

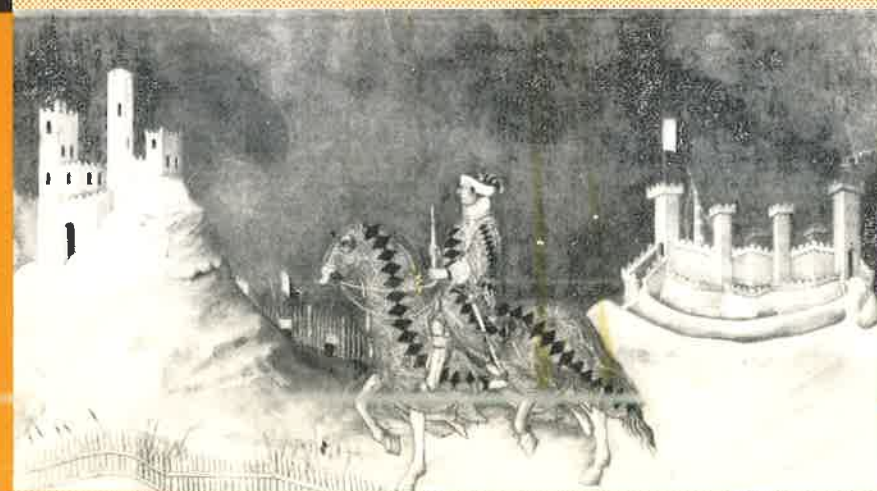
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Frank Hahn

ON GROWTH THEORY



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Frank Hahn

ON GROWTH THEORY



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1. INTRODUCTION¹

Growth theory flourished in the fifties and sixties, died, and has now been resurrected. Romer [1986] led the way, but it needed Lucas's [1988] uncanny knack of creating followers to beget the now large and growing literature. The aim of the new growth theories is to have an account of an economy's growth rate which is not exogenous to the theory. In what follows I make an attempt at a somewhat general formulation of the problem which appears to be needed. For at the moment there is a bewildering variety of models all relying on special functional forms and special assumptions. Most of these models are "closed" in the sense that they have enough relations to determine an equilibrium growth rate. In one, everything hinges on the production of human capital, in another this is ignored and we focus on R and D, while in yet another it is the process by which the variety of goods is increased which makes the world go round. There are common features but they are not easy to discern. Moreover for each process singled out as central, for instance the production of human capital, one can think of a large number of others which plausibly could also claim centrality.

The theories I am concerned with, in spite of some novel features, are all intent on models which allow equilibrium growth at a constant rate. Hence suitable functional forms are arrived at by a backward reasoning from this requirement. I am quite unsure that this is a good procedure. Certainly it is uncomfortable to have what after all amounts to a theory of economic history hinge on functional forms for which there is no pretence that they are empirically based. One must therefore regard these models as parables which may

¹This paper was presented to the IEA World Conference in Moscow, August 1992.

illuminate but seem unlikely to describe.

It may be useful in this introductory section to remind you from where all this new activity started.

Harrod [1948] (who is never given a reference) was the postwar beginning. He took the rate of growth of population and of (Harrod-neutral) innovations as given, and called their sum the natural rate of growth (g). He distinguished this from the equilibrium (warranted) growth rate which is that growth rate which, if expected, would lead savings (a fraction s of income) to grow at the same rate as the capital stock was required to grow to keep the capital output ratio, $1/v$, constant. Thus $g = s/v$. Here s was a parameter and Harrod was never very clear whether v was a parameter also. In any case he concluded that in general $s/v \neq g$. This conclusion then led him to distinguish between inflation and depression-prone economies.

Solow [1956] continued Harrod's assumption of an exogenously given saving propensity and an exogenously given natural rate, but treated v as an unknown in the equation $s/v = g$. To do so he postulated a well-behaved aggregate production function equipped with "Inada conditions" and showed that there existed a solution to the above equation which implicitly gave real wages and capital rentals at which the solution would also be chosen in a perfectly competitive economy. He also gave a convergence result, but that is another story.

It is obvious that neither s nor v , whatever their value, can affect the steady state growth rate for the simple reason that the latter is given exogenously. But of course Solow did not believe this to be so in reality — neither he nor anyone else believed that the growth rate was a fundamental constant. Rather, economists were reluctant to give formal expression to unknown and ill-understood processes such as population growth and the rate of innovation. Nonetheless some attempts were made.

Ignoring innovations and considering only population growth, Jorgenson [1961] and others supposed that population growth might be a logistic function of the real wage. For

Solow's production function the real wage is an increasing function of v . Hence there is now a relation between v and g , say $g(v)$. Solving the equation $s/v = g(v)$ may now yield several steady growth rates, that is solutions v . (It is not hard to have plausible assumptions where one steady state growth rate is zero which is separated from a high positive rate by a Solow unstable middle value.)

Arrow [1962] on the other hand, following Kaldor [1957], made the rate of growth of productivity endogenous (population was assumed constant) with his famous account of learning by doing. Productivity growth now depended on the rate of growth of the economy's capital stock. This of course implied an externality since the investments by one firm benefited other firms. Once again the growth rate was made endogenous. For the functional form chosen by Arrow a unique steady state equilibrium resulted.

There were elaborations of Arrow's theory (e.g. Sheshinski [1967]), and also of the demographic approach, but this is more or less where the story stopped until Romer [1985] published his paper. That is also where our story starts.

2. A GENERAL APPROACH

I shall now attempt a more general formulation of the issues which arise. Doing so of course sacrifices structure, but nevertheless may provide us with the boxes which need filling either empirically or theoretically.

In ordinary theory we endow a firm with a production set which is a subset of a given commodity space. But suppose the firm had to pay someone to tell it what its production set is. This payment would constitute a set-up cost. It is immediate that even if the production set it buys exhibits constant returns to scale the firm will be producing under diminishing costs. The knowledge of the production set once paid for is given and needs no change with scale. This scenario can be made less drastic if we assume that the firm knows a given production set $\bar{Y}$ and can by payment obtain knowledge of a set Y of which $\bar{Y}$ is a proper subset.

Increasing returns to scale cannot be reconciled with perfect competition unless they are external to the firm. Marshall proposed this way out of the threat to perfect competition and he has been followed by many of the authors. That externalities exist and are important cannot be denied, and I shall return to them. But firms do pay for knowledge and information when they engage in R and D or seek advice from consultants. It therefore seems to me that we should allow for imperfect competition and not strive to produce only theories faithful to the perfect competition assumption.

But let us leave this to one side at the moment and return to information of production possibilities. I want to formulate the matter somewhat abstractly by defining a universal commodity space and a universal economy wide production set on this space. By a universal commodity space I mean a list of inputs and outputs which could ever be used or produced. Indeed it might be better to replace "universal" by "divine" or "platonian" since this set is not known to any agent. Similarly the universal production set consists of techniques or activities which will ever be available using and producing goods which will ever become available. It too is unknown to agents. We can now think of innovation as search through these spaces and resulting changes in the known production set and commodity space.

But we now have a new activity — search. This activity requires inputs like any other and, indeed, there may be many alternative ways of searching. The inputs are goods and services, but as new goods are found in the universal commodity space the set of available ways of searching is also likely to change. Think of the effect of the electron microscope on research activity. The output of a search activity is an enlarged commodity space and production set known in the economy. However it is in the nature of the problem that the output is uncertain not only in the sense that search may be unsuccessful but also because the searcher is uncertain of what will be found. (If he were not then he would have found it already.)

One might now think of a universal set of search activities but that would lead to

further search sets ad infinitum and I have reached a point where some specific exogenously given structure is needed. It seems to me plausible to suppose that it is the history of search which is instrumental, or largely instrumental, in revealing new search activities as possible. So if we do think of a universal set of search activities we do not envisage search over this set but rather that the enlargement of the set of known search activities is a by-product of the primary search for production sets and goods. Of course one can think of counter-examples. For instance, research aimed at finding an apparatus which will help one to decide whether the atom can be split. But I do not pursue this further. Certainly, although far less abstractly put, the current literature implicitly takes this line. For instance, Helpman speaks of "knowledge capital", the stock of which is an input into the discovery of the productivity of what I call search, as more of it is accumulated. I prefer to think of the history of search and I shall later explain why I do so.

But only one half of the scene has been set. History will, at any date, deliver the known production sets, research activity sets and commodity space. What happens next depends on human volition and the society in which it can find expression. Continuing abstraction for a little longer, I distinguish between three action sets: a universal, a possible and a feasible set. The universal set is again the set of actions which could ever become available to agents. It is a subset of the product of the universal production and commodity and the search sets. The possible set is the set of actions actually available in the economy, and it is a subset of the product of the production set, the commodity set and the search set. The feasible set is the set of actions which agents can actually carry out, and it is a subset of the possible set. We can think of a map from the possible action set into itself yielding the subset of feasible actions. This map will embody the wealth distribution of agents, institutions such as the availability of markets and the laws relating to property, money and banks and the level of education etc. It will also depend on information. The map is likely to change with time, and I do not doubt that such changes are important for understanding growth. For instance a transition from a centrally

planned to a market economy will change this map. A change in education level will increase understanding of what is possible. But I have no idea how to capture such changes in a formal manner, and most of them will have to be considered as exogenous.

That leaves choice. We should note at once that it is not clear who should be the choosers. Once again there are government and individual choices as well as choices by boards of directors and similar committees. I think that here too one had better take government choice as exogenous and I fear also close one's eyes firmly with respect to committee decisions. As far as agents are concerned we are accustomed to think of choice of actions as depending on their consequences. These may not be precisely known. The most convenient hypothesis is that agents have expectations of consequences and that these are capable of being formulated probabilistically. One then assumes there to be a map from actions to the probability space of consequences. Agents are supposed to have an ordering over this space and then act so that no element of the set of feasible actions yields an outcome preferred to the action actually chosen. There are very many criticisms possible of this approach. But I have nothing better on offer. I shall however argue that this may not matter if plausible ad hoc assumptions concerning choices can, if desired, be rationalised according to the theory by some postulate on preferences and distribution or, if not, simply left ad hoc. At any time all these sets must be brought into relation with resource constraints. These will of course vary through time. The extent of and educational level of labour is an obvious element. I of course here consider education as a production process like any other.

I conclude this abstract section with some formalities:

- (i) Commodities are taken as dated and indexed by the state of nature. I include services, e.g. labour services, amongst commodities.
- (ii) Universal sets are denoted by asterisks. The C^* is the universal and $C \subset C^*$ the actual commodity space; Y^* is the universal production set and $Y \subset Y^*$ the actual set and similarly A^* is the universal action set and $A \subset A^*$ the possible action set. Let $\bar{A} \subset A$ be

the feasible action set. R_H is the set of search activities indexed by the history of search activity.

We now have some conceptual machinery, but it is not at all clear that it can be put to use in the formulation of a growth model. That however is possibly an advantage. In any case, what it does do is to provide us with a set of boxes which growth theory must fill.

3. FILLING THE BOXES

A theory of growth at the minimum must answer the question how growth is physically possible. By growth here I mean growth in output per citizen. Almost all the answers we have focus on search activity for an answer. An important exception is learning by doing, where new goods — more skilled labour — are discovered as a by-product of ordinary production.

Lucas [1988] has focussed attention on the growth in "human capital", that is, skills which result from devoting time to their acquisition. This of course is very simplistic. It does not deal with innovation in the education production process of which history furnishes a number of examples. This can be thought of as a search activity. Others, e.g. Aghion and Howitt [1992], Grossman and Helpman [1991], Hahn [1990] have taken research (i.e. search) as their primary motor. This is sometimes explicitly modelled as search in the universal commodity space. That is, research yields new goods which are more productive and possibly more desirable. Extensions of the commodity space then imply extensions in the economy's production set.

In all of these suggestions it is clear that one needs to postulate more than just search. If the search set is subject to diminishing returns then resource constraints may make it impossible to continue and so, insofar as growth depends on search, it will eventually cease. That is why many authors postulate increasing returns to search. This is true for Romer [1990], Grossman and Helpman [1991] and indeed for most model builders. Recall that I have indexed the set of possible search activities by the history of search. If

one simplifies, one could sum up the history as the stock of "knowledge". As knowledge increases, given inputs into the search activity can again produce more knowledge. But if the rate of growth of knowledge is not to tend to zero, there must be constant or increasing returns to the stock of knowledge. I don't think that it is now worthwhile to consider special functional forms — one can think of many, but the archtypal one is $\dot{K} = K^\alpha$ where $\alpha \geq 1$ and K is the stock of knowledge.

But in filling my boxes we want, if at all possible, to utilise as much of the space which they provide as we can. The idea of a "stock of knowledge" which enters into its own production with increasing returns is suggestive but vague. What we really want to know is how search activity affects production and commodity sets, and it might indeed be possible to characterise increased knowledge by these effects. For instance we might represent the history of search simply by the production set and commodity space which is known at any one time. That does not make for simple algebra, but it has the virtue of reminding us of the multifaceted nature of knowledge. It also suggests something about the quality of knowledge. It may, for instance, be the case that knowledge of certain production activities and goods is very favourable to the accumulation of further knowledge, while knowledge of others is less favourable. For instance, knowledge of orbiting satellites and of the way to produce them may be very favourable to the production of new knowledge like satellite transmission, miniaturisation and computers. On the other hand, knowing an activity for baking bread may not be helpful, or not very helpful, in finding new activities and goods.

I am here stressing the possible importance of the path search takes and has taken through the universal sets. For instance I suspect — but do not know — that the path taken by the ancient Egyptians or indeed by medieval Europe — one concerned with the building of pyramids, the other with medieval cathedrals — may have led to an accumulation of knowledge and that in turn may have been raising the productivity of search, without leading to growth. It may be that the path taken by the Japanese economy will have

different consequences for production sets and commodity spaces than that taken by the American economy. There is here a trade-off: if one wants a simple model of aggregate output, production and research functions, growth models are rather easy to construct, and some definite conclusions are possible. On the other hand the chances are that one has missed elements which not only affect growth but are crucial to it, for instance the composition of output. But if one wants to avoid this, simple algebra is of no use, and it is likely that one will have to turn to simulation. I return to this below.

Here I want to make only one additional theoretical point. It is natural for economists to pay attention to activities which in some sense are efficient amongst those available. In the literature the stipulated "production function" of "knowledge" is implicitly taken as efficient. However that is not discussed. By the way it is formulated, efficiency here involves an infinite path. There is no way one could discuss the relative importance of fundamental research and R and D to growth and possibly different intertemporal profiles of new goods. The high degree of aggregation precludes that and, as far as I can see, any discussion of choice of research activities. That certainly throws some doubt on the welfare exercises which are usually added in the literature. Very much the same remarks apply to Lucas's "production function" of skills. It matters to growth whether workers become skilful monks or skilful mechanics.

The next question is: if growth is possible, will it take place? If there is a steady state growth rate, how will it be determined? These are the questions asked by the new literature.

One assumption widely made is that there is a set of identical infinitely lived consumers with perfect foresight. They are given a special utility function and are supposed to maximise the infinite discounted sum of these, subject to the usual budget constraints. The next assumption concerning production varies between authors. Lucas supposes there to be a set of perfectly competitive risk neutral firms producing the single good for consumers. They maximise profits and pay a wage equal to labour's marginal

product. Workers, by acquiring skills, forego some of their wage in favour of the higher wage their skill gain will command. But the production function of skills depends positively (indeed linearly) on the total stock of skill, so that there is an externality and this source of increasing returns does not disturb the orderly accumulation of skills.

Other authors, for instance Romer and Grossman and Helpman have the firms engage in R and D which takes the form of finding new goods in the universal commodity space. Households' utility now depends on all the goods as they appear. Sometimes obsolescence is allowed for. But the main point is that this production is under increasing returns. Hence the firms are not competitive, but taken to be monopolists in each of the goods. The value of each firm is the present discounted value of profits, and the discount rate at each t is equal to the rate of change in that value plus profits divided by the value of the firm. This cost falls with the accumulation of knowledge and new firms take advantage of that. There are other unimportant details. But here increasing (and not just constant) returns in R and D may be required, especially in the absence of obsolescence. For if this were not so, growth could not continue if both R and D and production require labour. There is no reason why Lucas's skill accumulation should not be grafted onto this model except that he would have to sacrifice the perfect competition assumption.

Aghion and Howitt [1992] have produced the most sophisticated version of this kind of model. They recognise that the output of R and D is stochastic, but make the arrival rate of success depend on resources devoted to R and D. They distinguish between a sector producing final output, intermediate output and research. The kinds of labour required in different activities are also distinguished and their relative availability is exogenous. (There too a Lucasian graft of human capital accumulation might have proved enriching.) The authors argue that the expectation of a high innovation rate in the future adversely affects the current rate. That is because of an expectation of a higher obsolescence rate and of higher real wages. The authors' steady state equilibrium is stochastic. Since they deal with forward looking difference equations, convergence is not guaranteed and they

note the possibility of cycles.

What have all these models in common? The first obvious answer is that they are all long run equilibrium models in which agents are motivated by the lure of profits and the rational search for higher utility and in which a market economy mediates between these self-interested strivings by making them capable of implementation. In other words, all these models have a highly traditional theoretical aim which they pursue traditionally. Several more or less ingenious hypotheses are provided for the search of what I have called the universal sets which result in new commodity spaces and new production sets. All of the authors quite correctly postulate that this search will use resources and be at the cost of current consumption. They thus forge a link between savings and the growth rate. (For reasons which I have never understood, people have been puzzled by the lack of a link between savings and growth in the Solow model. The answer is that there was no link of any kind between any economic behaviour and an exogenously given growth rate.) Given resource constraints, diminishing returns to the research activity had to be avoided. Romer saw more clearly than others that if final producers need to expend resources on research (or buy its fruits) that this, as is usual in the case of information acquisition, immediately implied increasing returns. He took the bull by the horns and postulated imperfect competition. More tradition-bound theorists who fear the unknown territory of imperfect competition stuck to their guns and let external economies solve the perfect competition dilemma. As already noted all of these contributions employ special functional forms which ensure the possibility of exponential equilibrium growth. This extrapolation of a relatively brief historical episode (say 150 years) may come to look odd to our descendants.

There are a number of other common features which need stressing. I have not come across any model which explicitly discussed limitational resources: say rare metals, the atmosphere or even land. There does not seem to be anyone who considers a growth in leisure as part of a growth in utilities. (Nineteenth century Britain for instance allowed far

less leisure than late twentieth century Britain.) Although this may be in the process of being remedied, I have seen no analysis which makes income and wealth distribution part of the endogenous story. There is no attention given to innovations in the financial system or indeed in the transaction technology. The role of government is universally ignored. Ignored also are legal innovations and indeed all interactions between institutions and the economy. There is also no room for what Keynes called animal spirits and, given the high level of aggregation, changes in industrial structure cannot be captured.

It is easy to enumerate elements missing from formal models. Often they are left out because we cannot accommodate them given current knowledge and techniques. But here I believe the aim of the model builders is open to doubt. The aim is to have a model of equilibrium steady state growth in which the growth rate depends on some basic characteristics of the economy. But what Joan Robinson called "the golden age" is a fiction. It can at best serve as a reference point. After all we all agree that the world has seen and is seeing fluctuations which may or may not be equilibrium fluctuations. Schumpeter made these integral to his growth theory, not so the current models which leave one puzzled how to accommodate fluctuations. "Real business" cycle models are the closest one gets to an accommodation between growth and cycles, but it is not easy to take them seriously. In other words, one is not convinced that the insights provided by these models are at all robust or directed to the most important elements. To put it mildly: there is still a very great deal of exogeneity about.

In particular I am unconvinced that we have improved on Solow or for that matter on Harrod. In taking the "natural" growth rate as given, just as in taking utility functions as given, we signal our ignorance. A serious project of explaining the natural rate itself is the project of providing a theory of economic history. Such a project may, as Popper would argue, be impossible to carry out. But less drastically it will hardly yield to formulation by three equations. What do we lose when we say that saving behaviour may influence the rate at which new knowledge is produced and do not enshrine this in some

simple algebraic equation? What is lost when we notice the fixed cost element in information and do not struggle to accommodate it in a perfectly competitive equilibrium? And so on. One cannot object to the construction of models to sharpen one's thinking, but one can be fearful when it is claimed that an endogenous theory of growth has been born.

I now want briefly to return to my own abstractions and remind you of my three action sets and of the map from possible to feasible actions. This map, or rather the distinction between possible and feasible actions, is missing in the literature which I have described. It strikes me as important. To know of possible actions does not imply that one can carry them out.

Let me start with an example. The savings of individual agents need to be made available to those who wish to invest in either capital or search. In the models which I have discussed this either is not discussed or becomes impossible to discuss because of the device of the representative agent. An agent may know that search is possible and indeed has a high probability of being profitable, but if there is no organised loan market the search action may not be feasible. Now it would be child's play to make a formal model. One thinks of economies with high costs of borrowing because of undeveloped financial institutions. Search activity is accordingly restricted, as is growth. In other economies the costs are lower because of well developed markets and so more search activity will take place. A couple of equations, and maximising will do the trick. But that is not interesting. What is, is our comparative ignorance of the process by which markets — here, financial markets — develop. For the moment that must remain exogenous. But search technology and preferences, etc., may be the same in both economies while their growth differs.

It seems to me that laws and political institutions can also be given their due without explanation of why they are what they are. In the Soviet Union the action: set up a supermarket, was always known to be possible without being feasible. Less drastically, strict zoning laws will render many possible actions infeasible or more costly. Insecure property rights do not mean that property cannot be acquired, but they may make many

possible contracts infeasible.

The uncertainty inherent in all intertemporal activities will affect them more or less according to the possibility of insurance. It is likely that uninsured uncertainty or only poorly insured uncertainty will mitigate against the more uncertain activities like search through the universal sets. These activities are possible but, with debtors prisons etc. looming, not feasible. Once again a potentially important element in understanding growth is forced on our attention by the abstract distinctions which I have proposed.

Many of these elements can be included in formal models rather easily. But at present they are like parameters — given.

Now different agents or different classes of agents face different feasible action sets. This on its own can be expected to affect an economy's saving behaviour since different groups face different possibilities of transforming foregone into future consumption. Relatively few mainline economists have caught up with developments in general equilibrium theory which show that in general these differences will be present whenever insurance markets are incomplete. They will also be present when moral hazard leads to the demand for collateral on loans and credit rationing. (See Stiglitz and Weiss [1981]). So even when we accept the relation of savings to an economy's growth which I have discussed, the distribution of wealth and income may be expected to play a role also. Indeed conservative politicians claim this to be the case almost daily. In any case the distribution of feasible action sets between agents is likely to be pretty relevant to growth.

One could go on for a very long time. I can only report my own experience: starting with the empty economic boxes which I have introduced is a powerful motive for trying to see how they need filling.

I conclude this part of my discussion with some brief and obvious remarks relating to the theory of choice.

I have argued that for want of anything better the traditional model of the rational agent will have to serve. It is agreed that this introduces an important exogenous element:

the utility function. But rationality must not be confused with omniscience. For instance for an agent without arithmetic the feasible action will be a much smaller subset of the possible one than it is for the numerate agent. Moreover feasible actions often involve an understanding of cause and effect and the rational agent may not have it. Even in the economics of our textbooks the rational agent may not know his full feasible action set because of the costs of exploring it. This is nothing to do with bounded rationality, a term which should be reserved for the agent who "satisfices" rather than maximises. All of these things are relevant to the "private" map from possible to feasible actions and so almost surely to growth.

But this is not the end of our difficulties. The domain of utility functions may change. No one can take seriously a utility function for which consumption is the only argument. There is power, and esteem as well as the welfare of some others which, to mention only three, should self-evidently be in the domain. But I want to focus on "animal spirits". One could, I suppose, translate high animal spirits to low or even negative risk aversion. But that is at best only a part. The utility function of the Schumpeterian entrepreneur is closer. As I understand it he is not primarily motivated by the consumption that high profits make possible, but in high profits as a signal of success which is valued as such. Any good history of the Renaissance, for instance, or of some nineteenth century British magnate will make clear what I mean. Search through the universal set is valued for itself, just as climbing the Himalayas or proving a theorem is. But the embodiment of esteem will vary through time and place: it was different for Achilles than for Rockefeller. Neither of their actions can be accounted for with the traditional domain.

All of this is woolly and inevitably so. But in that wool there may lurk the most significant elements of a growth theory.

4. SOME FURTHER PUZZLES

From any point in the universal commodity space and production set which the economy has reached at any time t there will be a large number of possible paths to the next point in these sets. One of these is to stay where one is. The relation between search and the probability of following any one of these paths is likely to be extremely complex. I have already argued that we are likely to lose much understanding by concentrating on aggregates (or indeed single good economies) and using simple exponential functional forms. For instance, some innovations in computers, railways etc. will give rise to many externalities, others will not. Some will imply large structural changes, others will not. I have provided the boxes against which we can measure our ignorance and which invite us to somewhat greater sophistication even if we need eventually to simulate. The question is whether the stylised models which avoid this brutishness would not after all suffice.

Growth theory in its modern form has been preoccupied with the "golden age". One of the fruits of the new literature is that there may be a number of these for an economy specified by given parameters. From this and a further hypothesis it has been deduced that "history matters". The further hypothesis is that economies behave in a manner which leads them to a golden age. Putting this into dynamic equations entails the conclusion that initial conditions matter. When these thoughts are handed over to the econometricians they feel justified in making the assumption that economies are in their golden age. They certainly are not deterred by the findings that for the dynamics which has been proposed as leading to the golden age, the time required to get into its small neighbourhood (starting from a given price and outside it) is very long indeed. (See Atkinson [1969]).

Now our boxes also suggest very strongly that "history matters". That is because it seems safe to suppose that as the economy travels through the universal sets, some paths which are possible no longer attract the research to implement them. For instance, once we have the motor car, improvements to horse-carriages are unlikely to be undertaken.

This is not proof but perhaps sufficiently suggestive. Work by David [1985] and Arthur [1989] and Agliardi [1991] which give quite orthodox motives to agents comes to the same conclusion. In a sense it was the stylised models which first suggested that history did not matter, and it is new stylised models which say that it may. It is quite unclear what has been gained by stylisation.

The answer to my argument is that we are interested in aggregates like G.N.P. per head. It is the growth in this and other aggregates which we wish to capture. My reply is that there seem strong reasons to suppose that the rate of growth of G.N.P. is not independent of the changes which occur in its composition. I can certainly construct a stylised model for which this is true. I also reiterate the extremely plausible hypothesis that the direction of research is likely to be highly relevant. But this requires much further work. It would be interesting to see whether a stylised box model which does not stylise their main content away can be constructed and what support it would lend.

But this is not the occasion for such an attempt, and I sum up. I have found the new growth models interesting and useful in that they have extended the questions asked to encompass some of the elements I have tried to delineate in my boxes. On the whole they have taken a plausible simple hypothesis which, once stated, could be seen to have the required consequences. I have not found my understanding increased by the formalisation: the hypotheses are far too simple and direct to make formalisation very necessary. Sometimes one gets the impression that the claim is that we now have endogenous growth theory. By this is meant that growth rates can be expressed in terms of some "fundamental" parameters such as time preference and degree of monopoly. Unfortunately, most of these parameters are not self-evidently exogenous. For instance the degree of monopoly may depend on the pace of innovation, and time preference may change with educational standards.

Indeed as I have already noted, the construction of an "endogenous theory of economic history" is not an attractive project. My own view is that at this stage we have

far more to learn concerning the economic elements of growth by attempting to construct models not with an eye to a golden age nor even the very long run but to a much richer account of the travel through the universal sets.

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