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Economic Growth Theory: A Tail of Two Paradigms

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Abstract: This paper outlines the conceptual problem which lies behind the research program, '*Technological Change as a Determinant of Sustainable Growth: A Case Study of the Philippines* currently being undertaken by the author at the School of Economics. It shows how current growth theory tends to tail or follow two quite distinct physics models - one of thermodynamic equilibrium the other of non or rather far-from-equilibrium thermodynamics. These perceptions of growth are dramatically different, the first seeing changes in industry structure as one of the epiphenomena of growth and not central to it. The second model sees such structural change as central to the process of growth; indeed growth itself is held to emanate from structural change which in turn is the outcome of technological change. The apparent contradictions in these alternative perceptions of growth are ignored in practice, both being used simultaneously to measure structural change within an economy. By examining an economy which although showing a quite reasonable rate of growth in the 50s 60s and 70s but nevertheless has shown an extremely low rate of productivity increase, it is hoped to cast some light on which of these perceptions of growth appears to be the more meaningful.

Keywords: Economic Growth Theory, Neo-Classical Growth Theory, Evolutionary Growth Theory, Hamiltonian, Chaos Theory, Structural Change.

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ECONOMIC GROWTH THEORY: A TAIL OF TWO PARADIGMS

1. INTRODUCTION

The aim of this paper is to explain the theoretical/conceptual problem which I see bedevilling economic growth theory - is it growth which leads to development or development which leads to growth? Now you must bear with me for a little while and not be put off by what may appear to be a chicken and egg circularity. There is a fundamental difference in the causation implicit in each of these perceptions of growth and hence their policy implications are different in fundamental ways, as I shortly hope to demonstrate. The research project referred to in the Abstract, through which I aim to throw light on that problem, will then be briefly outlined. My hope is to engender some interest in what I am trying to do with a view of obtaining useful comment - or warnings of any pitfalls - in tackling this research project.

The first step is to try to explain the appalling pun in the title. The point is that growth theory - at least in recent years - has tended to tail 2 diametrically opposed physics paradigms or models, one being the thermodynamic equilibrium model on which endogenous growth theories (and neo-classical balanced growth models before that) are based; the other a model of physico-chemical transformation which occur within non-equilibrium thermodynamic systems and which are reflected in the properties of evolutionary economic growth models.

2. THE TWO PARADIGMS

A. The first physics model explains the behaviour of a many bodied (corpuscular) system where energy is conserved according to the First Law of Thermodynamics. Now conservation is the key: the features of the model outlined are merely aspects of that one underlying feature - the conservation of energy.

(i) The Hamiltonian defines the dynamics of that system, expressing its total energy through transformation of the potential and kinetic energy. But the system's total energy cannot change so H cannot change; any transformation that takes the system outside its original structure, is simply not permissible.

(ii) The conservation of energy implies that any transformation will follow a particular path - the path of least action. The Hamiltonian defines that path and it is from this definition that our concepts maximisation or constrained optima can be derived.

(iii) The movement of bodies within a system subject to a force field will be path-independent. This indeed defines a conserving force. A corollary of this is that there can be no change in the field of force arising from the behaviour of the bodies in the system in response to that force.

B. The alternative model, reflects the sorts of physico-chemical changes which are quite usual in living systems. Unlike the behaviour of the system in thermodynamic equilibrium in non equilibrium systems, the relationship between a force that determines the rate or flux of energy change (entropy), is non-linear making the systems state no longer stable. Fluctuations are amplified pushing it to evolve an entirely different pattern of entropy, the point of transition marked by an abrupt change or bifurcation which is not predictable in terms of behaviour at the micro-level. What is being suggested is that under conditions of sharply increasing stress when a system is in far-from-equilibrium conditions characterised by considerable turbulence/chaos, a new state can emerge, displaying more symmetry and more structure. As Stewart and Golubitsky [1993] suggest,

> "... symmetry and chaos - pattern and disorder - can coexist naturally within the same simple .....framework" [p.240].

Prigogine [1985] calls these new states 'dissipative structures' to reflect on the one hand structure and order, which is associated on the other hand, with 'dissipation and waste and suggests they,

> "actually correspond to a form of supramolecular organisation". [p.143]

Now because such transformations occur under far-from-equilibrium conditions the order which arises or emerges cannot be an outcome of equilibrating processes but is rather an outcome of self-organisation. As such, outcomes are not knowable in advance and as a result the process leading to those transformations tends to be path-dependent. Finally such transitions or transformations are governed by the boundary conditions as well as the prior history of the system and once made are irreversible. This characteristic of irreversibility is an important factor distinguishing evolutionary models from classical physics/neo-classical economic model. In the latter cases time is treated as any other variable - it is reversible. The dynamics of neo-classical growth theory are the dynamics of the Hamiltonian: there is only theoretical time which permit transformations to run either forwards or backwards. Theoretical time therefore has no links with historical time. With evolutionary theory time becomes irreversible - aging is a one way process reflecting the arrow of time. There therefore exists a discontinuity between past and future; a discontinuity starkly reflected in the changing economic structure of the city. referred to in the next Section.

Properties of self-organisation, non-linearity and path dependency are essentially the properties of Chaos Theory and as Gleick points out,

> "chaos is a science of process rather than state, of becoming rather than being"[1991 p.5]

3. A GROWTH MODEL BASED ON THE MODEL OF THERMODYNAMIC EQUILIBRIUM

Before describing each of these models it is necessary to repeat that the aim is to explain the conceptual basis for the research program. In order to do this it is only required to demonstrate the differences in their perception of the causes of growth and hence the differences in their policy implications. For this reason the mathematics is simply to assist that understanding, not to show how one equation is derived in terms of another.

As an example of an economic growth model which reflects thermodynamic equilibrium, I have taken Lucas' (1988) model - one of the class of endogenous growth models. Now the issue with most, if not all, of these models was not to find out what the determinants of growth actually are. Rather it was to find a way to modify the earlier neo-classical growth models so that non-convergence of per capita incomes or capital flows could be explained. In accordance with this approach, Lucas aim was to show that the externalities associated with investment in physical and human capital could be sufficient for the marginal productivity of capital to achieve unity and hence generate the required condition for sustained divergence. Lucas sees learning as impacting upon growth in 2 ways,

(i) an internal effect upon the workers own productivity.

(ii) an external effect upon the productivity of all factors of production.

Also, in his initial formulation of the model he defined learning in an educational sense - i.e. as requiring withdrawal from the workforce for the period required for the lear ning. Then, as with all the endogenous growth models, growth is conceptualised as a control problem - how to maximise utility over time given the technology constraints.

Despite the presence of externalities in the formulation of this model they do not affect the optimum time path of growth: the problem is to choose a time path for human as well as physical capital, consumption, and the time devoted to production rather than learning, that will maximise utility subject to all constraints. These constraints are:

(i) The technology of goods production involves the productivity of capital and labour bearing in mind the externality factor associated with human capital.

$$AK(t)^{\beta} [u(t)\, h(t)\, N(t)]^{1-\beta}\, h_a(t)^{\gamma}$$

(ii) The 'technology" of human capital accumulation. Lucas assumed a linear relationship between the effort devoted to the accumulation of human capital and the rate of change in its level, such that, within the extreme values for u(t) of 0 and 1, a given percentage increase in h(t) requires the same effort regardless of the level already attained.

$$\dot{h}(t) = (h(t)\,\delta\,[1 - u(t)]$$

(iii) The constraint that $h(t) = h_a(t)$ for all t.

This optimisation problem is given by the current-value Hamiltonian

$$H(k, h, \theta_1, \theta_2, c, u, t)$$

where θ_1 and θ_2 are the prices for increments of physical and human capital and u is the proportion of time devoted to production.

There are now 2 decision variables - consumption and the time devoted to production - and these need to be selected to optimise growth. Thus the first order conditions for optimisation are that at the margin: -

(i) Goods must be equally valuable in their 2 uses of consumption and capital accumulation.

$$C^{-\sigma} = \theta_1$$

(ii) Time must be equally valuable in its 2 uses of production and human capital accumulation.

$$\theta_1 (1 - \beta)\, AK^{\beta} (uNh)^{-\beta}\, Nh^{1+\gamma} = \theta_2\, \delta h$$

All these conditions, together with the specification of the rates of change in prices then describe the optimal time path for K(t) and h(t) from any initial mix of these 2 types of capital.

Because of the presence of externalities the equilibrium path is different from the optimal. The equilibrium path Lucas defines as that path where households decisions to accumulate personal capital ((h(t)) are the same as the expected outcomes embodying the external effects of human capital ($h_a(t)$). The private sector solves basically the same control problem as the optimisation, except with $h_a(t)$ as given. In effect it is a positive γ which creates the divergence between the 2. Lucas then seeks to characterise each growth path by determining balanced growth solutions for each: i.e. solutions in which c, K and h are growing at constant rates and the prices of each type of capital are declining at constant rates. Lucas confesses to some doubt as to what exactly is balanced along this path, but argues it is useful label for solutions which have this property of constant growth rates. From this particular characterisation of each growth path a solution for both the optimal and the equilibrium rates of human capital accumulation may be obtained. It can perhaps be noted that in both cases the outcome is affected by the effectiveness of investment in human capital and the level of the discount rate. As Lucas exclaims

> "Here at last is a connection between thriftiness and growth" [ibid p.23].

something which does not occur with the Solow model!

One of the intriguing aspects of Lucas approach is his focus on the city, rather than the national economy as the centre of economic growth. This is an outcome of the central role assigned to the external effects of human capital, which required proximity for those externalities to be internalised. He therefore uses those externalities to explain agglomeration economies found in urban areas, suggesting that the human creativeness which those externalities embody, is the field of force driving national economic growth through the medium of city economies. Human creativeness, is the overarching driving force existing prior to and independently of agents' economic decisions and in this respect offers a much more meaningful field of force than technology. Technology cannot be said to exist independently of agents' economic decisions. He considers his perception to be essentially the same as Jane Jacobs: cities are what make modern economies work because the creativeness which engenders national economic development takes place in those cities.

By observing the sorts of changes which have taken place in city economies it is possible to check whether these changes are broadly consistent with Lucas model, bearing in mind the limitations imposed by using the Hamiltonian. In particular it is necessary to remember that that change which takes the system outside its initial structure is inconsistent with the application of the Hamiltonian. To what extent then is the pattern of observed economic change in cities consistent with the requirement of the Hamiltonian? At this juncture I should point out that I am using my own and Carter's [1979] rather than Jane Jacobs' analysis of urban employment change as it is much more closely related to economic development rather than import replacement.

The results of that analysis were as follows:

(i) When all US towns (SMSAs) are clustered according to their employment structure, in 1950 a prime split is obtained which separates out one group of manufacturing towns and one of services.

(ii) A secondary split breaks up each of these groupings into a further 2 sub-groups in which size appears as an important characteristic in one of each of the 2 sub-groups. These large centres were characterised by employment in those industries showing the largest increases in the sales of intermediate outputs that were located in urban areas (i.e. excluding such industries as petroleum refining).

(iii) When the same exercise is carried out for SMSAs in 1970 then the 2 sub-groups of large cities - which could not be more different in 1950 - grouped together in 1970 again characterised by those industries showing the largest increases in the sales of intermediate outputs - in this case 'producer services'.

(iv) On the other hand industries such as communications, aircraft and motor vehicles which tended to locate in large cities in 1950 but which in the meantime had undergone sharp increases in labour productivity, by 1970 did not characterise the employment structure of any particular sort of city. They tended to be diffused throughout the urban hierarchy or located outside it.

Thus the changing pattern of urban activity reflects in an extremely accentuated form, the most fundamental aspects of economic development - the increase in intermediate output relative to total output and/or final demand, and second the decline in primary inputs - especially labour per unit of output.

Does this quite dramatic movement from services/manufacturing centres to 'producer service' centres suggest that they have so altered their structure that the Hamiltonian is no longer applicable? That is impossible to answer because there is no measure to structural change which is independent of the way growth has been defined, so it is possible to define such change as unimportant. But we would have to ignore the rich pattern of change those economies experienced, as being of no structural significance. As Nordhaus and Tobin [1972] complained, you miss.... "all the drama of the events" [p.2]

Perhaps the crucial issue raised by Jane Jacobs was that the process of economic change within a city was subject to a positive feedback mechanism in which "one thing leads explicity to another", this has a number of serious implications for the applicability of equilibrium theory in general and the Hamiltonian in particular:

1. Economic change is path dependent so that human creativeness cannot be interpreted as a conserving field of force.

2. Path-dependence implies the process of transformation is not knowable *ex ante*, but rather an act of creativeness which positive feedback mechanisms build into a self-reinforcing system. To such a system concepts of equilibrium, as well as optimisation, do not apply: change is more meaningly perceived as self-organisation.

3. As a path-dependent system the process of change is strongly conditioned by its history so that movement if not completely irreversible is subjected to strong hysteresis.

In other words it exhibits the properties of Prigogine's dissipative structure' rather than a body in thermodynamic equilibrium.

4. *A GROWTH MODEL BASED ON THE MODEL OF FAR-FROM-EQUILIBRIUM THERMODYNAMICS*

Before outlining the alternative model, there are general points on causation which need to be brought out so that you may better appreciate the way growth is seen to take place within this framework. This alternative model perceives growth as emanating from the development of a more complex structure with increasing inter-dependency and hence organisation, in the relationship of the parts making up that structure. Note that the emphasis is now on structure and the structural changes excluded by the use of the Hamiltonian. Richard Feynman [1992] has pointed out;

> "The same kinds of atoms appear to be in living creatures as in non-living creatures; frogs are made out of the same 'groups' as rocks" [pp.149-150].

so that their totally different physical properties must be a consequence of the way those atoms are arranged. Arrangement or structure rather than deterministic cause effect relationships has become the organising concept of science [Bronowski 1976 p.112] and it is therefore to changes in structure that one looks for change in properties. In this context the changing properties associated with growth can be seen as the outcome of a changing structure. [Little 1995] The analogy to use here, is the development path of an embryo as it develops its various component structures - stomach, nerve system, muscle tissue, etc. This pattern of growth is called epigenesis and can be compared with the unchanging structure of our previous physics model which implies that everything must already exist within that system - a theory of growth known as preformation which was rejected in biology more than 100 years ago. Now it is important to understand that the epigenetic explanation of development does not contain a detailed description or plan of each component but rather a prescription for when change must occur: the laws of physics then look after everything else.

When concerned with understanding development/growth as an evolutionary process we must distinguish that "change" part from the "everything else" part. Many evolutionary economist see change in neo-darwinian terms - as an outcome of selection after random mutation. But adaptation to a change does not explain the change itself: that requires a theory of structural change or morphogenesis. As biologists/evolutionists have pointed out morphogenesis is anything but random: rather it follows certain self-organising paths along the lines described by Prigogine [1985] and his co-workers.

Perhaps the clearest perception of the need to see change independently of day to day adaptive economic behaviour was demonstrated by Schumpeter [1950, 1951] in his 'creative destruction' model of economic change. Now such transformations can be captured within a relatively simple mathematical framework: as Stewart and Golubitsky[1993 ch.9] point out, they can be contained within the simple logistic equation.

$$f(x) = k\,x\,(1 - x)$$

which expressed as a nonlinear first order difference equation is.

$$x_{(t+1)} = f(x_t) = kx_t\,(1 - x_t)$$

This means that any point x maps it to the value f(x) while k is simply a relative growth factor. Given any value for k it is then possible to calculate an infinite sequence of xs. the way x changes defining its dynamics. If the xs in the sequence stay bounded and yet do not display any discernible pattern then the dynamics of that system or set is defined as chaotic.

A recent model of self-organising behaviour , has been developed by Silverberg, Dosi and Orsenigo [1988], which they say,

> "represents a dynamical system which due to the vintage structure, should be categorised as a set of differential-difference equations with age-dependent effects." [ibid p. 1042].

Although it does not incorporate an explanation of morphogenesis the process of technology diffusion is contained within the broader context of the industry's adaptation to 2 different technological pathways or trajectories. It aims at showing the process of adjustment to changing technology under conditions where the correctness of actions taken today will not be known until some considerable time in the future and in which there are complex interdependencies with the other agents as well as with the aggregate magnitudes within the system. An approach which assumes an equilibrium outcome to which all agents would subscribe *ex ante*, cannot therefore be adopted. Indeed it is the diversity in the various firm's responses which is one of the most important factors driving the adjustment process and the pattern of industry response. In this respect it is a self-organisation model.

The way the market structure evolves in the model is governed by the way a firm's market share responds to the difference between its own and the average competitiveness. This is a basic diffusion equation, except that the competitiveness parameters can be change in quite complex ways in response to the firm's strategies or feedback from the rest of the system.

$$\dot{f}i = A_9 (Ei - < E >) fi$$

Where *fi* represents the market share of the ith firm

Ei its competitiveness

< E > the average competitiveness.

This is similar in form to our logistic equation except that the Es themselves are complex functions of other factors within the system. e.g. Competitiveness of the ith firm is defined as,

$$Ei = - \ln pi - A_{10}\, ddi$$

Where - ln represents a linear combination of price (*pi*) and current delivery delay (dd*i*).

The firm's decision-making is in 2 parts,

(i) Certain rules of thumb governing pricing and output.

(ii) Decision rules ('animal spirits') governing replacement and the expansion of capacity.

Now the prices firms charge are a compromise between the desired mark-up on unit costs and relative competitiveness. This allows the firm's changing relative cost structure to be transmitted through the market.

$$\dot{p}i = A_7 (pci - pi) + A_8 (Ei - < E >)$$

Where *pi* represents the log of the ith firm's market price

pc*i* its desired mark-up price based on its unit prime costs.

With investment behaviour, capacity expansion may be set at any level, but it is then revised in the light of any deviation in the rate of capacity utilisation from the desired level (this uses first order feedback).

$Ni = ri\ ki$

Where Ni is the net expansion (negative or positive) of the ith firm

ri is its desired rate of expansion.

$ri = A_{13}\ (ui - uo)$

Where $ui - uo$ represents the deviation of the rate of capacity utilisation from its desired level, uo.

However it is replacement investment which largely determines the unit production cost per unit of investment outlay, because these costs are determined by the age structure of the capital stock and the history of technological change it embodies. With replacement decisions, it is not merely a question of determining the best-practice technology but one of weighing up the gains from immediate experience in advance of competitors, or waiting and "floating in on the rising general skill level" [ibid p.1042] without committing oneself to the new technology and thereby avoiding possible development costs, bearing in mind the outcome is unknowable in advance. The gain in skills/learning from adopting the new technology is expressed as,

$Si = A_{15}\ [Pi/(CPi + C)]\ Si\ (1 - Si)$ if $Si > Sp$

Where S(p) is the level of skill generally available (external learning)

Pi is the firms current production

CP its cumulated production employing the new technology

C is a constant proportional to the capital stock.

External learning/skill lags behind the average internal skill levels with an exponential delay.

$s\,(p) = A_c\ (< s > - Sp)$

Where $< s > = \Sigma\ fi\ Si$

If firms are going to switch to the new technology they will need to abandon their usual investment criteria and take into account the gains from the higher productivity as well as any competitive edge resulting from acquiring the skills associated with its use. If the firm believes these gains can be achieved within its payback period, then it will switch.

$P2 - P1/(c1 - c2/S_i X_i) \leq b_i$

Where b_i is the firm's target payback period.

c1, P1 and c2, P2 are the unit cost and the price per efficiency unit cost and the price per efficiency unit for the old and the technologies respectively,

X_i is the firm's 'anticipation bonus' of switching to the new technology.

Thus *projection* of the alternative gains from internal and external learning, as well as what ones competitors are doing, will determine the firm's investment strategy. It's a bifurcation point.

What are the implications of such model of technological change?

(a) There is no such thing as an average economic agent so that market behaviour cannot be seen in terms of individual economic units.

(b) There is no determinate outcome: it is unknowable in advance. If no firm is willing to risk the initial costs of implementing the new technology the older less efficient way may remain. It is the collective effects of the different firms which determine the outcome i.e. it is a case of industry self-organisation. What this demonstrates is that although it may be possible to specify the structure of a model *ex ante* it may not be possible to specify its dynamic properties *ex ante*. Properties may only emerge from simulations with the particular parametric values (as with the logistic equation referred to earlier).

(c) Change is not smooth and continuous but is abrupt and discrete. Non-linear cumulative causation makes the form of the interaction between agents, complex and subject to bifurcations.

Underlying this perception of change is the view that the way an industry grows is largely the outcome of the way firms adapt to technological change: i.e. it is technological change, under-pinning structural change within the economy, which in turn leads to growth. Obviously this is very much an epigenetic view of growth.

5. *CO-EVOLUTION OF TECHNOLOGY INDUSTRY AND INSTITUTIONS*

Evolutionary theory has so far been illustrated only in the context of technological diffusion. However as already pointed out the radical transformations associated with structural change also need to be explained and this section describes some of the research programs focused on a particular aspect of that change - co-evolution. The recognition of the role of boundary conditions in radical transformations of an economy has led to considerable research into the co-evolution of technology, industry and institutions. The nature of the institutions included in these research programs varies from industry and trade association to what may be broadly called 'cultural' institutions where the changing economic relations inter-act with the social relations in which they are embedded to change these as well, this change then impacting back on the way economic activity is evolving. Perhaps one of the most highly developed areas of co-evolution research, has been on the relationship between industry and science where the research carried out in a particular field of science initially arose in response to the demands of industry, after a key technological breakthrough had established that industry. Rosenberg [1982 ch. 7] highlights what he calls the 'classic case' of solid state physics where industry was teaching academia after the introduction of the transistor. The rise of the 'technological society' has led to the proliferation of areas in which daily economic life has become closely linked with science, defining the direction that science will take. As Nelson [1995] points out, this nexus frequently requires firms to forge links with universities, with ramifications not only for the science faculties, but also related faculties - such as law and management - as well.

Another area where there is considerable evidence of co-evolution, is between economic activity and cultural institutions. Economic relationships are embedded in social relationships so that if the economic relationships are to change the social relationships will need to co-evolve with them. Even in so-called traditional societies this co-evolution is going on as Little [1995] pointed out in the case of East New Britain's (P.N.G.) economic development.

The importance of having economic relationships embedded in social relationships so that both may co-evolve has been stressed by Granovetter [1985]. To Granovetter the evolution of subcontracting relationships embodying informal ties go beyond contracts, becoming the basis for the trust on which economic relations must rest. Such relations obviously require proximity therefore offering on alternative explanation for the spatial concentration of economic activity distinct from externalities and agglomeration economics. But this proximity offers more than economic relationships: it enables social relationship to be re-inforced at the same time ensuring a particularly reinforced form of embedding. It is this co-evolution of social and economic relationships which this theory's protagonists argue, will lead to the economic growth of a region where ever such a program is introduced.

6. *THE CONCEPTUAL PROBLEM*

Implicit in these 2 models is a marked dichotomy in the way an economy is perceived to grow over time. On the one hand it is seen as an outcome of the way resources are devoted between present and future production/consumption with the significance of structural change being restricted to the need to conserve the integrity of the economy. On the other hand it is technological changes; embodying both technical and organisational innovations, which are seen as leading to structural change and sustainable economic growth. How do we cope with this dichotomy? The answer is of course that we don't: it's ignored. This is most readily seen in exercises aimed at measuring the different factors contributing to structural change within an economy. Usually it is done by breaking down the change into such items as domestic demand (perhaps broken down into its individual components), export demand etc. and technological change. Technological change is usually defined in terms of the increase in intermediate inputs required to produce a unit of output of a commodity while domestic demand would be defined as the increase in final demand for that commodity. [see Kubo, Robinson and Syrquin, 1988 p.130]. Using a general equilibrium framework Dixon and McDonald [1995] pose the issue of measuring structural change as;

$$\Delta X = (\Delta B)\,(C + I \,......) + B\,(\Delta C) + B\,(\Delta I)\,......$$

Where X is the vector of industry outputs

B is the Leontief inverse

C, I..... are vectors showing the composition of the final demand aggregates [p.9].

They go on to point out that the terms on the right hand side of the equation are interrelated [ibid].

Now my point is that such a breakdown is quite arbitrary in terms of fundamental causation. Measuring structural change in this way has 2 important consequences for assessing the contribution of technological change:

(i) The most important aspect of technological change - the decline in primary inputs per unit of output which is often associated with increasing intermediate inputs - is completely ignored.

(ii) Any increase in final demand output associated with the fall in primary inputs and hence costs, is then ascribed to an increase in demand.

The pattern of economic change shown by U.S. cities illustrates a more general problem I have with the way growth accounting attributes causality. Attributing an increase in output to an increase in the supply of labour regardless of the structural transformations taking place may have limited meaning. The increase in young college-educated female employment which took place with the growth of the producer industries, was the result of the transformation of industry structure in large cities, not the result of an increase in the supply of that type of labour. There is no reason to believe that that particular labour supply would have been any less in a large city such as Youngstown, Ohio, than it was in any other large city. But that employment was not generated in Youngstown because that particular urban economy did not transform itself and as a result failed to grow. This is strongly suggestive that the ability to absorb an increase in factor supply is not independent of prior structural transformation, as it is frequently assumed to be in growth accounting exercises.

This brings me to the core of the issue as to why it is necessary to determine the nature of causation between growth and development and to determine which comes first. This is not an arcane academic question because the policy basis for accelerating growth is dramatically different under each paradigm. In the case of the primacy of growth we look for deterministic cause-effect relationships which will impact on growth: following Lucas model we would look to increasing education. In the S.D.O. model there are no deterministic cause-effect relationships. Although learning is a crucial aspect of their model any increase in education (e.g. external learning) does not, as was the case in Youngstown, automatically lead to an increase in growth rates. It can only do so within the context of certain transformations taking place and of course different types of transformation will require different types of 'education'. The policy implications of this approach are how to facilitate this transformation process which will bring about the required change in structure: not the search for cause-effect relationships that in some mysterious way are supposed to transcend the structure in which they are embedded.

7. *THE RESEARCH PROGRAM*

The aim of the research project is to seek to understand the role of technological and hence structural change in economic growth by studying what happens to growth in the absence of technological change That it is why is being carried out in the Philippines. Structural change and growth cannot be separated where technological change does occur, because both models would predict structural change and growth to be associated with that technological change. Besides there is impeccable scientific precedence for this approach. Darwin's visit to the Galapogos Islands to help in formulating theories of evolution, where relatively little had occurred.

The way it is intended to carry out the program is,

(a) First to measure the degree of structural change that has occurred within the economy over the period of the early 60s to the early 90s using the pattern of employment change. This will of course be more than the change in the broad sectoral composition of employment: it is necessary to determine the extent to which new industries are being generated within these sectors rather than increases in employment simply being added to existing activities. It is also important to determine the extent to which any increase in activity is associated with increased sales of intermediate output as these are a more accurate reflection of structural change than the changing sectoral composition of employment, [Carter 1970] whatever the level of disaggregation. However this would only hold if the increasing intermediate inputs were associated with declines in certain primary inputs - especially labour. It is particularly important to try to gauge the extent to which there has been increasing intermediate sales from the producer services industries, not only because of their role in developed economies, such as the U.S. and Singapore but also because of their rapidly increasing significance in countries like Malaysia [Behuria & Khuttar 1994].

(b) Second to determine whether those industries/sectors which have undergone some degree of technical change (as measured by falls in their direct primary co-efficients) have had a dissimilar pattern of output change to those industries/sectors which have not and try to account for such differences.

Finally why undertake the study only in the Philippines' rather than carrying out a comparison of productivity changes and growth across a number of countries? My main reason for not adopting that approach is that any statistical relationship based on cross-country comparisons is unlikely to be very satisfactory, for two reasons:

(i) I am not sure how much credence can be put on a statistical relationship where there is inter-dependence between the primary variables - technological change and growth .

(ii) More importantly, as has already been pointed out, history, the institutional environment and organisational structure will all impact upon the way structural change unfolds in an economy. It is difficult to see how these secondary variables could even be measured let alone standardised for within a cross-country comparison.

I therefore believe it is necessary to conduct the study within the context of an individual country. It may be possible to subsequently test individual elements in the results, through cross-country analyses, but not at this stage.

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