economic development is or rather involves. In another context(Meier (1989, p.6) defines development as the increase in per capita G.D.P. ie. synonymous with economic growth but with the proviso that no group should become worse-off. The problem with such distinctions between growth and development is that they tend to focus on the unease felt in accepting growth theories as an explanation of economic development, rather than focusing on what economic development involves - as Kindleberger and Herrick have done.

This ambivalence raises a question as to whether the nature of economic change is adequately captured within our various frameworks. For example, is change merely part of the epiphenomenon of growth or is it central to the very process of growth itself? Boulding (1956) in formulating an approach to a general theory of growth, lists 3 categories of growth similar to those mentioned above: viz.

> (a) Simple growth measured by the change in a single variable (such as per capita G.D.P.)
>
> (b) Populational or differential growth measured by the changes in the various categories or sectors which make up the "homogenous aggregate".
>
> (c) Structural growth which he defines as "the aggregate which "grows" consists of a complex structure of interrelated parts and in which the growth process involves change in the relation of the parts." (ibid, p.109).

He goes on to point out that;

> "Problems of structural growth seem to merge almost imperceptibly into the problems of structural change or development, so frequently "what grows" is not into the overall size of the structure but the complexity or systematic nature of its parts." (ibid)

Much of his paper is then devoted to the general principles of structural growth, a particular principle emphasised being non-proportionality of change.

> "As any structure grows, the proportion of its parts and its significant variables cannot remain constant." (ibid, p.118)

This suggests that structural change is then a necessary condition for further growth: ie growth leads to a certain form or structure but that structure will then limit the ability for further growth to take place unless structural change occurs (ibid, p.120). This gives an entirely different perception of the relationship between growth and change to that suggested by the differential growth theorist: growth is the outcome of change rather than vice versa.

In order to determine the role of change in growth and development it is necessary to look well beyond economic theory to those areas of science where change itself is the central concern. These areas include the far-from-equilibrium physics of Prigogine and his associates (such as eg. Prigogine, I.; Nicolis G.; and Agnes Babloyantz, 1972) and the work in biological evolution by Waddington (1957, 1974, 1975, 1977) and Kauffman (1992, 1996). The nature of change as outlined in these sciences is discussed in Section II. It suggests that a major distinction should be made between adaptation - as reflected in natural or market selection - and structural transformation - as reflected in mutation or structural/technological change: the behavioural properties of each appears to be dramatically different. In Section III the significance of these quite different patterns of change is broadly related to a number of economic areas, finally focusing upon organisational theory - in particular the 'new theory of the firm'. In Section IV these theoretical explanations of change are then compared with Chandler's (1962, 1977, 1990) historical explanation of organisational change amongst - *inter-alia* - U.S. firm's and their economic performance. According to Chandler it was the firms ability to develop the organisational capacity required to embarque on an appropriate investment strategy which generated the sort of market structure which characterised the U.S. economy for the first 2/3 of the 20th Century: not the market structure which determined the firms' performance. Section V attempts to look at the significance of organisational change in the 80s to see if this may obviate Chandler's argument: it is suggested that these change's do not do so in any fundamental way. In the light of this conclusion, a number of implications are drawn for development policy.

II. A Conceptual Framework for Structural Transformation.

(i) *Relational Responses vs Structural Change.*

Economics is not the only discipline having problems coping with the nature of change: science has traditionally been bedevilled by the problem. The traditional scientific perception of the nature of causation - as developed for example in Newton's theory of planetary motion - is of a stable and unchanging view of the world. Explanation is sought solely in terms of relational responses within an unchanging system: all that is required to explain motion as it relates to a moving body in Newton's model, is the body's position and velocity at some point in time and the relationship governing its acceleration (given by Newton's law of gravitation). The relationship becomes the sufficient and necessary condition for the effect. Now these relationships were held to exist independently of any other relationship which may act upon the system: they exist as in an "environment-free" world. They were also reversible, implying no discontinuity between past and future: theoretical time involved in these relationships has no links with historical time. Prigogine and Stengers (1985) summarise the behavioural properties of such systems as;

> "The basic characteristics of trajectories are *lawfulness, determinism,* and *reversibility."* (p.60, their emphasis)

Because these models are divorced from historical time, they cannot incorporate change in the sense of aging or evolving. This distinction between change as a relational response and changes as evolution - ie a change in the structure of the system itself has been developed by Prigogine (1980) in his differentiation between "being and becoming": a differentiation taken up by Gleick (1991) in his introduction to chaos theory:

> "... chaos is a science of process rather than state, of becoming rather than being." (p.5)

Indeed it is the work of Ilya Prigogine and his co-workers at the Brussels Institute, that have made path breaking discoveries concerning the behaviour of systems undergoing radical transformation. Their focus was on thermodynamic systems operating under far-from-equilibrium as distinct from equilibrium conditions. At or near equilibrium only one stable state, that will depend upon the value of certain control parameters, will tend to exist. Chemical reactions, for example, if left to themselves, will tend to that attractor state, just as the uniform spread of temperature throughout a closed system will also reflect it. (Prigogine & Stengers, 1985). With the addition of more and more of one of the control parameters, (the others remaining constant) nothing may at first appear to happen within the reaction. However, as the system moves further and further away from equilibrium with the increase in the control parameter, a point is reached at which the system becomes unstable: it is no longer able to dampen the fluctuations which occur within it. Rather these fluctuations tend to be amplified until a crisis or bifurcation point is reached, at which point the system moves away from its stable state and spontaneously re-organises itself into a radically different one: it undergoes a structural transformation or change.

That transformation is on a *large-scale*. Prigogine and Stengers (ibid, pp. 141-142) use the onset of convection currents and turbulence from laminar flows, to illustrate the macro-scale nature of this self-organisation. Part of the energy contained within the individual bodies of a corpuscular system is transferred at the phase transition, to organised motion. This is a classical case of emergent behaviour, where the behavioural properties of the system are not discernible from the properties of the individual bodies making up that system.

Finally the response is not determinate:

(a) The lack of a single point attractor implies there is no potential function under conditions of far-from-equilibrium transition: equilibrium is no longer applicable. The system is not stable in terms of the general laws of physics, so that any order which does occur must therefore lie outside those laws. There is therefore no universally valid law from which the overall behaviour of the system might be determined.

(b) As a corollary of (a) the particular branch followed after bifurcation will depend on many factors including the particular history of the system (physical as well as social systems), as well as the boundary conditions governing the macrostate and the kinetic constants governing the microstate. (Ibid, p.161). Accident and random change - as eg. in the left-handed helix of DNA where a unique event may have favoured this particular outcome, which has then been replicated by the autocatalytic processes (Ibid, p.163) - also have a major role to play.

(c) The third point to emphasise is that the transformation does evoke Schumpeter's concept of 'development from within' despite its occurring within an open system (see Hodgson (1993, p.289) for an alternative view). The dissipative structure[1] certainly requires energy from outside the system to maintain its increased organisation. And although the processes of change may adapt to variations in outside conditions (Prigogine & Stengers, 1985, p.165) those outside conditions do not drive the change. As they explained it;

> "... a new molecular order has been produced spontaneously. It corresponds to a giant fluctuation *stabilised* through energy exchanges with the outside world" (Ibid, p.143 my emphasis).

Prigogine and Stengers (1985) conclude their account of the behaviour of far-from-equilibrium systems by pointing out that, by adhering to physics models of very limited applicability, economists may be drawing completely unjustified analogies. He is particularly critical of the use made of the optimisation paradigm.

> "..... to consider optimisation as the key to understanding how populations and individual survive is to risk confusing causes with effects.
>
> Optimisation models .... ignore both the possibility of radical transformations - that is transformations that change the definition of a problem and thus the kind of solution sought - and the inertial constraints that may eventually force a system into a disastrous way of functioning .... To restore both inertia and the open character of history - we must accept its fundamental uncertainty." (ibid, p.207)

It is now necessary to turn to evolutionary theory to see how Prigogine's argument might apply in a biological context.

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[1] This is the term used by Prigogine to describe the transformed system;

> "... to emphasise the close association, at first paradoxical in such situations between structure and order on the one side and dissipation or waste on the other." [Prigogine & Stengers, 1985, p.143],

(ii) Evolution: The Neo-Darwinian View.

The neo-Darwinian[2] view of evolution holds that heredity resides exclusively in the DNA/genes (which tend to be treated as synonymous). These genes are faithfully copied and transmitted from parent to offspring unchanged, except for rare mutations and this accounts for both similarities between parents and offspring, as well as occasional deviations. Any change therefore emanates from random mutation of the genes. It is this evolution or change in the DNA, which is then reflected in changes in the phenotype. Because of the way the genome is organised the type of change will be determined by the type of gene mutated: large scale changes in phenotype could easily arise from random mutation of the 'higher-level' gene organisation. It is important to understand that gene mutation is random in two senses;

(i) A strong sense which suggests that it is unpredictable.

(ii) A weaker sense in which it is not correlated with any selective external factor.

Together these senses suggest that a research program aimed at understanding the nature of genetic change, would have little meaning.

The second point - the fundamental focus of the theory - is that natural selection is the primary organising concept in evolution. Indeed it can be argued that the theory perceives natural selection as the sufficient and necessary condition for evolution to take place. Organisms are competing for resources - food, light, shelter and so forth. Any genetic mutation which permits the organism to compete more effectively will be reinforced in successive generations who inherit the change, while those who do not will tend to die out. After a time depending upon the organism's reproductive rate and the degree of competition, the new mutation will characterise the population. This implies that the process of evolution is gradual: as Gould (1990, Ch.18) described the Neo-Darwinian interpretation of the process - "slow, steady, gradual and continuous". There was therefore a Malthusian basis to evolution in the struggle for survival: nature red in tooth and claw" as the poet described it. Evolution was therefore claimed to be a process of "survival of the fittest" (not I would emphasise by Darwin, but by Herbert Spencer). Fisher's (1929) study was the basis for the development of this view: his mathematics developed from the work of biometricians studying the genetic variation within a population that can occur with a number of alternative genes at many loci. This work led to the concept of continuous variation and the discipline of population genetics. The mathematical framework was essentially simple - reversible dynamics limited to the study of the 2-body (loci) problem. From this, Fisher developed his Fundamental Theorem - the rate of increase in average fitness of a population is equal to the population varieties in fitness. He then re-inforced the Spencerian view that long term biological evolution has a direction in time. Such a perception of evolution fits in quite closely with the neo-classical growth paradigm: again a unchanging structure (morphological change is a purely relational response) operating within a 'free space' (devoid of any external influence) and equilibrating framework with even an objective function to be maximised. It was therefore little wonder that the neo-Darwinian paradigm of biological evolution was so widely adopted in evolutionary economics.

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[2] This section represents a somewhat over-simplified interpretation of alternative viewpoints. A distinction should perhaps be made between the "Modern Synthesis" which would include biologists like Dobzhansky, Mayr and Simpson and the "Synthetic School" represented by Fisher, Haldane and Wright.

(iii) Evolution as a Joint Dynamic between Genes and Organism.

There are a number of serious limitations to the neo-Darwinian perception of evolution. Perhaps the most obvious one is the assumed close link between genotype - the system within which mutation takes place - and genotype - the system on which selection acts. Geneticists such as Waddington (1957, 1974, 1975) found that environmental stimuli could activate dormant DNA in fruit fly, which could lead to mutations, that under certain conditions could appear in subsequent generations without the environmental stimulus. He explained these results by developing the concept of epigenesis as the environment space between genotype and phenotype space, thereby breaking the simple causal relationship between changes in genotype and its effects upon the phenotype and incidentally increasing the complexity between genotype and fitness far beyond anything suggested by Neo-Darwinian theory.

There are a number of important implications or extensions which may be derived from this particular perception of development/evolution:

(a) Because of this buffering not all genetic change will be reflected in changes in the phenotype. The idea that nearly all individuals within a population will be from a very similar gene pool with only a few abnormal variations had been shown to be incorrect:

> "The individuals that are phenotypically almost identical, looking alike as two peas, contain wildly different genotypes each a sample drawn from the population's highly heterogeneous gene pool." (Waddington, 1975, p.259).

(b) Change is never from one stable state to another: there is instead a continuous process of change. Environmental perturbations may occur, disrupting the process until either the original process is restored or a new one developed. Waddington, called this process homeorhesis, meaning 'preserving a flow', to distinguish it from homeostasis meaning preserving a state. He argued that homeorhesis should be the focus of attention:

> "We are concerned with the stabilisation/control not of things but the processes, with homeorhesis, not homeostasis". (1977, p.115)

(c) The epigenetic landscape changes overtime eventually leading to a change in the development path (chreod). Waddington suggests that the change can be of two types - chaotic or catastrophic (a bifurcation) with the implication that it would also be self-organising.

> "It may then break down into a general chaotic turmoil, or it may undergo branching into two alternative new paths, each with its own stability. It is perhaps rather surprising that so many systems we come across seem to behave in the second way." (1975, p.111)

If change is either chaotic or catastrophic, then it will not be gradual or smooth. Gould (1990, Ch.17) suggests this interpretation of events is given some credence by the fossil record. There appear to be two main features neither of which is consistent with gradual change. The first is that most species appear to be stable during their time on earth "morphological change is usually limited and directionless". The second is that "species do not arise gradually by the steady transformation of (their) ancestors" but appear suddenly, fully transformed. Gould then goes on to suggest evolution has two alternative models of progressing - transformation of a complete population which changes from one state to another, or speciation where species split-off existing parental stock. Transformation of a population does not increase diversity and therefore cannot contribute to evolution. Gould suggests that it is speciation, where species split-off exiting parental stock, which is responsible for almost all evolutionary change. As Darwin himself found in the Galapagos islands, this splitting takes place most rapidly in very small populations. When the fossil record shows that all the various species are static it is because records are

the remains of large central populations which do not show much tendency to change. Lineages show only minimal change over most their history although this stability may occasionally be interrupted by bursts of sudden speciation. This is Eldridge and Gould's concept of 'punctuated equilibria', (see ibid).

Waddington's work suggests that saltatory changes in non-genetic DNA sequences can occur in response to environmental perturbations which may then be reflected in morphological change. This is of course not to say that genetic mutations cannot result in morphological change but simply that they are not a sufficient condition for that change. This point may be illustrated using Waddington's (1957) theory of genetic assimilation. Evolution does not act on the raw content of the DNA string but on what that content implies within a suitable context - the organism to which it belongs. In that process interaction is important. Adaptability of the body type in conjunction with non-obvious genetic change - at perhaps the control or development kit (Cohen & Stewart, 1995) level of genetic organisation - interacting within the epigenetic or environment space, leads to evolution. It has to be a balancing act in which the relationship of the parts to the whole will change (ie. Boulding's definition of structural growth or change). Morphological change requires too much coherence to be driven only by a random genetic change: the integrity of the biological system is unlikely to be maintained by such changes. As Cohen and Stewart (ibid) explain[3] an initial change - such as the longer neck of a proto-giraffe, can be initially supported by a more exercised heart and muscle structure, which, along with third level genes - versatile kits - permit the animal to adapt to the longer neck. But it is likely to survive only in a state of stress. Over time genetic variation within the species permits a more adapted genotype to become assimilated within the population.

The conclusion which may be drawn from these criticisms of neo-Darwinism is that there is no simple cause-effect relationship between changes in genotype and subsequent changes in phenotype: it is a joint dynamic, which is as yet largely unexplained (ibid). The only evidence of a direct relationship is in a number of characteristics, such as hair, eyes and skin colour, which bear little observed relationship to either development or growth. Catastrophic or bifurcational change, which is at the basis of Waddington's (1974) theory of evolution, may well be the explanation for Gould's sudden burst of change (speciation) engendered by the far-from-equilibrium conditions necessary for such changes. Evolution is not random - it is not as Monod so strikingly suggested, "chance caught on the wing"[4]: perhaps in neither of the senses proposed by the neo-Darwinists, but certainly not in the weaker sense that the environment has no significant role in the epigenetic space. However, it is not deterministic in a Laplacian sense: it does not lead to finality nor a unique end state. It is self-organising: -

> "As Darwin taught us, the order of the biological world evolves as natural selection sifts among random mutations for the rare, useful forms. In this view of the history of life, organisms are cobbled-together contraptions wrought by selection, the silent and opportunistic tinkerer. Science has left us as unaccountability improbable accidents against the cold, immense backdrop of space and time.
>
> Thirty years of research have convinced me that this dominant view of biology is incomplete. As I will argue in this book, natural selection is important, but it has not labored alone to craft the fine architectures of the biosphere, from cell to organism to ecosystem. Another source – self-organization – is the root source of order. The order of the biological world, I have come to believe, is not merely tinkered, but arises naturally, and spontaneously because of these

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[3] They point out that the growth of a long neck in response to random genetic mutation would be self-defeating: in the absence of a more powerful heart it is likely to lead to heart failure (ibid, p.315).

[4] Quoted in Kauffman (1996) p.7.

> principles of self-organisation- laws of complexity that we are just beginning to uncover and understand," (Kauffman, 1996, p. vii).

A further implication of evolution as a joint dynamic is to blur the distinction between mutation and natural selection. Genetic assimilation suggests that the organism and the environment behave as a unit in evolutionary development. Environment/phenotype directed changes in DNA - perhaps as already suggested at the control or development kit level - may take place and the idea of directed germ line DNA change has been further developed by Pollard (1988). This means that the physiological processes generating mutation may themselves be engendered by selective forces in the environment so that it is not possible to determine where mutation ends and selection begins. As the distinction between mutation and natural selection lacks any form of developmental basis, a number of biologists have suggested the distinction should be dispensed with altogether. (Ho, 1988; Goodwin, 1988).

Although one may wish to maintain natural selection as separate part of evolutionary theory, it needs to be seen within the context of self-organisational change. The suggestion that evolution is at least to a significant extent the outcome of spontaneous self-organisation under far-from-equilibrium conditions offers both an explanation for how life itself may have formed, as well as a possible explanation for the evolution of complex organisms - and organs, such as the human eye. The alternative view has been put by Mayr (1960).

> ".... the evolution of the eye hinged upon one particular property of certain types of protoplasm- photosensitivity... Once one admits that the possession of such photosensitivity may have selective value all the rest follows by necessity..." (pp.208-9),

But selection cannot explain the process of change which permits photosensitive protoplasm to become a complex organ. The suggestion that such complexity could be the outcome of simultaneous random mutations (itself a contradiction in terms) which would have to occur within one generation is simply not tenable. However, the suggestion that under certain (as yet unspecified) conditions, sub-assemblies of self-organising structures could be the building blocks for ever increasing complexity, appears to provide a basis for a more meaningful research program.

(iv) Mutation within an Hierarchically Organised System.

One of the major advantages of Waddington's perception of the genome implicit in his theory of genetic assimilation, is that it is a system of hierarchical organisation - just as cells or organisms are: the "architecture of complexity" (Simon, 1962) To a physicist these are the distinguishing features of living systems - complexity and organisation (Davies, 1990, p.59). This simply reflects the point that structure, rather than direct cause-effect relationships has become the organising concept of science (Bronowski, 1976, p.112) and this presents us with two new precepts which lie outside the traditional (reductionist) perception of scientific method.

(a) Firstly, the behavioural properties of the system are not simply a reflection of its constituent parts but also the way those parts are related to one another - as in a chemical isomerism. Properties which relate to the way the system is organised rather than a particular aspect of it are emergent properties, as already pointed out in (i) of this Section. Now as Feynman (1992, pp.149-150) is at pains to point out, all matter, living and inanimate, is made up of the same atoms, so that life itself must be an emergent property:

> Life, in this view, is not to be located in its parts but in the collected emergent properties of the whole they create. It is able to reproduce itself and to evolve. The collective system is alive. Its parts are just chemicals. (Kauffman, 1996, p.24).

(b) Change needs to be seen in terms of changes in the structure of the system and not only in terms of relational responses within an unchanging system, especially where structural change is likely to lead to markedly different emergent properties.

This dichotomous nature of change brings us back to Prigogine, reinforcing the distinction made in (i) between relational responses and structural transformations of a system. What needs to be emphasised is the different - almost diametrically opposed - behavioural properties of each type of change - especially as it relates to evolutionary processes. If as Kauffman and Waddington (implicitly) suggest, self-organisation plays an important role in evolution, then following Prigogine this implies at best a limited role for optimality criteria such as "survival of the fittest". Also where existing complex structures are the building-blocks for even more complex structures then the process of change becomes path-dependent. Outcomes at any given period are likely to depend upon the previous events which led to it, rather than being pre-determined by the initial conditions (Hall, 1994). To use Waddington's example of homeorhesis, with such a pattern of change evolution locks-in on one course of development over time: history cannot be ignored. But it is important to see that history is not only important in determining the selected course of development. It is also important in determining the particular path adopted at points of bifurcation of the system - as emphasised by Prigogine and Stengers (1985).

> "The state we reach depends on the previous history of the system. Until now history has been commonly used in the interpretation of biological and social phenomena, but that it may play an important role in simple chemical processes is quite unexpected (p.161).

Now as already pointed out, the suggestion that 'history matters' in the transformation process is the reverse side of the argument that there is no universally valid law - no potential function such as 'order' (entropy minimisation) or 'fitness' - which is applicable to that process. There is therefore no absolute standard against which the 'appropriateness' of the system's performance can be gauged: they can only be judged in terms of the context within which those responses took place. Appropriateness must be largely context dependent. However, context is much more significant than a measure of appropriateness: it is the very basis for understanding the transformation process taking place. Like language, the meaning of the message sent by the chemical code of DNA can only be understood within the context that it is transmitted. In the case of language this context would be cultural: 'the culture shared by those who speak the language'. In the case of DNA it is the biological organism within which that DNA resides, that is the context.

> If the manner by which DNA code is transformed into creatures is ignored, we have no idea whatever of the possible complexity of the creature that result from a given segment of DNA." (Cohen & Stewart, 1995, p.354).

Development itself is context driven, so failing to take into account the context in which it is taking place, implies a failure to understand that process.

Now given that evolutionary change is a joint dynamic of both mutation and natural selection, it is reasonable to ask which of these two forces for change is the 'prime mover' in this dynamic - especially given the self-organising nature of mutation. Currently this is largely unknown - "we have the gravest difficulties understanding how self-organisation might interact with selection" (Kauffman, 1996, p.186). Nevertheless he does go on to suggest,

> "that self-organisation is a prerequisite for evolvability, that it generates the kinds of structures that can benefit from natural selection..." (ibid, p.188)

This is the same point made by Prigogine and Stengers (1985) when they discuss the behaviour of physico-chemical systems undergoing transformation. In describing the 'historical' path along which the system evolves (p.169), - they highlight the succession of two quite distinct processes which occur: stable periods when deterministic laws can be said to predominate and unstable periods, at bifurcation or self-organising points, when the system has the opportunity to choose between a number of alternative futures. They go on to suggest;

> "Both the deterministic character of the kinetic equations whereby the set of possible states and their respective stability can be calculated and the random fluctuations 'choosing' between or among the states around bifurcation points are inextricably connected. This mixture of necessity and chance constitutes the history of the system." (ibid, p.170).

Obviously, the 'evolvability' of this system is as much dependent upon what happens at the bifurcation point, as Kauffman's biological system depends upon self-organisation. The system needs to undergo a transformation before stable growth can proceed: form does appear to limit growth!

III. Economic Change and Organisational Theory.

(i) Structural Change vs Market Selection in Economic Theory.

The dichotomous nature of change adumbrated in Section II does not appear to be clearly developed in many areas of economic theory. Change is not 'catastrophic' but a gradual process of accretion - usually seen as the gradual build up of certain factor characteristics. This perception of 'change' is seen e.g., in Chow and Kellman's (1993) analysis of the changing composition of NIC exports to major OECD markets in terms of embodied factors and their characteristics. They feel able to claim that;

> "..... the past several decades may be understood in terms of a clear linear 'maturation' process" (ibid, p.79).

Even in areas where change is central to the theory - such as evolutionary economics - the roles of innovation and market adaptation in economic change, are not clearly distinguished. The exclusive reliance on natural selection as a basis for economic change by evolutionary games theorists (see eg Weibull, 1995, Introduction), is a case in point. However, even in Nelson and Winter's (1982) seminal work, their aim appeared to be to build an evolutionary theory of the firm, largely based on natural selection. Instead of optimisation, they propose decision rules or routines which are both regular and predictable (ibid, p.15). These routines determine the firm's market performance and given that these routines will vary between firms, we have both the variation and replication required for neo-Darwinian selection. Thus routines act as the genotype, through which the population of firms can evolve. Nevertheless, Nelson and Winter do allow for occasional change to occur, through modification of the routines when a firm institutes a search program in response to perceived inadequate performance. Their theory therefore

> "contemplates both the inheritance of acquired characteristics and the timely appearance of variation under the stimulus of adversity." (ibid, p.11).

Although this variation has some of the properties of Prigogine's and Kauffman's self-organising models - viz. irreversibility, uncertainty and path-dependency (p.172) - it represents adaptation to market conditions. Although claiming inspiration from Schumpeter's work, Nelson and Winter's model is markedly dissimilar from the concept of economic change embodied in theory of development, which as Schumpeter argues, takes place outside the general operation of the market system.

> "... the explanation of the development must be sought outside the group of facts which are described by economic theory. Nor will the mere growth of economy.... be designated as a process of development. For it calls forth no qualitatively new phenomenon but only the process of adaptation of the same kind, as the changes in the natural data." (Schumpeter, 1934, quoted in Hanusch, 1977, p.97).

Thus the difficulty with Nelson and winter's specification of economic change is that it does not allow of a separate cause quite distinct from the operation of market selection. Indeed in the formulation of their model (Nelson and Winter, 1982, Chs. 12 and 13) adaptation has all but been absorbed into the process of market selection. Virtually all economic change is therefore assumed to flow from market operations so that no interaction between innovation and selection, along the lines suggested by Section II, is possible.

This could well be because - as in biological evolution - the two tend to interact and may therefore not be defined as separate forces acting for change. In particular, adaptation may be seen as a quite separate mechanism from natural selection (Vromen, 1995, Ch.6), especially where the diffusion of technology embodies similar self-organising properties (Silverberg, Dosi and Orsenigo, 1988) to those shown by technological change. The diffusion of innovation is therefore sometimes seen as almost the sole mechanism for economic change. One would certainly have to agree with the previous authors that the diffusion of new products and new processes of production ..... is clearly one of the fundamental aspects of the process of growth and transformation of contemporary economies". (ibid, p.1032). And as Utterback (1994, Ch.2) has shown, the emergence of a dominant design is associated with a dramatic falling away in the number of competing firms as market selection weeds out those whose innovational activities are inconsistent with this new standard. Nevertheless a careful distinction needs to be made between the process of technological, including organisational and institutional innovations, which actually lead to changes in market structures and the consequent processes of adaptation and selection which then take place. Even where a large proportion of productivity growth results from individually small movements in innovation - as in the case of Du Pont's rayon plants (Rosenberg, 1982, pp.67-8) - it is difficult to see the success of that program separately from the major organisational innovation the company went through in the post World-War I period. Indeed the dependence upon a preceding major innovation is stressed by the author (ibid). An attempt will be made to develop this distinction between adaptation and innovation by comparing the implications of Williamson's transaction costs approach to organisational change, with Chandler's historical account.

(iii) *The Role of Organisation in Economic Theory.*

Given that living systems can be defined by the characteristics of complexity and organisation, any non-mechanical theory of economic change would need to take some account of organisational change. Traditionally, economic theory has displayed little interest in developing a theory of organisational, as distinct from market co-ordination and determination of economic activity, despite its obvious importance in the course of economic development. One only has to cite the role of the transformation of textiles from a cottage to a factory industry in the industrialisation of England in the 19th Century, to be aware of its significance. By 1850 the industry had become wholly factory based, output had increased 100 fold although employment had not changed: male employment on the other hand experienced a "massive meltdown" as the Cambridge Economic History of Europe described it (vol.7, pt 1, p.133). The great waves of increasing output, especially from 1820-40 need to be seen in the context of the radical re-organisation the industry was going through. Technical innovations (such as the introduction of the power

loom) and the dramatic increase in productivity and capital:labour ratios, were all closely linked to the organisational transformation the industry underwent.

More recently, organisation has come to play an increasing role in theories of economic change and especially in innovation theory - a marked change in emphasis being reflected in what is called the 'new theory of firm' (Vromen, 1995).

> "One of the main purposes of this new theory is to shed light on the internal organisation of firms.... Whereas the old theory analyses industry behaviour as the result of firm behaviour the new theory studies firm behaviour as the outcome of the behaviour of individual participants." (ibid, p.41).

The forerunner of this new perception of the firm was Coase (1937) who suggested that the firm is an organisation in which market type, voluntary exchange transactions, have been replaced by the authoritative directives of the 'entrepreneur-co-ordinator'. The justification Coase gave for replacing the price mechanism by authoritative direction is the cost-saving advantage the latter has.

However, the idea that the firm is an alternative to market co-ordination characterised by its authority and disciplinary action has been criticised by Alchian and Demsetz (1972) and Jensen and Meckling (1976). They suggest, the "behaviour" of the firm is like the behaviour of the market; ie. the outcome of a complex equilibrium process (ibid, p.311). Jensen and Meckling's perception of the issue is that, because of the separation of ownership and control, there is a need to ensure that the behaviour of the managers (the agents) is consistent with the interests of the owners (shareholders). This problem cannot be resolved without incurring 'agency costs', but these costs are capitalised in the equity value of the firm so that the lower the agency cost the higher its equity value. Thus a reduction in agency costs would benefit both managers and shareholders (assuming managers have some equity participation in the firm). Thus it is the operation of efficient equity markets which will monitor the behaviour of the managers: not the shareholders. Alternative mechanisms for monitoring agency costs proposed by Fama (1980) included the labour market management salaries and as a last resort (because of the cost involved) the threat of takeover. These views all have in common the idea that "firm relations are nothing but a continuation of market relations" (Vromen, p.47). There is no role for authority and direction.

(iii) Williamson and Transaction Costs

Williamson takes up Coase argument that the firm is essentially different from the way the market functions. It serves the same function as the market, viz economising on costs, but it does so by a quite different method: by "hierarchical governance structures'. Authority and hierarchy are the fundamental distinguishing features of *intra*-firm relationships. Williamson therefore believed that Coase's critical contribution was to perceive economic organisation in institutional terms.

> ".... Coase proposed that firms and markets be considered alternative means of economic organisation. Whether transactions were organised within a firm (hierarchically) or between autonomous firms (across a market) was thus a decision variable. Which mode was adopted depended on the transactions costs that attended each." (Williamson, 1985, pp. 3-4).

Thus transaction costs are located not only in market exchange - as was implied by Coase - but also within the firm ie. in intraorganisational transactions.

Williamson's transaction costs rest on two behavioural concepts - opportunism and bounded relationality. Opportunism he initially describes as the condition of 'self-interest seeking with guile' (ibid, p.30), a concept derived from Arrow's linking of market failure with the market's inability to capture all the relevant information to parties involved in a particular transaction. It therefore, "refers to the incomplete

or distorted disclosure of information, especially to calculated efforts to mislead, distort, disguise, obfuscate or otherwise confuse." (ibid, p.47). Opportunism is 'attenuated' by the ability of one party to choose not to transact business with another, a condition which may be provided by the market. If it does so, there would be no opportunism and hence no need for internal organisation. Opportunism is therefore necessary, but not a sufficient condition for internal organisation, because it only creates a transaction cost in the presence of incomplete information - what Williamson calls bounded rationality (the term derived from Herbert Simon's work). If agents possessed unbounded rationality - there were no limits to their cognitive competence - they would simply avoid entering into transactions with those prone to 'self-interest seeking with guile'. Williamson believed that the insights gained from the transactions cost approach arose from the linking of these two concepts of opportunism and bounded rationality. As he claimed:-

> "Transaction cost economics pairs a semi strong form of cognitive competence (bounded rationality) with a strong motivational assumption (opportunism). Without *both*, the main problems of economic organisation with which this book is concerned would vanish or be vastly transformed." (ibid, p.50, author's emphasis).

However, given that markets may permit business decisions to be made in an adaptive sequential manner rather than having to resolve the contingent claims of all the contracting parties simultaneously, bounded rationality is not even a necessary condition for " internal governance" of economic activity. In addition, if opportunism can be attenuated under competitive conditions, what can justify the relevance of internal governance? The answer Williamson suggests is the presence of asset specificity: it is opportunism and bounded rationality in the presence of asset specificity that gives rise to the need for internal governance. This is because the inability to redeploy certain assets (both human and physical) without specifying production value, implies that the movement from the *ex ante* to the *ex post situation* changes the nature of the transformation from competitive to monopolistic. Williamson calls this transformation the fundamental transformation:-

> "... a large numbers bidding condition at the outset is effectively transformed into one of bilateral supply thereafter." (ibid, p.61).

Thus it is the nature of the transaction which will determine the appropriateness of the particular form of governance to be adopted. Under conditions of fundamental transformation, opportunism in the presence of bounded rationality could generate high transaction costs if the market mechanism was employed to deal with asset specific transactions. In this context it may be in the interest both of those who own and those who buy or rent assets, to join in vertical integration because it would remove the 'hit-and-run' element in the post-contractual period. In other words the contractants are protected from destructive market imperfections under internal governance which establishes its own internal orderings which comprises the 'appeal court' for the settlement of conflicts and disputes.

Internal Governance and Survival of the Fittest.

Although Williamson, unlike Alchian and Demsetz, Jensen and Meckling and Fama, does not accept that internal governance is an extension of the market, he does accept that, like the market-based explanation, internal governance is efficient. Those structures are efficient because they have survived in competition with other structures. According to Williamson they produce at lower transaction costs and therefore outcompete and hence supplant those structures with higher transaction costs. Thus all these writers on the 'new theory of the firm' accept the concept that existing organisational forms prevail in a competitive world simply because they are the most efficient: a case of 'survival of the fittest'.

This apparently 'Panglossian' view of organisational structures was criticised by Granovetter (1985) as well as Dow (1987). Granovetter argued that Williamson's assumption of Darwinian natural selection was simply an unsubstantiated article of faith (1985, p.305). Dow on the other hand criticised Williamson's arguments for efficiency on the grounds that they were inconsistent with his own behavioural postulates of bounded rationality and opportunism, because they did in part hinge on the 'intentionality' of the participants and the idea that bounded rationality might itself be bounded, by the ability to learn. Dow also criticises Williamson's claim that the market competition provides an analogue for Darwinian natural selection, suggesting that perhaps selective outcomes may well be inefficient - reminiscent of the 'Panda Principal'[5].

However, it may be maintained that Williamson's argument is not Panglossian in the sense that the efficient form which survives depends upon which particular organisational forms are actually tested. Thus his weak-form selection may simply entail survival of the fitter rather than survival of the fittest. (Vromen, 1985, p.60) This is somewhat different from, eg, Jensen and Meckling whose market extension theory suggests a much stronger form of the selection argument. Williamson uses Chandler's (1962, 1977) account of the development of the multi-divisional structure (the M-form) to illustrate how a less efficient structure is replaced by a more efficient one. The M-form structure supplanted the U-form (centralised functionally departmentalised) structure, bringing with it not only the anticipated 'economising on bounded rationality' but also the unanticipated reduction in sub-goal pursuits, thereby reducing the significance of opportunism. U-forms defects are spelt out as follows: -

> "In the language of transaction cost economics, bounds on rationality were reached as the U-form structure labored under a communication overload while the pursuit of sub-goals by the functional parts (sales engineering production) were partly a manifestation of opportunism." (Williamson, 1985, p.281).

However, Williamson is locked into a view of change as adaptation to an economic environment that leads to greater efficiency. The process of change which he emphasises and wishes greater research effort in, is the process of selection.

> "To be sure, as more well-developed theory of weak-form selection - when it works well and partly - is greatly needed. The important work of Richard Nelson and Sydney Winter not withstanding much remains to be done to assess the efficacy of the selection process." (1988, p.177)

As Lazonick (1991) point out this is not the perception of organisational change which Chandler was using as the basis for his understanding. Rather than suggesting that it was the markets which shaped business organisation, Chandler (in 1962, 1977 and 1990) was strongly suggesting that it was the business organisation which was shaping the markets. Chandler is describing the organisational component of the sorts of structural transformation which underpin economic development: the radical transformation outlined in Section II.

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[5] The panda's thumb is often cited as the classical example in biology of an inefficient but workable solution. It is not a thumb but an enlarged wristbone and therefore not an opposable manipulating digit but nevertheless quite adequate for stripping the leaves from a bamboo stalks as they are run between the panda's fingers and the thumb (Gould, 1990, Ch1).

Innovation vs Adaptation.

The differences inherent in the two approaches is readily seen from Chandler's analysis of Du Pont's change in organisational structure. Du Pont's initial use of the U-form structure was extremely successful: it enabled the company to manage the dramatically increased activity associated with World War I.[6] The success appears to have been associated with two main factors -

(i) A management system which permitted the distinction between organisational and departmental issues with the delegation of decision-making on departmental issues to the functional heads. The management system was adopted from Pennsylvania Railroad.

(ii) The second factor was the development of an innovational financial management system involving the measurement of the return on investment.

> "... it provided executives at both central and departmental headquarters with an accurate standard with which to appraise each operating unit's performance..." (Chandler, 1962, p.47)

and which he saw as a measure of 'economies of speed'. Lazonick (1991) was extremely critical of Williamson's inability to see the significance of this measure;

> "... more than six decades after Brown's ROI formula had been brought into the service of the [U] industrial enterprise, Williamson saw fit to contend that "economies of speed remain unspecified" (p.251).

After the war Du Pont found itself not only with considerable excess capacity and personnel but also with large amounts of investable funds, so the company embarked upon a program of product diversification into those areas of the chemical industry in which it is now a household name. However, despite their common technological base, these new product lines had to be sold on either new or at least very different markets. An organisational structure which had been developed to make and sell a single product line was not necessarily appropriate in this context. As Lazonick points out:

> "Du Pont's top managers came to realise that as in the case of explosives, the success of *each* new and different product line required its own *unified* organisational structure to plan and coordinate its vertically related processes of production and distribution." (ibid, p.252-3, author's emphasis).

As Williamson quite rightly pointed out, this situation generated a 'communication overload'. However, it was not the organisational structure *per se* which generated that overload, but Du Pont's decision to embark upon a program of product diversification. It was the need to find new outlets for their excess resources that generated the strains for the existing organisational structure and the pressure to search for an alternative. Williamson's explanation - 'economising on bounded rationality' - does not seem consistent with the nature of the organisational change which took place in Du Pont. It appears to imply a given level of bounded rationality - akin to economising on source resources - where the problem is seen as the most effective (efficient) way of living within those *given* constraints. The aim of innovational behaviour is not to accept such constraints as given, but to change the structure of the systems relationships (in this case the organisation relationships) and so remove the constraints.[7] Thus although

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[6] Du Pont's sales (of the main product) increased by 5,400%, while its labour force grew by some 1,600% although it [illegible] increased by only 275% (Lazonick, 1991, p.251).

[7] [illegible] existing organisation - in much the same way as the introduction of the U-form structure overcame the [illegible] existing prior to that change.

Williamson appears to accept the M-form introduction as an innovation (Vromen, 1995, p.61) his framework is not applicable to innovational behaviour.

A perhaps more important difference between Williamson's and Chandler's approach lies in their respective treatments of asset-specificity. To Williamson it is one of the conditions which *causes* market failure and hence the need for internal governance. Such a view is quite inconsistent with an innovational view of asset-specificity: this sees it as the *result* on outcome of technical[8] change. The firm in deciding what new product or process innovations to develop, will determine the technical conditions it will need to employ in order to successfully introduce that innovation: ie. it needs to develop the productive resources required and those resources or assets will be specific to the firm which has organised them: Certainly at least initially and probably for quite a considerable period, their subsequent developments will tend to ensure they remain specific to the firm developing them. This point may be illustrated using Ford's development of the Model T. When Ford embarked upon his dream to make every American farmer the owner of an automobile one of the means he adopted to do this was to re-organise the process whereby automobiles were produced. To Graves (1994) this:

> "... required basically two things: first mass production assembly work and specialised labour, with its ensuing economies of scale and second precision made interchangeable components." (pp.213-14)

But this appears to miss the point of what was actually required. Ford's underlying problem was to organise production on a continuous basis rather than designing the process around the machines used and this required designing the machines that would fit into that continuous production process. It would then permit the machines to be automatic.[9] It was as part of this introduction of a continuous production process that the moving production line (adopted from the meat packing industry) and precision interchangeable parts (adopted from Cadillac) were introduced. These cannot be seen as isolated technical events, but part of an interrelated production system. Despite being borrowed from other industries and firms, these features were an integral part of Ford's particular production system and therefore specific to it.[10] It therefore reflected the development of a highly asset-specific production process. As Lazonick (1991) contends,

> "... *asset specificity is not a cause of 'market failure'* as Williamson has contended, *but an outcome of 'organisational success'.*" (p.218, author's emphasis).

The production process which Ford developed, was closely linked to the organisational structure he established. That organisational structure was highly interactive: -

1. Ford developed a high level of internal competition by refusing to precisely define responsibilities. The organisation was therefore characterised by a high degree of internal conflict, especially between Couzens - the bottomline watchdog - and Ford himself who at least in his initial years, appeared very keen to improve the vehicle.

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[8] In this paper technical change incorporates only the technical aspects of technological change. Technological change embodies both the organisational and the technical aspects because both are required to bring about a structural transformation (see Section II). Chandler's definition of technological change appears to exclude organisational change and therefore appears to be same as my technical change.

[9] This was incidently the same problem faced by the U.S. steel industry in the early 1980s.

[10] Even the interchangeable part system borrowed from Cadillac had to be adapted for a quite different end or purpose.

2. The administration of activity was highly interactive: both Ford and his senior engineers interfaced directly with the various divisions of the company. They formed what were eventually to become called 'skunkworks' where,

> (i) Management/engineers operate on the basis of rough drawings rather than detailed designs.
>
> (ii) They then have to interact with the machinists on the factory floor rather than a production department in order to introduce the design.

3. Management involved people with wide range of backgrounds and skills. According to Nevins and Hill (Ford's biographers), "The largest single role in developing the new system however was played by this university trained thinker (Avery) so recently brought in from his schoolroom." (Quoted in Klein, 1977, p.98).

This is of course simply the point made in Section II - that increasing complexity and organisation must evolve together - a view endorsed by Teece (1993) when he suggested that, "Chandler would undoubtedly agree that technologies and organisations, co-evolve. (fn, p.211).

The implication of this interdependence is that outcomes are likely to be an *emergent* property of the way the production system is organised: they cannot be attributed solely to any of the particular technical conditions comprising that system. Teece (ibid) shows how Chandler (1990, p.15) has embraced this perception:

> "... the modern industrial firm is basically an organisation that has developed capacity, through complex hierarchy, to make the activities and operations of the whole enterprise more than the sum of the parts." (p.200).

However, this particular perception is by no means consistent throughout Chandler's work.

> "The critical entrepreneurial act was not the invention - or even the commercialization - of a new or greatly improved product or process. Instead it was the construction of a plant of the optimal size required to exploit fully, the economies of scale or those of scope or both." (1990, p.26).

Such a perception seems to suggest that the technical condition can exist independently of the organisational structure: they are simply awaiting the appropriate structure, to be realised. Now although the technical conditions may well exist in other industries - as in the case of Ford's transformation of the automobile production process - they do not exist *ex ante* for that particular industry. Those conditions have to be 'created' and the organisational role in that process is vital - as again illustrated by Ford. To fail to distinguish the ex ante and the ex post situations confuses two rather distinct stages - firstly, 'creating' the technical conditions required to underpin the transformation of the production process and secondly, the establishment of the operating plant which actually embodies all those innovations. The first stage took something like 8 years, but it was not until 1921 that the second stage was achieved with what (Chandler (1964)) referred to as the "fully integrated behemoth at River Rouge". This plant enabled Ford to increase output and hence sales from 845,000 in 1921 (approximately 56% of the U.S. market) to 1.7 million in 1923 (about 46%). (ibid, p.3).

Nevertheless 1927 saw Ford's share of the automobile market plummet to less than 20% and the company haemorrhaging badly. The problem was that Ford had shut out any process of change from his rigid hierarchical structure at River Rouge, so that he was unable to read the indicators of change despite the increasing competition coming from 'enclosed' second hand cars. Then in 1923 Dodge introduced the all steel enclosed automobile and by 1926 80% of all autos were of this type (Utterback, 1994). Lazonick

(1991) suggests that this problem was not due to the high degree of vertical integration but to "failure to plan and co-ordinate the movement into new models and methods" (p.247). However, it is suggested that these two are interrelated but this issue will need to be returned to in the next section.

Just as Chandler does not accept that the technical conditions required to generate the 'economic of scale and scope' do not evolve independently of organisation, so he does not accept the market as shaping or determining business organisation. Teece's (1993) summary of Chandler's thesis (derived from Scale and Scope') is;

> "... that the business firm and its managers are not merely reacting to broader technological and market forces, rather they are shaping technological development and market outcomes. Firms are not simply agents of the market; rather, markets are also agents of the firm." (p.223).

This is a dramatically different view from that of Williamson and the other developers of the 'New theory of the Firm' outlined in Section III, (ii) and (iii) above. Williamson believed it was the market which was instrumental in selecting the appropriate organisational form, his 'main case' proposition being that;

> "... economic organization has the main purpose and effect of economizing on transaction costs. According to this hypothesis, governance structures are aligned with transactions in such a way as to effect a transaction cost economizing result." (1985, p.17).

Economising an transactions costs is precisely what the firm does not do when it incorporates economic functions within its own organisational structure. What it permits a firm to do is to use resources in such a way that is not necessarily consistent with market strictures but is consistent with the firm's perceived technological priorities. It is for this reason that firms have tended to maintain R & D - perhaps the most important element of technological change - in-house, rather than contracting that activity out to stand - alone R & D institutes linked to the firm through market relations. In a similar way Japan's firms maintain their own firm or even plant based system of pay incentives rather than employing market generated pay scales. (Aoki, 1990, p.13). Japanese firms are looking for particulaar problem solving and communication skills which relate to the organisation of activity in the particular firm/plant, and these skills are highly appreciated and valued. Market-based pay rates would have no relationship to those firm-based values, so they cannot be used. Thus once again, at a pivotal point in the nexus between the firm and economic activity, it is the firm's 'internal governance' rather than the market, which determines the nature of that nexus.

The final point in demonstrating just how different Chandler's understanding of the process of change is from Williamson's, is the issue of path dependency: Teece (1993, pp. 214-15) emphasises how important path dependency is within Chandler's (1990) framework. This phenomenon is reflected in the results of Chandler's (1990) study, in the high probability of firms which were the leaders in their industry in 1917 (ie. first or second place), being similarly ranked at the end of the period in 1947. In the case of the U.S. the survival probability was estimated at 57%, (Teece, 1993, p.215). This behaviour pattern was clearly reflected in Du Pont's performance, where the U-form organisational structure enabled them to cope with the dramatic expansion generated by war-time demands and how the company was then able to adapt to post-war conditions by transforming that organisational structure, permitting it to take advantage of the war-time build-up of resources to develop into new products and markets. Nevertheless as Ford (and U.S. steel) showed, being the leading innovator within an industry did not automatically entail an unassailable position. Now although the argument frequently made about path dependency is that it can lead through "lock in" to less efficient forms of production (Arthur, 1988, 1989) this is not the point here. The underlying issue is whether path dependency is more likely to be associated with adaptation or innovation. As pointed out in Section II and as also suggested by the definition at the beginning of this paragraph,

path dependency is much more likely to be consistent with the 'perception' of change as radical transformation rather than gradual adaptation.

Thus Williamson does not recognise the role of technological change in the development of the U.S. economy; indeed he specifically rejects the idea. When commenting upon Chandler (1977) he asserts;

> "Suffice it to observe here that strategic behaviour mainly has relevance in dominant firm or tightly oligopolistic industries. Since most of the organisational change reported, occurred in nondominant firm industries, appeal to strategic considerations is obviously of limited assistance in explaining the re-organisation of American industry over the post 150 years." (ibid, p.128)

The new theory of the firm reflects a pre-occupation with the assumed over riding importance of the market in determining economic outcomes: it is a framework which views change as largely the outcome of Darwinian natural selection. Chandler (1990) shows how such a conceptualisation of change is totally inadequate, not only in explaining the development of the U.S. economy, but more particularly in explaining the much slower development of the British economy. Indeed Teece (1993) suggests that the British failure to make the critical investments in production, distribution and management actually makes Chandler's case for the pivotal importance of organisation in bringing about those investments - a view echoed in Elbaum and Lazonick (1986).

> "what British industry in general required was the visible hand of co-ordinated control, not the invisible hand of the self-regulating market." (p.10).

The implications of this view of the determinants of economic development for the role of economic policy, will be touched on in the final section.

V. Beyond 1970.

Chandler's studies (1962, 1977, 1990) have brought home the importance of technological change in economic development and more significantly, the importance of organisational change in bringing about the technical conditions necessary to underpin that development. To Chandler the key is the organisational capacity to be able to invest on a sufficient scale in the three key areas - production, distribution and management - which will enable those technical conditions to be put in place. This had two important implications for him -

(i) those who innovated early stole a march on their competitors and largely remained the industry leader;

(ii) the organisational form most conducive to that innovational behaviour was a managerial hierarchy.

neither of which is necessarily correct. To some extent Chandler was a victim of the particular historical period which his study covered. The main weakness is his assumption that a strictly hierarchical organisation is essential for achieving the required economies. This is incorrect, in that it is probably only valid for the period after the dominant design (Utterback, 1994) stage of development has been reached. Prior to that stage a highly flexible organisational structure is likely to be much more conducive to the innovational behaviour required - as illustrated by Ford's organisational structure during the development of the Model T. (See p. 16-17 above). However, what Ford failed to recognise was that although his innovation transformed the automobile industry from a craft to a mass production system (Graves, 1994) the Model T was not the ultimate form of the dominant design. That required Dodge's introduction of the

all metal body (Utterback, 1994) and Ford's refusal to recognise that change almost cost him his company. The point being emphasised here is that technological change is all about introducing a process of change through firm re-organisation - illustrated by the very different responses of Du Pont and Ford.

The shortcomings of the hierarchical system became obvious with the changing economic environment of the early 80s; associated with the increasing inroads of Japan into the U.S. economy. Although by no means restricted to automobiles, the effects are starkly shown by that industry. By 1986 automobile production in North America was some 14% lower (in unit terms) than 8 years earlier, while Japanese exports, mainly to the North American markets roughly doubled over the 80s. (Graves 1994 Tables 16.2, 16.4) The problem was that the flexibility introduced into the organisational structure by Ford in its development phase had completely disappeared from the industry. Productive activity was split into separate compartments: R & D, involving both the design of new models and the machinery to produce them, was completely divorced from the factory floor where those models were to be produced. A detailed set of instructions and scheduled for mass producing the new product were then sent to the factory floor. The effect of this form of industry organisation was devastating. Although it was supposed to be geared to minimising the down-time of the extremely expensive plant equipment, it had the opposite effect. The lessons of the teens and twenties had obviously been lost. This compared with the 'lean' machine of the Japanese production system, described by Womack, Jones and Roos (1990) in their epoch- making story of the automobile: 'lean' because; -

> "It uses less of everything compared with mass production - half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects and produces a greater and ever growing variety of products." (p.13).

The differences in the performance of the respective Japanese, U.S. and European automobile industries were analysed in a research program carried out by Clark and Fujimoto of Harvard Business School, from 1983-1987. The findings were briefly summarised by Graves (1994) and show that: -

> "Japanese producers take forty seven months to design a new vehicle compared with sixty months in the U.S. and Europe. In addition, the Japanese producers use 1.7 million engineering man-hours whilst the US and European producers employ 3.1 million to develop a similar vehicle. Furthermore, they claim that US and European firms employ 903 engineers during the development process, as opposed to 485 by their Japanese counterparts. The efficient organization of product development not only requires fewer engineers over a shorter period of time to complete the same task but also results in a much lower staff turnover." (p.221)

It was the way the Japanese organised the training management and motivation of their workforce that constituted the key difference between themselves and the way U.S. firms were organised.

(a) The percent of the workforce in teams: Japanese firms in Japan and America were roughly four times greater than American firms.

(b) The number of job classifications were approximately 5 1/2 times higher in the American firms than Japanese in Japan and 7 1/2 times higher than the Japanese firms in the United States.

(c) The time spent on training workers, both in the Japanese firms in Japan and in the U.S. was roughly eight times what it was in American firms. (MIT Study by J.D. Power and Associates, Quoted in the *Economist*, August 10th, 1991, p.61).

The implications of these differences are that Japanese firms co-ordinate their work through horizontal rather than an hierarchical form of organisation. This horizontal co-ordination amongst operating units is based upon knowledge sharing and not upon skill specialisation and requires nurturing information processing skills and communication abilities, achieved largely by learning by doing and work related training. These skills are only achieved in the context of the firm or plant's network and therefore do not require a skill classification for new entrants. The implication is that the firm is not looking for market-based specialisation or skills as already pointed out (p.18) It is suggested that the development of in-house organisational structures which permit major innovational transformations - in this case the movement from a mass to a flexible production system capable of reacting quickly to changing consumer demands - relates more to Chandler's perception of the role of organisation than it does to Williamson's perception of transaction cost minimisation. Organisational change is much more clearly related to the sorts of radical transformation associated with technological change, than to the gradual process of change brought about through market selection. Thus in this regard Chandler's thesis remains intact, despite the change to management hierarchy that has evolved; and it may well remain intact in the event of further organisational changes. The horizontal form of organisation within Japanese firms need be no more permanent than the vertical form which Chandler (1990) saw as so successful in Europe and North America: it may not be uniquely superior for all forms of technical change. The orientation of this form of organisation towards an in-house knowledge and learning base as well as consensual decision-taking, may make it inappropriate for pursuing a break through innovation requiring an entirely new organisation of its R & D - as could perhaps be the case in a new field such as bio-technology.

VI. Conclusion.

Using the distinction provided by biology, between natural selection and mutation, offers a distinction between alternative ways of perceiving the causes of economic change - market selection or technological change. An important point to emphasise is that these two distinct types of change embody quite different behavioural properties - the first, law - like and stable, the second self-organising and a context within which history matters. A second point to emphasise is that it is the interaction between these two processes which determines outcomes although neither Prigogine nor Kauffman specifies the form that interaction might take. Indeed Kauffman (1996) emphasises in the case of biological evolution, that interaction is by no means clear: "we have the gravest difficulties understanding how self-organisation might interact with selection" (p.156). Given the present lack of understanding as to how the two types of economic change might interact, interaction could not be the focus of a paper of this nature. Instead the focus has been to show how these different perceptions, as they relate to the role of organisation in economic change, can arrive at totally different conclusions - Williamson claiming that strategic effects (the effects of firm behaviour on market structure) are only of limited explanation of that change (see p.25) while Chandler claims that strategic effects actually shape the market structures. Williamson is adopting an approach common in economics, which examines change from purely adaptive or market selection perspective. However, as Chandler has amply demonstrated, this ignores those changes introduced through the structure modifying behaviour of firms themselves. Insofar as Williamson uses the evidence presented by Chandler, as in the shift from U to M form organisation, his explanation of the change is a definitional outcome derived from his model: quite misleading in terms of the process of organisational change that actually took place. The evidence which Chandler presents for the

overwhelming significance of the structure modifying behaviour of firms themselves, is itself overwhelming: it appears that form, without structural change, may indeed limit growth!

If Chandler's view of the role of organisational change and the co-evolution of technical capacity is correct there are extremely important implications both for evolutionary theory and for economic policy. Organisational structures, rather than routines, become the inheritable basis of economic behaviour in the sense that changes in organisation become the basis for changes in economic behaviour - as instanced by the textile industry during the industrial revolution in England, by the pattern of industrial development in Europe and the U.S. during the 20th Century and by the response of the U.S. auto and steel industries to Japanese competition in the 1980s and that once in place those organisational structures appear to be 'locked-in' for a considerable period[11]. Routines only operate within the context of a given industry organisation: organisational change is not the outcome of routine rules. The examples of both Ford's and Du Pont's behaviour strongly support Teece's (1988) contention that "the creative part of research is at least partly ad hoc" (p.265). It is only after the innovational project has been successfully introduced that routines are likely to be developed - again as reflected in Ford's behaviour: "routines characterise efficient post-development behaviour in production, marketing, distribution and sales" (ibid). Thus, when structural change occurs, the organisational transformation associated with it will bring in its wake major changes in firm's routines. The search for new routines Nelson and Winter (1982) refer to are likely to lead to only limited changes in routines within the existing organisational framework - more akin to the somewhat limited biological evolutionary process of adaptive specialisation (Dunn, 1971, Ch.II).

The implications of Chandler's view for economic policy are very significant indeed. Obviously, simply setting the macroeconomics conditions for improved competitiveness would not be sufficient to increase the propensity to innovate. Indeed Chandler's perception of change appears to be quite the opposite: it is the co-evolution of organisational capacity with improved technical capacity which will bring about market competitiveness - not vice-versa. There are two important implications that flow from the conclusion.

1. The first is that organisational transformation helps explain the "Myth of Krugman's Miracle" (Krugman, 1994): the ability of labour and capital resources to "miraculously" transform themselves into new competitive industries (as in the case of the NICs). As the examples referred to in the paper illustrate, the supply of those resources is not a sufficient condition of itself for their absorption either into new industries - as in the case of Du Pont - or into existing industries - as in the case of the British textile industry during the industrial revolution, without an associated firm/industry organisational transformation. By attributing the growth of output to the increase in factor employment we are simply conferring an effect with the status of a cause and therefore underestimating the effect of technological change. Metcalf (1997) has suggested that its contribution to economic growth might be better measured by the increase in output per person on the grounds that without growth there would be no capital deepening and without technological change there would be no growth. This view has been given some empirical support from Anne Carter's (1970) analysis of structural change in the U.S. economy when she suggests a tendency for capital productivity to change in line with, but to a less extent than, labour productivity, although this association is far from clear from the data she presents (vide, pp. 143-145).[12]

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[11] In terms of Freeman and Perez's (1988) model of technological it appears to be for the period of Kondratief cycle.

[12] This criticism ignores all the aggregation problems associated with the use of the aggregate production function in growth accounting. However, if the conceptual basis - the early Solow models (1956, 1957) - is not applicable as the subsequent

This suggests the need to build organisational capacity along with technical capacity within a program of industry-biased incentives - reminiscent of Korea and Taiwan's government/industry co-operative programs. This of course raises difficult questions on the appropriate role of government in the formulation of development policy, although, it does appear that Western thinking on this issue may be undergoing some change - as much because of the experience of the NICs as anything else. Of course the lesson of Section II - that history matters - implies that any development program will need to be formulated in the light of the particular institutional limitations existing in that country: the experience of a Korea as Taiwan are not directly applicable to a Philippines,. Nevertheless within the context of the Board of Investments' 'flagship industry' framework greater focus on organisational and improved technical capacity, especially in those industries which are potential domestic suppliers to new developing export sectors. Policies are therefore going to be industry-biased, which suggests at least to some degree ignoring the myth of the level playing field. In a world of rapid technological change there is no such thing as a level playing field.

2. The analogy suggested by both the physics and the biological frameworks is that development and growth interact to generate the pattern of change: the implication for developing economies being that without technological change, economic growth is not sustainable, barely a contentious statement even to the most die-hard neo-classicist. What is much more contentious is the implication that the quite different behavioural properties underlying growth and development might have for economic theory. Just as an accelerated rate of natural selection is unlikely to lead to an increased rate of genetic mutation, so improving the competitive conditions for market selection is unlikely to increase the propensity to innovate. It is suggested that this is precisely what Chandler's comparison of economic development in the U.S. and Europe clearly highlights: improving the effectiveness of the 'invisible hand' will not increase the rate of technological change. Even though increasing the effectiveness of the market mechanism may well facilitate the diffusion of innovations that have already occurred,[13] if technological change is not taking place improving market conditions alone is unlikely to significantly alter that situation.

What this implies for a country like the Philippines which at least up until the early 80s, has shown an extremely limited rate of technological change as reflected in its extremely poor productivity performance (IBRD, 1980; De Dios, 1984; Hooley, 1985) is that the market movement towards a more market based policy framework since 1980, is unlikely to have a significant effect upon the rate of technological change. That is the post 1990 growth rates are unlikely to prove to be any more sustainable in the 90s, then the pre-1980 growth rates were in the 80s. Of course not all policies aimed at improving competition will impact only upon market conditions. Privatisation of public monopolies which have been markedly backward in innovating may well lead to improved organisational along with technical capacity - as appears to be almost universal in the case of

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'wave' of endogenous growth models have suggested (although of course not for the reasons presented here) then even in the absence of aggregation problems the model is still invalid.

[13] A interesting example of where the failure to use the market mechanism may have inhibited the diffusion of a new technology is in the case of water supply, under the National Irrigation Authority, to irrigated palay forms in the Philippines. Instead of using the individual schemes as their own profit centres, they have been used as a funding basis for a large centralised staff and their equipment, for the planning of new schemes. This has been a significant factor contributing to the inadequate funding of the maintenance of existing irrigation schemes, with a consequent gradual erosion of the 'green revolution' technology in irrigation-dependent areas.

telecommunications privatisation. But it is the increased organisational and technical capacity which is the key to more productive performance, not any increase in competition. The Philippines failure to embody virtually any technological change in their post World-War II economic growth record implies the need to focus on that economic issue - not on any other in the hope of spin-off in terms of increased innovative behaviour.

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