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# Induction, Growth and Trade

Essays in honour of Sir Roy Harrod

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# ECONOMETRICS IN THE WORLD OF TODAY

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## 1. *Introduction*

WHEN I was invited to speak at the First World Congress of the Econometric Society, held in Rome in September 1965, it was inevitable that my memory should go back some thirty years to the First European Meeting of the Econometric Society, held in 1931 in Lausanne, the place where Walras[1] lived and taught. I had the good fortune to be present at that meeting and to speak about the nature of econometrics. If I remember correctly we were about twenty persons all counted. At the First World Congress in 1965 there were several hundred. But if it is possible to measure the absolute volume of enthusiasm I venture to say that the sum total of enthusiasm present at that first meeting was not very much below that which was present at the 1965 Congress. We, the Lausanne people, were indeed so enthusiastic all of us about the new venture, and so eager to give and take, that we had hardly time to eat when we sat together at lunch or at dinner with all our notes floating around on the table to the despair of the waiters.

When we take a look at the number of papers and the variety of subjects treated at the First World Congress and make a comparison with the list of papers given at the Lausanne meeting, we must be amazed at the development that has taken place in this single generation. This comparison could perhaps have tempted me, at the First World Congress, to indulge in a eulogy of econometricians and their work. However, I resisted this temptation. If there is one thing which our Society must *not* be, it is a society for self-admiration. My attitude had more a leaning towards the critical side than towards the eulogical, and so I was rather outspoken. So much so that some of the audience may perhaps have found it a bit embarrassing. However, at that juncture of econometric development, I believed I could render a better service to the econometric fraternity by being critical and outspoken than by sugar-coating the pill. I still hold that view today.

[1] As we learned from Walras's pupil and close friend Professor Bonninsegni, Walras himself and those who knew him pronounced Walras with the 's' sounded.



It is very much in line with the Editorial I wrote in the first Volume of *Econometrica*, published 1933, where I said *inter alia*: 'The policy of *Econometrica* will be as heartily to denounce futile playing with mathematical symbols in economics as to encourage their constructive use.'

The econometric army has now grown to such proportions that it cannot be beaten by the silly arguments that were used against us previously. This imposes on us a *social and scientific responsibility* of high order in the world of today.

To bring home forcefully what I mean by social and scientific responsibility in this connection, let me mention a signal development that has taken place in the economic life of Norway in recent years. During wage negotiations between trade unions and employers, with the government as a very active 'observer'—negotiations the outcome of which may mean the paralysis of active life in the Norwegian economy for months and years to come—it has now become customary to have at one's disposal a fairly advanced *econometric model* based on Norwegian data and coded on the electronic computer of the Central Bureau of Statistics, ready at any time *quickly* to produce estimates of answers to certain highly important questions that may come up in the course of the negotiations. Subsidies to agriculture and fishing are also worked into the model. Norway is probably a country where this kind of practical application of econometric models has been pushed the farthest. But year by year this and other kinds of practical applications of econometric models are penetrating deeper and deeper into economic decisions also at the *national* level. It is only in recent years that we begin to see the *real impact* of the econometric idea that began to take shape when the Econometric Society was founded in 1930.

Herein lies the great opportunity of the econometricians of today—but herein also lies the great social and scientific responsibility that is imposed on them.

## 2. *A simple Example illustrating the Mathematical Essence of the von Neumann Path*

There are many types of growth theories and growth models. There is in particular one which is relevant to my subject, namely, the type characterized by such concepts as the von Neumann path and turnpike theorems. Therefore let me begin at this end of the spectrum. I think it is possible to suggest the essence of the von Neumann path by an example which is so simple that it is really nothing more than a little exercise in elementary college algebra and function theory.

Let us consider a system of two homogeneous linear differential equations

$$\begin{aligned} \dot{x}_1 &= a_{11}x_1 + a_{12}x_2 \\ \dot{x}_2 &= a_{21}x_1 + a_{22}x_2 \end{aligned} \tag{2.1}$$

where the $a_{ij}$ are given constants, $x_1$ and $x_2$ functions of time and $\dot{x}_1$ and $\dot{x}_2$ derivatives with respect to time. We may, if we like, look upon (2.1) as the definition of a *velocity vector* whose components $(\dot{x}_1, \dot{x}_2)$ are defined in any point $(x_1, x_2)$ by (2.1).

A concrete interpretation of $x_1$ and $x_2$ might (apart from additive constants) be the physical outputs in two sectors in a dynamic growth model. In a realistic situation the number of variables in the model will, of course, have to be much greater, but for describing the principle involved two variables will suffice.

My little exercise on this example will not include the usual study of the time shapes of the solutions as a sum of two exponential functions whose exponents are the, possibly imaginary, roots of the characteristic equation, but it will be concerned with something that is even simpler than this.

Let us ask if there exists a beam—that is a straight line through the origin —which is such that in any point on this beam the velocity defined by (2.1) *is directed along the beam itself.*

Any beam through the origin is defined by the two equations

$$\begin{aligned} x_1 &= d_1\omega \\ x_2 &= d_2\omega \end{aligned} \tag{2.2}$$

where $d_1$ and $d_2$ are two constant direction numbers defining the direction of the beam, and $\omega$ is a parameter whose variation from $-\infty$ to $+\infty$ generates the beam. The geometric properties of the beam are, of course, not changed if we multiply the two directing numbers $d_1$ and $d_2$ by a common non-zero factor. Therefore it is only the *ratio*

$$\lambda = \frac{d_2}{d_1} \tag{2.3}$$

between the direction numbers that counts. The ratio (2.3) assumes that $d_1 \neq 0$. In the case $d_1 = 0$ we simply consider the reciprocal of $\lambda$, or we may change the numbering of the variables. At least one of the two direction numbers must be different from zero if the beam is to have a meaning.

At any point on the beam (2.2) we have by (2.1)

$$\frac{\dot{x}_2}{\dot{x}_1} = \frac{a_{21}d_1 + a_{22}d_2}{a_{11}d_1 + a_{12}d_2} = \frac{a_{21} + a_{22}\lambda}{a_{11} + a_{12}\lambda}. \tag{2.4}$$

If this ratio is to be equal to $\lambda$, then $\lambda$ must satisfy the equation

$$a_{12}\lambda^2 + (a_{11} - a_{22})\lambda = a_{21} \tag{2.5}$$

hence

$$\lambda = -\frac{(a_{11} - a_{22}) \pm |\sqrt{(a_{11} - a_{22})^2 + 4a_{12}a_{21}}|}{2a_{12}}. \tag{2.6}$$



This is a necessary condition on $\lambda$. On the other hand if $\lambda$ has any of the values (2.6) it is easy to see that the properties we require from the beam are fulfilled. So the condition (2.5) is both necessary and sufficient. A beam whose $\lambda$ value is determined by (2.6) will be called an *intrinsic beam* of the system.[2]

All the various cases that may occur can be classified as follows:

(2.6.1) $0 < a_{12}a_{21}$ (hence $a_{12} \neq 0$) gives one real finite positive root *and* one real finite negative root. No root $\lambda = 0$ and no complex roots.

(2.6.2) $a_{12}a_{21} = 0$. This case can be split into the following three subcases:

(A) $a_{12} \neq 0, a_{21} = 0$ gives one root $\lambda = 0$ *and* one root which has the opposite sign of $(a_{11} - a_{22})/a_{12}$ (zero if $a_{11} = a_{22}$).

(B) $a_{12} = 0, a_{21} \neq 0$ gives a single root which may be either positive or negative (infinite if $a_{11} = a_{22}$).

(C) $a_{12} = a_{21} = 0$ gives one root $\lambda = 0$ if $a_{11} \neq a_{22}$. If $a_{11} = a_{22}$ any finite value of $\lambda$ will satisfy (2.5).

(2.6.3) $-\frac{(a_{11} - a_{22})^2}{4} < a_{12}a_{21} < 0$ (hence $a_{12} \neq 0$ and $a_{11} \neq a_{22}$) gives a case where *either* both roots are positive *or* both roots negative.

(2.6.4) $a_{12}a_{21} = -\frac{(a_{11} - a_{22})^2}{4} < 0$ (hence $a_{12} \neq 0$ and $a_{11} \neq a_{22}$) gives a double root which may be *either* positive *or* negative (but not zero).

(2.6.5) $a_{12}a_{21} < -\frac{(a_{11} - a_{22})^2}{4} < 0$ gives no $\lambda$ root in the real domain.

It would not be difficult to study in more detail all these various cases, but this is of no interest for my purpose. I shall confine myself to the case (2.6.1), i.e. the case where the effect of $x_1$ on $\dot{x}_2$ is of *the same sort*—with regard to sign—as the effect of $x_2$ on $\dot{x}_1$. This case will give me all the examples I need.

If we confine ourselves to case (2.6.1) and we only consider points *in the first quadrant* i.e., where both $x_1$ and $x_2$ are positive, we are left with *one and only one* intrinsic beam, viz., the one characterized by the positive value of $\lambda$.

If we *happen* to be at a point on our intrinsic beam, the velocity vector defined by (2.1) is directed along the beam, and consequently *we will stay on this beam indefinitely.*

Along this beam $x_1$ and $x_2$ will be equal to the constant direction numbers

[2] The intrinsic beam has no direct connection with the characteristic roots and the characteristic vectors of the system (2.1).

$d_1$ and $d_2$ respectively, multiplied by a common function of time $\omega$. The rate of change with respect to time of this common function is easily determined by noticing that along the beam we have $\dot{x}_1 = d_1\dot{\omega}$. Utilizing the first of the two equations in (2.2), we therefore get along the beam

$$\frac{\dot{\omega}}{\omega} = a_{11} + a_{12}\,\lambda. \tag{2.7}$$

This rate of change is a constant *depending only on the coefficients of the given system of linear differential equations (2.1)*. Since the rate of change of $\omega$ is constant along the beam, $x_1$ and $x_2$ will by (2.2) also have the same rate of change along the beam. That is, we have[3]

$$\frac{\dot{x}_1}{x_1} = \frac{\dot{x}_2}{x_2} = \frac{\dot{\omega}}{\omega} = a_{11} + a_{12}\lambda \qquad \text{(along the beam).} \tag{2.8}$$

This is as good a von Neumann path as you can ever hope to get. And you see how extremely simply it follows from the assumption of a linear and homogeneous system of differential equations. In the linear and homogeneous case it is really a next to obvious conclusion. The case would in its essence not be much different if we considered difference equations instead of differential equations or if we increased the number of variables in the system.

What will happen if we start at any initial point $(x^0{}_1, x^0{}_2)$ and from there on let the movement be guided by the differential system (2.1)? This can best be exhibited by depicting (2.1) as a velocity field represented by a set of velocity vectors with components $(\dot{x}_1, \dot{x}_2)$, these vectors being distributed all over the first quadrant. Figures (2.9) and (2.10) are two numerical examples where the $a_{ij}$ matrix of (2.1) is respectively

$$\begin{pmatrix} 1 & 1 \\ 2 & 0 \end{pmatrix} \quad \text{and} \quad \begin{pmatrix} -1 & 1.04 \\ 1.04 & -1 \end{pmatrix}.$$

If we start at an arbitrary point in the first quadrant, we will proceed along a trajectory defined by the velocity vector field and will end up by approaching the intrinsic beam of the system. And once we have gotten into the close vicinity of the intrinsic beam we will remain permanently in this vicinity.

The equations by which Figures (2.9) and (2.10) were computed are

$$\begin{aligned} \dot{x}_1 &= x_1 + x_2 \\ \dot{x}_2 &= 2x_1 \end{aligned} \tag{2.9}$$

$$\begin{aligned} \dot{x}_1 &= -x_1 + 1{\cdot}04x_2 \\ \dot{x}_2 &= 1{\cdot}04x_1 - x_2 \end{aligned} \tag{2.10}$$

[3] Instead of the right-hand expression in (2.8) we could have written $(a_{22} + a_{21} \cdot (1/\lambda))$. The two expressions are equal by virtue of (2.5).



For clarity the lengths of the vectors were reduced to one-fifth in (2.10). In (2.9) they have their original lengths.

In both cases the intrinsic path is a diagonal sloping upward at 45°. But otherwise there is a big difference. If in Figure (2.9) we start in the north-west or in the south-east, it would only be *very far out* and *after a very long time* that we would approach the vicinity of the diagonal. As we draw closer to the diagonal the movement in Figure (2.9) becomes, indeed, nearly parallel to the diagonal with only a next to imperceptible further approach to the

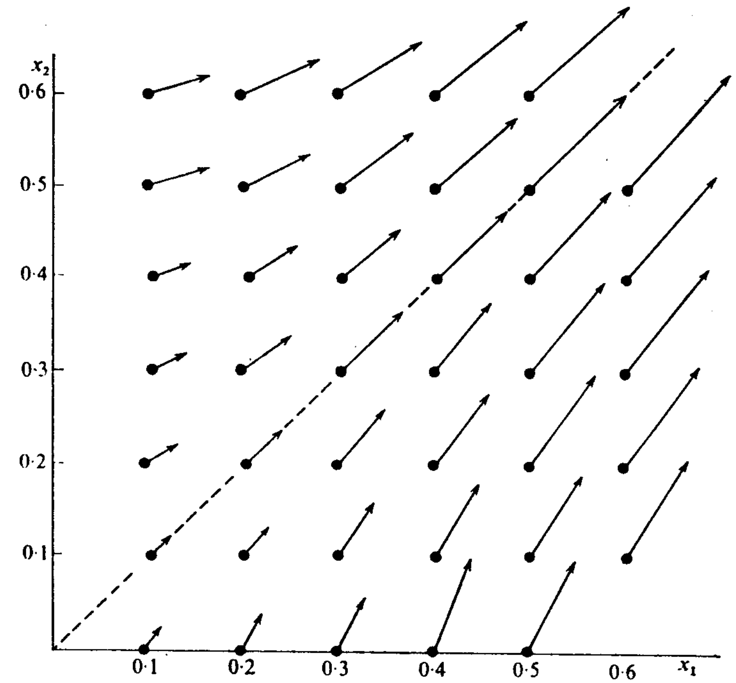


FIGURE 1 (2.9)

diagonal. On the contrary in Figure (2.10) the tendency towards approach to the intrinsic beam is very much *quicker*. Both figures can be taken to illustrate a *river bed*. In Figure (2.10) the banks of the river bed are much steeper than in Figure (2.9).

We note that if $a_{11} = a_{22}$ and if the units of measurement of $x_1$ and $x_2$ are conventionally chosen in such a way that the inclination of the intrinsic beam becomes $\lambda = 1$, and if the growth rate along the intrinsic beam is $r$, we have

$$\begin{aligned} a_{11} + a_{12} &= r \\ a_{21} + a_{11} &= r \end{aligned} \tag{2.11}$$

the matrix of (2.1) becomes[4]

$$\begin{pmatrix} a_{11} & r - a_{11} \\ r - a_{11} & a_{11} \end{pmatrix}. \tag{2.12}$$

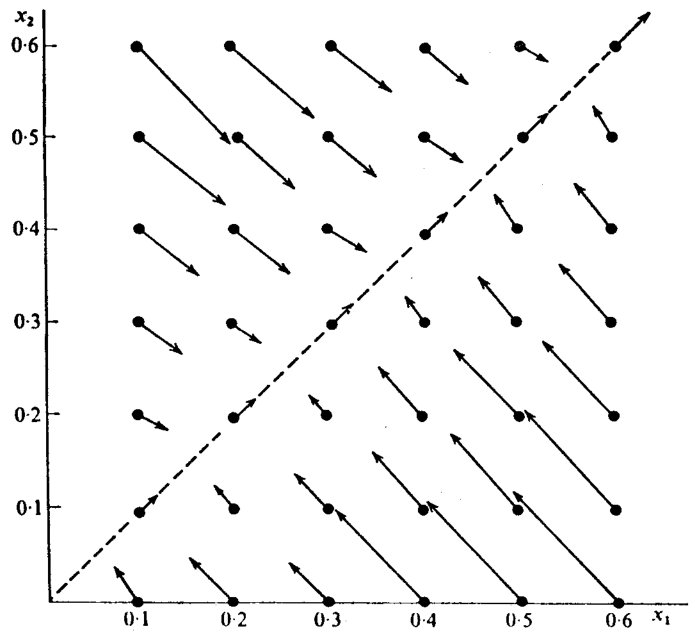


FIGURE 2 (2.10)

In the points ($x_1 = 1, x_2 = 2$) and ($x_1 = 2, x_2 = 1$) this gives respectively

$$\begin{aligned} \dot{x}_1 &= -a_{11} + 2r \\ \dot{x}_2 &= +a_{11} + r \end{aligned} \tag{2.13}$$

and

$$\begin{aligned} \dot{x}_1 &= +a_{11} + r \\ \dot{x}_2 &= -a_{11} + r. \end{aligned} \tag{2.14}$$

[4] As a check on (2.12) we note that in this case the positive root of (2.6) is 1, regardless of what $r$ and $a_{11}$ are. The matrix of Figure (2.10), being a special case of (2.12), must have $\lambda = 1$. The matrix of Figure (2.9) is not a special case of (2.12), but this example too has $\lambda = 1$, which is verified by inserting the matrix coefficients of (2.9) into (2.6).



This shows that if we choose $a_{11}$ negative, say equal to $-1$, we can, by making $r$ positive but small, produce an example with very steep banks, like the one illustrated in Figure (2.10).

In the case $\begin{pmatrix} 3 & 1 \\ 2 & 2 \end{pmatrix}$, the intrinsic beam will represent a *ridge* ('negative bank steepness') sloping downwards towards the north-west. In the case $\begin{pmatrix} -2 & 1 \\ 2 & 3 \end{pmatrix}$, growth will be negative. Putting $r = 0$ in (2.12) we get a stagnant case.

## 3. *The River-beddiness and the Bank Steepness of a General Field*

The case where there exists a single intrinsic path, which is even further specialized as being a beam—a straight line through the origin—is of course too simple to be realistic. We have to consider more general types of fields. In the case of two variables we get a good survey of the possibilities by thinking of the map of a hilly landscape and thinking of the trajectories which raindrops will follow when they fall on this country and seek their way to the ocean. Consider the projection of such trajectories on to the plane of the map. An extreme case would be one where the country contains a single river-bed with steep banks. We will then get a situation similar to Figure (2.10), perhaps with a river-bed that is curved instead of straight. In the case of a single river-bed with steep banks, any drop that falls will quickly find its way to the river and from there on it will follow the river to the ocean. In other cases there may be, say, two or three main river-beds, each with perhaps one or more tributaries and with banks that may be more steep or less steep. A look at the topographic maps of some region of the world will suggest the variety of cases that may exist.

In some cases the landscape may be more or less *diffuse* with no conspicuous river-beds so that nothing in particular can be said about the trajectories without specifying where precisely the *initial points* are, and the—more or less *random*—vicissitudes that may occur. For instance in the case of the Nile there is to begin with a fairly conspicuous river-bed. But later the waters of the Nile pass through a big diffuse swamp country at the end of which the river again gets back to a more conspicuous river-bed pattern, which is particularly sharply defined with steep banks in the cataracts immediately south of Aswan.

Economic life and technical possibility are—just as the pattern of river-beds and bank steepnesses we find in the concrete shape of a country—too diversified to be classified according to some rule derived from oversimplified assumptions.

### 4. *Technological and Preferential Features of the Field*

But for a moment let us nevertheless revert to the case (2.1) which led to the existence of a single, well-determined, intrinsic path in the form of a beam through the origin.

We note that there are many linear and homogeneous systems of the form (2.1) which will have the *same* intrinsic beams since the beam is defined by a single parameter $\lambda$ while the system (2.1) contains no less than four constants.

Generalizing the set-up, we may drop the assumption that the system of differential equations is of the linear and homogeneous kind and consider a variety of forms, all of which may lead to a well-defined intrinsic beam, or possibly to an intrinsic curved line. We may even go further and drop the concept of a velocity vector that is deterministically *given* in each point, and instead proceed by the following general type of reasoning.

*First*, regarding the vector field (or more generally the transmission field). We postulate that if we are in any given point $(x_1, x_2)$ the direction of move from $(x_1, x_2)$ is subject to satisfying certain conditions expressed by *equations* and/or by *bounds*, i.e., inequalities that depend on the point $(x_1, x_2)$. The equations and/or bounds may be deterministic or stochastic. This system of conditions we may call the *technology*, taking technology in a very broad sense. The technology is assumed to remain constant over the whole time period to be considered. All historical trajectories—or paths, if we like to call them so—will have to satisfy this constant technology. That is, they must be technologically *permissible*.

*Second*, we state a *supplementary convention*. This is an assumption about the vector field which makes it possible to define the concept of an *intrinsic* path. That is a path with the property that *if* we are on it (or close to it), this path is not only technologically permissible but such that we will stay on it (or close to it) for ever if we are guided by the vector field which has been specified through this supplementary convention.

Under a given set of supplementary conventions there may be *several* paths each with the property that we will stay on (or close to) it for ever, once we have gotten on (or close to) it.

If several intrinsic paths exist we may work towards the definition of *one specific* intrinsic path by *reinforcing* the supplementary convention in some way. There are several alternatives for doing this.

It may, for instance, be done by specifying that the bounds involved in the definition of the technology are everywhere to be replaced by strict equalities of such a particular sort that leads to a unique intrinsic path. We may specify in such a way that the uniquely defined intrinsic path derives its properties mainly from the *engineering* aspects of the technology. Or we might achieve the definition of the unique intrinsic path by assuming a specific *gaming rule* between the market and the engineering aspects of the technology, in which case the intrinsic path would to a large extent be influenced by our conception of some sort of behaviouristic pattern. At any rate the supplementary convention must be specified in sufficient detail to take away enough degrees of freedom so that we end up with a unique one-dimensional intrinsic path.



*Third*, regarding the preference function. There is a definite limit to the degree of reinforcement of the technological assumption that may be applied for the purpose of reaching the definition of a *unique* intrinsic path: the assumptions about the engineering aspects of the technology and about the gaming rules must not carry us too far away from the concrete situation studied. In most cases this limit will tend to lead us into a situation where we have to face, not a unique intrinsic path, but a *number of alternative intrinsic paths*, all of which are technologically permissible. In such cases it is necessary to introduce a *preference function* which will order all technologically permissible intrinsic paths in a preference order. This is the essence of a *purposeful* macroeconomic policy. That one of all technologically permissible paths which has the highest preference might be called the *optimal* path.

With such a theoretical set-up it might be possible to prove various types of turnpike theorems, i.e., theorems to the effect that under certain conditions the actual path will for a considerable part of the total time considered follow rather closely to the optimal path which has been defined through the three logical elements considered above: the vector field, the supplementary convention, and the preference function. To reach such theorems it is *necessary* to accept all the three logical elements discussed (or something equivalent to them). Whether it will or will not be possible to formulate a turnpike theorem will *depend essentially on how we specify the three logical elements in question.* Most turnpike analyses have escaped the problem of the preference function by—too often tacitly—making assumptions about the first and the second logical elements which will lead to a unique intrinsic path.

If we are resourceful enough we may invent a variety of supplementary conventions which may lead to a corresponding variety of kinds of intrinsic paths. And with an appropriate definition of the preference function we might be able to prove that the *optimal* path will for a time follow closely to one of the intrinsic paths we have introduced, and later, perhaps, switch to following closely to another of these intrinsic paths.

There is no end to the variety of turnpike theorems that could be invented in this way.

### 5. *The Economic Relevance of the Intrinsic Paths and Turnpike Type of Theorem*

What is the economic relevance of intrinsic paths and turnpike type of theorem of the kind I have mentioned?

To be quite frank I feel that the relevance of this type of theorem for active and realistic work on economic development, in industrialized or underdeveloped countries, is practically nil. The reason for this is that the consequences that are drawn in this type of theorem *depend so essentially on the nature of the assumptions made.* And these assumptions are frequently made more for the convenience of mathematical manipulation than for reasons of similarity to concrete reality.

In too many cases the procedure followed resembles too much the escapist procedure of the man who was facing the problem of multiplying 13 by 27. He was not very good at multiplication but very proficient in the art of adding figures, so he thought he would try to add these two figures. He did and got the answer 40, which mathematically speaking was the absolutely correct answer to the problem as he had formulated it. But how much does the figure 40 tell us about the size of the figure 351?

This example is not intended as a joke, but is meant to be a real characterization of much of the activities that are *à la mode* today in growth theories. In particular it is characteristic of the very popular exercise of investigating what would happen under an infinite time horizon. Questions of convergence under an infinite time horizon will depend so much on epsilontic refinements in the system of assumptions—and on the infinite constancy of these refinements—that we are humanly speaking absolutely certain of getting infinite time horizon results which have no relevance to concrete reality. And in particular we are absolutely certain of getting irrelevant results if such epsilontic exercises are made under the assumption of a constant technology. 'In the long run we are all dead.' These words by Keynes ought to be engraved in marble and put on the desk of all epsilontologists in growth theory under an infinite horizon.

Turnpike theorems of the usual kind have no relevance to the problems faced by a politician in an underdeveloped country. He is not interested in an assumption about an unchanged technology. He is precisely interested in *changing* the technology. And he is not interested in knowing whether an actual development path in his country will come close to or be far away from some intrinsic path that has been defined by piling up queer assumptions.

To avoid misunderstandings I must state explicitly three things to which I do not object in an absolute way, only in a relative way.

In the first place I have no objection in general to the application of rough approximation formulae. I use such formulae myself to a great extent. But there is a proviso. We must have a good reason to believe that the conclusions to be drawn—and to be taken seriously—are of such a kind that they depend primarily on the way in which the approximation *resembles* reality and not on the way in which the approximation incidentally *deviates from* reality.

For instance, if the purpose is to compare the speed of race-horses with that of ordinary horses, I might accept an analysis which assumes that all



race-horses have the same speed. But if the purpose is to conjecture which one of the race-horses will win tomorrow, this approximation has, realistically speaking, no sense. But a sufficiently resourceful theorist might perhaps take this assumption as the starting point for proving a theory to the effect that no race-horse can ever win a race.

In the second place there is no topic under the sun, even the most abstract or the most seemingly useless one, which I would remove from the list of subjects which might occasionally be made the object of a respectable scientific research. I might even consider with respect a study of the pattern of keyholes in northern Iceland in the first half of the thirteenth century. But I would strongly object to a situation where too many of us too often used too much of our time and energy on the study of keyholes in northern Iceland in the first half of the thirteenth century. If we did, we would have failed in our social responsibilities as econometricians in the world of today.

In the case of the intrinsic paths and turnpike type of growth theory, I have a strong and uncomfortable feeling that too many of us too often use too much of our mental energy on problems similar to that of keyholes in northern Iceland, or on proving theories to the effect that no race-horse can ever win a race.

In the third place I have all my life insisted that factual observations alone —observations taken by themselves—do not have much sense. Observations get a meaning only if they are interpreted by an underlying *theory.* Therefore, theory, and sometimes very abstract theory, there must be. And no kind of mathematical analysis in economics should be rejected just because it might be difficult and refined mathematics. But at the same time I have insisted that econometrics must have relevance for concrete realities—otherwise it degenerates into something which is not worthy of the name econometrics, but ought rather to be called *playometrics.*

Once in every century there may come along a genius like John von Neumann who on some specific occasion, more or less on the spur of the moment, throws out an interesting thought on something that would happen under some very special assumptions. Such a thought thrown out by a genius is valuable and should be put on record. But we should leave it at that. We should not mobilize an army of people to produce queer assumptions so to speak on the conveyor band and deduce consequences from these assumptions. If we do, we are on the wrong track both socially and scientifically, and we are not living up to our responsibilities.

Such exercises may be an entertaining intellectual game. I admit that they *are* highly entertaining and I can understand the great number of students to whom this kind of exercise appeals. But it might be a dangerous game both socially and scientifically.

Let me give four examples of modern econometric analyses which illustrate what I would call econometric analyses of the *genuine* kind because they are built on a theoretical set-up, but at the same time are deeply rooted in realistic situations.

In 1964 I had the good fortune to be present at the Zürich meeting of the Econometric Society and T.I.M.S., the Institute of Management Science. At this meeting Professor H. Albach of Germany presented to us a paper on long-range production plans in the operation of coal pits, a very serious and important problem in Germany at this moment. He spent more than one-third of his time explaining to us what a coal pit is and what the profile of a coal pit is. We sort of felt that his paper was written with dirty fingers because he had just come back from digging in the coal pits. From this concrete pre-occupation he derived his theoretical concepts and formulated his programming problem which now appeared as a problem full of life and reality.

My second example is another paper presented at the Zürich meeting by W. K. Holstein of the United States and produced by him and his colleague S. Reiter. The paper was one on job scheduling and control in a special kind of shop. Holstein too used more than one-third of his time describing the particular shop in question, the various types of machine, the way the machines were grouped together in stations, the way the incoming orders were recorded and passed on to the shop for execution, etc. On the basis of this concrete description he formulated the theoretical concepts and used the theory for a realistic programming set-up.

My third example is the paper presented at the Zürich meeting by J. Lesourne of France. He too used a good part of his time explaining the concrete geographical and population facts of the problem.

As a fourth brilliant example let me mention a Rome 1965 presentation that was very abstract but still had no touch of playometrics in it, viz., Professor Jacob Marschak's Irving Fisher lecture on 'Economics of Organization'. Marschak's very abstract concepts were all based on realistic situations and did not distort reality by artificial assumptions. On the contrary he pointed out, for instance, that the usually accepted entropy concept in information theory was too simple because it did not take account of the *purpose* for which the information was to be used. This purpose was made explicit in Marschak's general formulae.

Such papers as these are of the kind which it is soothing to listen to in the middle of a cascade of papers of the playometric kind.

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I am not the only person to have been seriously concerned about the development in econometrics. I vividly remember a reception in the Royal Palace in Oslo some thirty years ago, shortly after the founding of the Econometric Society. The reception was on the occasion of an international mathematical congress in Oslo. It was not by pure chance that Norbert



Wiener and I found ourselves deeply engaged in a conversation in one of the rooms of the Royal Palace, overlooking the main street of Oslo. Norbert Wiener was one of the founders of the Econometric Society, as you will see from the report of the organizing meeting of the Econometric Society held in Cleveland, Ohio, in December 1930. At the time of our conversation in the Royal Palace in Oslo, Norbert Wiener had begun to be quite alarmed by the happenings in econometrics and he appeared as a matter of fact to be rather sceptical about the whole thing. I was, as you can imagine, a bit disappointed by his attitude. But later developments have made me understand better the cause of his alarm, and have made me understand that basically his views and mine were genuinely the same. In his book *God and Golem, Inc. A Comment on Certain Points where Cybernetics Impinges on Religion*, written shortly before his death,[5] Norbert Wiener reverts to the misuses of econometrics. His attitude is just as critical against misuse as it was before, but now his pessimistic attitude is after all more positive than in our conversation in the Royal Palace in Oslo. On page 89 he says, 'The use of mathematical formulae had accompanied the development of the natural sciences and become the mode in the social sciences. Just as primitive people adopt the Western modes of denationalized clothing and of parliamentarism out of a vague feeling that these magic rites and vestments will at once put them abreast of modern culture and technique, so the economists have developed the habit of dressing up their rather imprecise ideas in the language of the infinitesimal calculus. . . . Difficult as it is to collect good physical data, it is far more difficult to collect long runs of economic or social data so that the whole of the run shall have a uniform significance. . . .'

These difficulties, of course, have been and are quite familiar to those working in econometrics. Therefore they try, whenever possible, to rely on *engineering data* instead of statistical time series. The difficulties are familiar to them in principle, but I am sorry to say that some econometricians have often been liable to forget these basic principles in practice and, therefore, have not been critical enough when they apply their techniques and mathematical analysis. This remark is particularly important when it is a question of drawing conclusions about *the economic policy to be followed in a concrete situation.*

Norbert Wiener concludes by saying, 'This does not mean, however, that the ideas of cybernetics are not applicable to sociology and economics. It means rather that these ideas should be tested in engineering and in biology before they are applied to so formless a field' (as economics).

I will subscribe to the essence of Wiener's critical remarks, and at the same time *emphasize the optimistic tone* at the end of what he says. And I would like to add that the time has now come when mathematics and statistics may

[5] Published by the Massachusetts Institute of Technology Press in 1964.

be and should be applied ever more intensively in economics, thus building up econometrics as a respectable science. But I must also, and must emphatically, add the proviso that we must work for genuine econometrics—not for playometrics.