What is an effect? Presentation for the session of RC33 – Causality revisited.

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> 'There is more to the world than patterns of events …' Andrew Sayer
> *Realism and social Science* Sage 2000 14

Debates about causality have generally focused on the character of the causal side of the binary pair: Cause and Effect. Arguments here have been both ontological – in relation to the actual nature of causes themselves, and epistemological – in relation to how causes may be known. In crude summary the contemporary state of the debate might be characterized by saying that there is an ontological argument between positivists and critical realists with critical realists asserting the complex, contingent and generative character of cause, and an epistemological debate between critical realists and post-modernists with the latter reducing the social world to merely knowledge of it (Carter and New *Making Realism Work* Sage 2004 3). This paper is firmly set in the critical realist camp and endorses both the understanding of causation as complex and generative and our ability to make knowledge claims about the world as it is. However, the argument draws on Complexity Theory (Byrne *Complexity Theory and the Social Sciences* Routledge 1998, Cilliers *Complexity and Postmodernism* Routledge 1998) as well as critical realism and asserts that our understanding will be advanced if we think about the nature of effects in the social world.

The central premise is simple. The interesting objects in the social world at whatever level – micro, meso, macro – are themselves complex systems. There are numerous definitions of complex systems and it is useful to reproduce both a very early version and a canonical more recent version before turning to a specification in the language of mathematical dynamics. Let us begin with Weaver who distinguished a set of problems which could neither be described in the simple deterministic terms of Newtonian mechanics nor addressed by probabilistic techniques in the form of frequentist statistical methods which describe the aggregate behaviour of multiple simple entities. It was not just a matter of multiple variate components:

> '…much more important than the mere number of variables is the fact that these variables are all interrelated… these problems, as contrasted with the disorganised situations with which statisticians can cope, *show the essential feature of organisation.* We will therefore refer to this group of problems as those of *organised complexity.*'
>
> Weaver, 1958 (italics in original)

Rosen extends this account by specific reference to causality. He defines a complex system precisely in terms of the necessarily complex character of generative causality for such systems:

> ' ... a simple system is one to which a notion of state can be assigned once and for all, or more generally, one in which Aristotelian causal categories can be independently segregated from one another. Any system for which such a description cannot be provided I will call complex. Thus, in a complex system, the causal categories become intertwined in such a way that no dualistic language of state plus dynamic laws can completely describe it. Complex systems must then process mathematical images different from, and irreducible to, the generalized dynamic systems which have been considered universal.' (Rosen 1987 324)

It is rather important to distinguish complex systems from other systems which have the potential for non-linear change. Mathematical dynamics employs the concept of state space – If a system can be described in terms of n variables, then its state space is n dimensional and we can describe its condition at any single point in time in terms of coordinates in that n dimensional space which coordinates are the values of the n variables at that single point in time. If we have measurements of the values of the variables through time, then we have an n+1 dimensional space, with the extra variable being time, and we can observe the path the system takes through its phase space. This path may take the form of an attractor. If the behaviour of the system was truly random, then as we measured its condition at repeated time points (note such measurements are inherently discrete rather than continuous) then it could be anywhere in the state space at any time point. If, however, we find that its trajectory is confined to a limited part of the state space, then we describe the path of that trajectory as an attractor. Mathematical dynamics distinguishes between conservative systems which essentially do not have the potential to transform the 'volume' (general shape) of their attractor and dissipative systems in which the form of the attractor may change. Another way of putting this is to distinguish among equilibric systems which do not change their position in the state space, close to equilibric systems which move back towards their original position if disturbed, and far from equilibric systems in which radical transformation of the attractor space of the individual system is possible.

All complex systems are dissipative systems but not all dissipative systems are complex systems. It is important to distinguish between chaotic systems in which very small changes in the values of system significant variates - control parameters in dynamics terminology – can generate radical changes in the attractor state of the system and do son repeatedly, and complex systems which are substantially more robust but do have the potential for radical change.

In general mathematical dynamics deals with the trajectories of single systems but it is useful for us to consider multiple systems – in the language of the physical sciences, ensembles of systems – and to consider that we might extend the idea of attractor to represent a domain in state space occupied by a set of systems with other attractors representing other domains. Position in a given attractor can then be regarded as representing membership of a category i.e. as a specification of kind. In this sense we can see change for a single system as involving movement to a new attractor set which implies that there has been a change in the kind of thing the system is.

Let me present a list of the characteristics of complex systems understood in this way.

1. Complex systems are inherently emergent. They cannot be understood by a process of analysis alone. Neither are they simply holistic. Understanding must address parts, the whole, interactions among parts, and interactions of parts with the whole.

2. Complex systems are not chaotic. Therefore, they do not change radically and frequently in consequence of small changes in key determinant parameters.

3. Complex systems are robust. Most of the time they continue to maintain the same general form with ongoing constant small changes within that form. In complexity terminology, most of the time their state space coordinates are located in a torus attractor. However, robustness is not the same as stasis, even with stasis understood as allowing change within an attractor. Robustness also resides in the capacity for radical change with continued existence.

4. Significant change in complex systems is qualitative and radical, not incremental. In complexity terminology it takes the form of phase shifts. Change in complex systems can be thought of as a process of metamorphosis – the system changes radically whilst continuing to exist. In terms of state space it moves to a new attractor.

5. Complex systems are nested and intersecting. All systems are contained within and intersect with other systems. Boundaries are fuzzy and plastic. Moreover, the nested character of a set of systems is not hierarchically deterministic. Systems nested within have a recursive deterministic relationship with the systems within which they are nested. Potentially every level has implications for every other level.

6. In consequence of the above complex systems display a high degree of autonomy. This does not mean that they can become anything, but it does mean that what they can and do become is in large part a function of the system, its own components, and systems nested within it.

7. The range of potential future states for a system which undergoes phase shift transformation is greater than one, but nonetheless limited. There are alternative futures but not an infinity of possibilities. Future state is path dependant but not path 'determined' in the usual sense of determination as exact specification.

It seems useful to introduce a term: 'effectality' – a neo-logism coined to try to express the view that in dealing with complex systems we really need to think as much about 'what is an effect?' as we do about the nature of causality itself. The central proposition around which the argument of this piece is founded is that for complex systems, effects are to be understood in terms of the location of those systems within their possible state space. We might consider effects to then fall into four kinds. The first is the kind of ‘specifying original position’ – in other words what kind of thing is the complex system – another way of saying what is its position in the possible state space – when it first comes into existence. The second is the kind of ‘staying the same’ – in terms of the language of attractors describing a system which stays within the boundaries of a torus attractor. Aspects may change somewhat over time but the system remains essentially what it was. The third kind of effect is the kind of ‘undergoing phase shift’ – which at least metaphorically implies that the system while remaining coherent changes its fundamental character. Crooke et al note that Parsons made exactly this kind of distinction between close to equilibric and far from equilibric systems in terms of the causal processes which he considered drove social change.

> 'Parsons makes a distinction between what might be called developmental processes and what might be called phase-shift processes. The former consist in a continuous and incremental elaboration and separation of sub-systems, which does not alter the general overall pattern of society. By contrast, phase-shift processes are fundamental differential leaps or evolutionary breakthroughs, typically caused outside the social realm (e.g. in the realms of culture or personality) which reorient the social pattern.' (Crooke et al 1992 5)

The biological process of metamorphosis provides us with a good heterologous analogy (see Khalil 1997) for phase shifts in social systems, not least because there is a direction to metamorphosis, although social systems may revert to their earlier form. The final kind of effect is ‘terminating’ – the system ceases to exist in any form which can be regarded as continuing its inherent integrity. Thus what matters about complex systems is how they come into existence, whether they stay much the same – occupy a torus attractor to use the language of mathematical dynamics – or change to some new state which is radically different, whilst maintaining their integrity as a system - or cease to exist. Understood in this way the nature of an effect for an existing system is rough stability – the essential character of social systems in the Parsonian framework, or radical and qualitative change which may involve termination of the system although it usually does not do so. Effects for existing systems are either about close to equilibric stability or non-linear transformation. We can also see both the creation of a new system and the termination of a system as non-linear transformations. In neither case – stability or transformation - are we dealing with the incremental linear change as this is understood in the causal descriptions which characterize Newtonian mechanics and which have served as a metaphor for change across the whole of the social sciences but particularly for that form of quantitative social science which draws on the General Linear Model.

Another way of thinking about this is to recognize that we can see the terms trajectory and history as synonyms when we are considering complex systems. Here we can profitably use Braudel’s formulation of the idea of the longue durée. A system whose trajectory can be described by a torus attractor – conventionally represented in three dimensions by a doughnut or three dimensional ring – is essentially passing through a longue durée. That is to say whilst things change, the essential character of the system remains the same, as for the social organization of early modern rural France. Phase shifts mark the end of the longue durée. This approach which directs us away from understanding effects in terms of changes in single dependent variables measured at whatever level, the usual focus of linear causal modelling, requires us to devote careful attention to the means by which we might identify effects. That is to say how can we establish that something has stayed the same or changed its kind? Identification of the special instances of coming into being or ceasing to be are relatively straightforward but establishing whether a change is one of kind or simply movement within the space state boundaries of present kind is more difficult. Here we are faced with establishing transitions which involve changes of kind.

A Change of Kind in a Single System – industrial to post-industrial Leicester

Let me illustrate this with an example drawn from my current research project investigating the nature of post-industrial industrial cities. All sorts of relevant issues emerge in work of this kind. There is an issue of definition by boundary setting. As Cilliers notes:

> Boundaries [of complex systems] are simultaneously a function of the activity of the system itself, and a product of the strategy of description involved. In other words, we frame the system by describing it in a certain way (for a certain purpose) but we are constrained in where the frame can be drawn. The boundary of the system is therefore neither a function of our description, nor is it a purely natural thing. (2001 141)

What are the boundaries of a city? Traditionally statistical descriptions take administrative definitions but these, whilst reflecting realities of governance, are themselves constructs.[1] I have tried to work with available approximations of urban areas – in the case of my UK examples with definitions based on judgements in relation to development patterns and journey to work areas. So for Leicester I define the city as the City of Leicester plus all of an adjacent district and parts (wards) of two other districts. However, this definition itself is dynamic. Certainly at the time of the UK's first census in 1801 or even in 1901 or 1951 it would have been incorrect to include free standing agricultural, industrial and coal mining villages as part of the Leicester metropolitan area. Suburbanization and industrial change has made them now in important but not absolute senses – Leicester. [2]

Leicester provides a good example to illustrate the argument about change in complex systems. Let us agree with Jane Jacobs, a participant in the original Macy seminars, that cities are complex systems:

> 'Cities happen to be problems in organized complexity, like the life sciences. They present "situations in which half a dozen quantities are all varying simultaneously *and in subtly interconnected ways.* [original emphasis] Cities, again like the life sciences, do not exhibit *one* [original emphasis] problem in organized complexity, which if understood explains all. They can be analysed into many such problems or segments, which, as

in the case of the life sciences are also related with one another. The variables are many, but they are not helter-skelter; the are "interrelated into an organic whole."' (Jacobs 1962 433)

If we look at the trajectory of Leicester over the last thousand years we find that a market town with a population of 2,000 at the time of Domesday book was by the end of the eighteenth century a mix of market town and industrial centre[3] with a population of 17,000. The town grew with great rapidity through the nineteenth century on the basis of industrialization to achieve a population of 230,000 by 1914 and 290,000 by 1961 which was the peak of its industrial fortunes.

Currently as of the 2001 census Leicester City has a population of 280,000, which is 47% of the total population of the Leicester Urban Area[4] which has a population of 579,000. For the Urban area as a whole there are 260,000 employed workers of whom 46% are female and 35% worked in industrial sectors.[5] Economically active people comprised 62% of the urban areas adult[6] population. Of the economically active 65% were full time employees, 19% were part time employees, 11% were self-employed, and 6% were unemployed. 75% of the urban area's population described themselves as 'White British', 15% as Indian or Indian British, and no other ethnic identity exceed 1% of the population. There were 230,000 households in the urban area. 70% were owner-occupied, 19% were social housing and the rest were other tenures. 27% of households contained dependent children. Of the households containing dependent children 63% contained two married parents, 13% contained two cohabiting parents and 24% were headed by a single parent. The above standard descriptive statistics for 2001 can be considered as constituting measurements at a single time point of ten variate traces[7] of the trajectory of the Leicester urban area as a complex urban system viz.

1. Total population of the area

2. Distribution of the population between urban core and suburban / exurban periphery.

3. Ethnic composition of the population.

4. Proportion of population aged 16-74 economically active.

5. Total employed population.

6. Distribution of the working population by sector of employment.

7. Distribution of the working population by kind of economic activity..

8. Distribution of the working population by gender.

9. Total Households

10. Tenure of Households

Some of the above variates are absolute measures e.g. total population, and some are relative proportions. We can treat all of them as representing the individual dimensions of the multi-dimensional state space of the Leicester Urban area. Let us consider what the measurements were at another point in time – in 1971 when the present local authority boundaries were established. This is laid out in Table One together with some available data from 1911.[8] Boundaries and definitions change but since we are dealing with variate traces of a complex system and not with reified variables, then this does not matter. We have time ordered descriptions of the system as a whole which are slightly differently constructed – and we have to be sure that the constructions i.e. the operationalizations, are only slightly different – and on that basis we can see if things have changed in any radical way. The very obvious change on this time series is in the significance of industrial employment. In the industrial era, which certainly lasted until 1971, it ran at about 60% of all employment. By 2001 it was less than 60% of that level at 35% overall. Actually at this level the Leicester Urban Area is significantly less deindustrialized than most former industrial UK conurbations but it still has deindustrialized in terms of employment base. Leicester traditionally was a centre for industries which employed women, an important factor in the city's historic prosperity since working class households were not dependent on one wage, so its workforce has not changed dramatically in terms of gender composition, in contrast with industrial city regions with a history of primarily male employment in heavy industry.

There are other significant changes. In 1911 less than 3% of Leicester and Leicestershire's population were born outside the UK (which then included the whole of Ireland). By 1961 the equivalent figure was still just over 3% but by 1971 this had risen to nearly 9% and although birthplace no longer is a significant descriptor for ethnic differentiation by 2001 we can see that 25% of the Leicester Urban Area's population self-identified as other than White British. This figure will have risen significantly since then with a large recent immigration of workers from EU accession states, principally Poland. Another change of significance is in household composition. In the East Midlands tenure changes were not so dramatic as in other post-industrial industrial city regions but the location of dwellings and population did shift with a definite movement towards suburban and ex-urban residence for families countered by an increase in single young people, especially third level students, living in the urban core.

Table One: - Leicester Urban Area – Characteristics over time

	2001	1971	1911
Total Population	579,000	534,000	
Percentage ethnic identity other than White British	24.7	8.8*	Less than 1**
Total of working age	420,000	392,000	
Total Economically Active	261,000	261,000	235,000
Percentage of working age economically active	62.1	66.5	
Percentage economically active female	46.6	38.2	35.1**
Percentage economically active in industrial employment	34.5	58.7**	63.1**
Total Households	230,000	177,000	
Percentage owner occupied	70.0	57.1	
Percentage social tenants	18.7	23.7	

- based on birthplace data

** figures for the whole of Leicestershire

Changes of kind in multiple systems – exploring ensemble trajectories through classification

The assertion that the Leicester city region has undergone a transformation from an industrial to a post-industrial form is based essentially on a single measure of the actual employment base of the working population which could be graphed over time and which shows a massive decline between 1971 and 1991 at which point it roughly stabilizes.[9] There really is not challenge to the notion that this city has de-industrialized but we cannot construct a description of social change on the basis of a single case. Here we can return to the idea of exploring the trajectories of ensembles of cases. Suppose we are interested in the trajectory of Western and Central European industrial city regions between 1961 and 2001. We might decide to include in this set all Western and Central European city regions with a population of over 500,000 and which are not capital cities. All the issues about boundaries and incompatibility of data sets arise, but the latter in particular don't matter much if we think of measures as traces rather than as operationalizations of 'real' variables. In 1961 these cities were industrial. Even European capital cities had very large industrial workforces but all non-capital cities of 500,000 plus were primarily industrial zones. Now many are not and at the same time the transition to post-industrial status has happened in different ways for different places. There are roughly 140 such industrial city regions in Western and Central Europe and we can classify them using standard numerical taxonomy approaches such as Cluster Analyses or by using a classificatory neural net approach.

The crucial thing is to construct typologies through classification at different time points. There is of course a lot of work involved in assembling even crudely approximate data sets but this can be done and we can construct our typologies AND map changes between them. The key thing here is that membership of a class in a typology should be regarded as a marker for an effect and we can map both changes i.e. transition from industrial to post-industrial form, and look at the particular kind of post-industrial form. Here effects are constituted in terms both of stasis against change, and if change, then the particular kind of change.

This idea has general application when we have data for an ensemble of systems. For example my colleague Wendy Dyer has used it to track trajectories of persons passing through a custody diversion process in Teesside in the UK and we can use it to describe patterns of effects whenever we have longitudinal data for ensembles of similar cases which enables us to construct such time ordered trajectory mappings.

Exploring causality with Effects understood in this way

The implications of this proposal about the nature of effects is that we explore causality by working backwards from specific different effects. In other words we should engage with processes of retroduction to explain what has happened and in terms of applied social science develop a retrodictive approach to guiding actions towards the achievement of desired outcomes. This is very much in accord with the general critical realist programme of explanation. We are dealing with effects understood as system states and understand these system states to be the product of complex AND multiple generative mechanisms. Charles Ragin's conception of configuration and his method of Qualitative Comparative Analysis (Ragin 2000) enable us to address causation in precisely this retroductive fashion. Fielding and Lee describe the procedure thus: 'Unlike the data matrix in quantitative research, where the analytic focus is on variables displayed in the columns of the table, it is the rows which are important here. What is being examined for each row is the configuration of causes associated with the presence or absence of an outcome for the case.' (1998 158) There is explicit recognition of 'causal complexity' (Coverdill et al 1994 57), that is of the possibility of multiple and/or different causal patterns associated with a given outcome. Essentially the procedure starts with a specification of different effects – understood in complexity terms as different states of similar systems in an ensemble of systems – and works out on the basis of descriptions of the characteristics of those system, sets of causal configurations which give rise to the outcomes observed. The simplest way of illustrating this is in relation to a binary effect.

Table Two is a Truth Table generated from a relatively simple data set describing state secondary schools in the North East Region of England. The outcome variable is whether or not the school belongs to a cluster in which a set of achievement criteria and generally high. The descriptive variates describe the admissions criterion of the school, whether or not it is religious in form, a binarized measure of percentage of pupils receiving free school meals (which indicates social deprivation), a binarized measure of percentage of pupils with special needs, whether or not the school is mixed in gender, and whether or not it has a sixth form. Thus the first line of the truth table describes a set of 26 schools which are comprehensive, mixed, have a sixth form, are not religious, don't have a high percentage of children who either have special needs or are socially deprived. 77% of these schools have adequate attainment. In contrast line four of the truth table describes a set of 14 schools which are comprehensive, mixed, not religious, don't have a sixth form, and do have high percentages of children in both the socially deprived and special needs categories. None of this set belong to the adequate achievement cluster. Of course this is not a complete account of adequate achievement. Six schools in the first configuration do not belong to the adequate achievement cluster. What this predicates is a qualitative investigation to identify further distinguishing factors.[10]

Table Two – Truth Table for NE England Secondary Schools

comp	religious	statpcfsmbin	highbinstatpcsp	mixed	sixthform	number	Yconsist
1	0	0	0	1	1	26	0.769231
1	0	1	0	1	0	18	0.611111
1	0	1	0	1	1	17	0.588235
1	0	1	1	1	0	14	0
1	0	0	0	1	0	11	0.909091
1	1	0	0	1	1	9	0.888889
1	0	0	1	1	0	8	0.5
1	0	0	1	1	1	7	0.428571
0	0	0	0	1	1	3	1
1	0	1	1	1	1	3	0
1	1	1	0	1	1	3	0.333333
1	1	0	0	0	1	2	1
1	1	0	0	1	0	2	0.5
1	0	0	0	0	1	1	1
1	1	0	1	1	1	1	1
1	1	1	0	0	1	1	1

All sorts of measurement and definitional issues – issues of boundary setting – emerge in relation to this method but it does have the defined advantage of working back from a recognized system state. Schools either are or are not achieving adequately. Given that there is available a longitudinal data set we have the possibility of mapping trajectories and exploring the potential for change.

Control Parameters

The idea of control parameter is central to understanding of causality in complex systems. Essentially the idea is that the trajectories of complex systems do not depend on all aspects of those systems but on subsets of them. This may be a single aspect – for example the Black Death as an external disturbance transformed feudal Europe. However, it is much more likely to be combinations of internal aspects in interaction along with external factors. So the deindustrialization of Western and Central Europe's industrial city regions reflects the external factors of generalized massive increases in industrial productivity in capitalism and the ability of capital to move globally to cheaper labour bases. That said the actual and very different post-industrial trajectories of those systems depends on the interaction of internal aspects of the city regions with national characteristics particularly at the policy level and with global factors. This indicates that causality is not simply internal but depends on the interaction of systems at all levels with those within which they are nested.

The QCA method suggested above is illustrated by examples which utilize variate trace information which describes only the internal aspects of the systems themselves. This can be justified in relation to the schools because they all operate within the same English policy system.[11] However, we can easily see how it can be extended to include information about variate difference in relation to systems external to the systems for which we are exploring causality. The example of city regions illustrates this. We can easily incorporate national level variate traces which differ from nation state to nation state. What this amounts to is an explicit and systematic way of conducting comparative research in general.

At first sight the idea of control parameters, of aspects of complex systems which have a governing influence on the trajectories of the systems, may seem to contradict the anti-reductionist character of complexity theory as a whole. In this way of thinking the control parameter is not likely to be a single variate characteristic unless that characteristic is on its own both a sufficient and necessary cause. We may well have single variate characteristics which are sufficient causes without being necessary but far more common is the situation as demonstrated in Table Two where we have a whole set of complex configurations as sufficient but necessary causes. We can see these complex configurations as control parameters, albeit in most cases since they do not retrodictively describe the outcome for all cases with that set of characteristics, as probabilistic rather than deterministic control parameters. Even understood as probabilistic these methods are actually better at predicting outcomes than conventional linear methods such as logistic regression but the key point is that they are part of an iterative process of establishing causality. In other words we establish what we can and then proceed to look for other variates to enter into the causal story.

Configurations whether expressed as sets of variates or in textual description are models of control parameters. But they are models which are simultaneously incomplete and necessary. Cilliers addresses this issue through a discussion of models which whilst they can never be perfect representations of complex systems may still be useful to us:

> ' … models have to reduce the complexity of the phenomena being described, they have to leave something out. However, we have no way of predicting the importance of that which is not considered. In a non-linear world where we cannot track a clear causal chain, something that may appear to be unimportant now may turn out to be vitally important later. Or *vice versa* of course. Our models have to "frame" the problem in a certain way and this framing will inevitably introduce distortions. … This is not an argument against the construction of models. We have no choice but to make models if we want to understand the world. It is just an argument that models of complex systems will always be flawed in principle and that we have to acknowledge these limitations.' (2001 138)[12]

If we think of configurations, with that term covering both quantitative and qualitative representation of configurations, as models, then we can proceed further following Cilliers and understand that our models are attempts: ' … to grasp the <u>structure</u> (original emphasis) of complex systems.' (2001 139). Here structure is <u>not</u> a static arrangement, a meaning which the common usage of the word can only too easily imply. It is the whole dynamic system in action with potential for radical change being part of the character of that system. Moreover complex systems are structured in hierarchies not of strictly defined and separate sub-units but as Cilliers puts it of messy, (with the messiness being indispensable), interpenetrating and mutable (although robust) hierarchical orders of components. (2001 143) Of particular significance is that these hierarchies are context dependent. In general they are inherently mutable entities.

The implication of this for case based research, whether the ideographic investigation of the specific instance or comparative investigation of multiple instances, is that what we are trying to do is to identify, however incompletely, temporarily, and locally, the nature of the structure of control parameters and the potential of those parameters for bringing about a given state of the system – a qualitative condition of the case. That is what we can do in terms of establishing causality on the basis of cases, and we can do so without falling into the trap of reification of variables outwith cases which has been the false road of quantitative social science for so long and has led to a wholly artificial and disabling separation of the quantitative and qualitative modes of social research.

Another point worth making before concluding is that these methods are best applied when we have, as we so often do have, information about all the cases of interest to us rather than about any probabilistic sample of cases. In both of the examples cited above – English state secondary schools and Western and Central European post-industrial industrial cities – we do have information about all cases. This is actually a very common situation and we should be careful not always to think in terms of establishing probabilistic causality on the basis of inferential statistics.

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[1] So London has a population of seven million but is actually at the centre of a complex poly-centric conurbation with a population of some twenty million which extends into three English regions – London itself, the South East and the Eastern region.

[2] Interestingly there is now a real question as to whether what certainly was a real spatial entity from the time of the Mercian kingdom of the sixth century A.D. through to the mid twentieth century – the village based agricultural and industrial county of Leicestershire surrounding a major city, has any real existence beyond the non-trivial ones of being both an administrative entity and a source of local identity. It certainly is no longer in any meaningful sense a social system other than in relation to those two components and if, as current UK central government policy would like, its administrative function is transferred to sets of districts, then it would become simply a residual source of identity through sport.

[3] Leicester's industrial development was based on light industrial innovation in the form of stocking making frames although it also had access to coal from the Leicester coalfield.

[4] Leicester City plus the adjacent districts of Oadby and Wigston, Blaby and Charnwood.

[5] Defined here as including manufacturing, mining, construction and transport / communications.

[6] i.e. aged between 16 and 74.

[7] See Byrne 2002 for an explanation of this term.

[8] Local government in England was substantially revised in 1974. Some of the 1971 census data was recomputed for the new local authority boundaries but not employment data. However, Leicester and the other parts of the Leicester urban area were the most industrial parts of what has always been an industrial county so using figures for the whole county probably slightly underestimates the industrial employment levels in the Leicester urban area.

[9] It must be emphasized that this is primarily a change in employment base. The decline in proportion of local GDP due to industry is much less than the decline in employment because one of the drivers is increased productivity in existing industry as well as the relocation of industrial production and capital usually referred to as the new international division of labour.

[10] Ragin's method proceeds further through the use of Boolean techniques to identify a reduced set of causal factors. Ragin has also developed a fuzzy set version of his method which allows for partial membership of sets.

[11] Actually with a larger data set it would be worth including information about the local education authorities within which the schools are located which would be a way of including information about variate characteristics of systems within which the schools are nested.

[12] For me the additional factor in our modelling is the potential for purposeful action to achieve a possible outcome. In other words models plus action may enable determination.

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