A POLITICAL-ECONOMIC MODEL OF URBAN GROWTH IN BRITAIN, 1801-2001

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ABSTRACT

Marxian economics is used as a new conceptual foundation for modelling urban growth. This conceptual model is made operational using the methodology of system dynamics to replicate the pattern of urban growth for an hypothetical city set in a British context. The predicted and actual patterns of urban growth are then compared to a set of British towns and cities from 1801 to 1971, with further predictions to 2001 in decennial intervals. Some advantages and limitations of this new approach to urban modelling are discussed.

INTRODUCTION

In recent years there has been a revival of interest in the relevance of Marx's writings for understanding and explaining urban growth. In 1973 Harvey, for example, argued persuasively that, 'the only method capable of uniting disciplines in such a fashion that they can grapple with issues such as urbanization, economic development and the environment is that founded in a properly constituted version of dialectical materialism as it operates within a structured totality in the sense that Marx conceived of it' (Harvey, 1973,

302, Marx, 1974). Not all academics are, however, convinced of the relevance of Marx's writings in tackling complex problems such as urban growth. Chisholm, in particular, claims that Marx's method of dialectical materialism, 'seems to be a metaphysical belief system and not - as its protagonists proclaim - a mode of rational argument' (Chisholm, 1975, 175). Clearly, then, there is a major ongoing debate between those researchers who believe that Marx's writings can give a new direction to urban studies and those who believe that Marx's writings are of little or no relevance.

As an alternative to becoming embroiled in an academic dispute over the relevance or otherwise of Marx's writings for understanding complex issues such as urbanization and economic development it would appear more profitable to build a model of urban growth using Marxian economics. If Marx's writings can be used to understand the dynamics of urbanization under capitalism then it ought to be possible to build a dynamic model of urban growth using Marxian socio-economic categories and then compare the predicted patterns with real world data. This approach would highlight the major strengths and weaknesses in using Marx's methodology as a base for new directions in urban modelling. Hence, the purpose of this paper is to build a political-economic model of urban growth in Britain based on Marxian economics and test the model with reference to real world data 1801-1971 in decennial intervals.

In the following section a conceptual model of urban growth under the capitalist mode of production is presented based, in part, upon the writing of Marx and some of the neo-Marxist scholars. This new Marxian conceptual model is then made operational using the methodology of system dynamics (Forrester, 1961, 1969; Moffatt, 1979a, 1979b) in order to predict the pattern of urban growth for an hypothetical city set in a British context. In the fourth section the predictions of a calibrated model are then compared with the actual patterns of urban growth for eighteen British towns and cities between 1801 and 1971. Some predictions for future urban growth until the year 2001 are given as well as further more detailed corroborative evidence based on Wigan in the nineteenth century. Finally, on the basis of the results of this preliminary model the advantages and limitations of using Marxian economics as a base for understanding urban growth under capitalism are discussed.

A CONCEPTUAL MODEL

As the writings of Marx are, 'forbidding in volume and turgid in prose' (Freedman, 1976 lx), nevertheless, it is possible to precis some of his major arguments in his attempt to lay bare the laws of motion of capitalist society so that we may be able to cast light upon the way in which urban growth is intimately related to the complex processes of capital accumulation. Apart from the problem associated with the

volume of Marx's writings it is clear that Marx had no strong desire to examine the role of urban growth in capital accumulation apart from two references to speculative building and ground rent (Marx, 1974, II 238, III 774). This particular problem has, therefore, fallen to later neo-Marxist scholars (Harvey, 1976, 1981, 1982; Castells, 1977; Dear and Scott, 1981) who are not, as yet, agreed upon the precise relationship between capital accumulation and urban growth. Hence, the conceptual model described below is merely a contribution to this area of research and assumes some knowledge of the socio-economic concepts embedded in Marxian economics (Mandel, 1968, 1975; Desai, 1974).

Consider, then, a model of the capitalist economic system (figure 1). Given a labour force, which has only its labour to sell on the market, this group of people work for the capitalist class who own the means of production such as factories, banks, shops. The labouring class, when employed, receive a wage in exchange for the production of commodities. The capitalists receive profits for owning the means of production. In Marxian terms it is the capitalist class who exploit the workforce in order to extract surplus value from selling the privately owned commodities in the market. In order for the capitalists to survive either singly or as a class it is necessary for a minimum surplus value to be extracted. Conversely, in order for the labouring class to reproduce itself, in order to work the next day, a minimum wage is required. From these essential social relationships, which are specific to the capitalist mode of production, various circuits of capital flow through the capitalist economy and have an obvious manifestation in the built environment of towns and cities (Harvey, 1973).

At least three circuits of capital have been identified in capitalism and the way they interact to produce the urban environment is described below (Harvey, 1981). In the primary circuit individuals working in capitalist owned factories produce both surplus value for the owner of the means of production and commodities for exchange in the markets. As individual capitalists wish to increase their own profits it is essential that they produce a large quantity of commodities so that they can compete with other capitalists. This competition for accumulation results in either an increase in the length of the working day for the labour force (i.e. an increase in absolute surplus value) or an increase in the productivity of each worker by the introduction of technological improvement (i.e. an increase in relative surplus value). The ceaseless quest for capital accumulation can lead to an overproduction of commodities on the market. Paradoxically, if the bulk of the population are unable to afford to buy these commodities, then a shortage occurs despite the excess quantity of commodities. As the capitalists are

unable to gain further profits from this circuit of capital then they can preserve their surplus value in the sphere of production by re-investing in the secondary or tertiary circuits of capital.

When the rate of profit is falling in the primary circuit of capital the secondary circuit of capital assumes greater importance. This secondary circuit includes aspects of fixed capital as part of the processes of consumption and production within the commodities fund. The fixed capital of the consumption aspect of the fund includes housing as well as consumer durables such as motor cars, whilst the production side of the fixed capital includes new offices and factories which would be used in another cycle of commodity production. One manifestation of this investment in the secondary circuit of capital is the mushroom growth of large, vacant office blocks and new empty factories in many urban areas. Another manifestation of the secondary circuit is the explosive pattern of housebuilding and communications especially in suburban areas. As Harvey notes, the decision to switch capital to this secondary circuit of capital accumulation is, 'one feasible if temporary switch to the overaccumulation problem' (Harvey, 1981, 96; Ambrose, 1976).

The tertiary circuit of capital includes investment in science and technology in order to increase production in the primary circuit or to accelerate the circulation of capital within the system. Included in the tertiary circuit are non-profitable activities which cannot survive in a pure market economy without introducing government intervention. The provision of decent health services to increase the efficiency of the workforce or the provision of compulsory, free education are aspects of this tertiary circuit. It could, of course, be argued that the privatization of these socially necessary, but less lucrative, investments could become profitable if left to unaided market forces. The current Conservative government in Britain, under the guise of monetarist dogma, is attempting this task. Unfortunately, they pay little heed to history which has shown clearly that the market is unable to provide adequate social provision to all members of society. The poor, unemployed and elderly are especially vulnerable to the full impact of unbridled market forces. If this course of action is pursued, however, then it is essential for the preservation of the capitalist class that the government invest in the forces of repression such as in increases in the police force and the military in order to contain class antagonisms.

It could, of course, be argued that since the Keynsian revolution (Keynes, 1936) the class antagonisms generated by the contradictions in the capitalist mode of production can be resolved by the intervention of the state as a regulator of the commodities fund. Engels, for example, suggested that, in

order that these antagonisms, classes with conflicting economic interests, do not consume themselves and society in fruitless struggle the state has a role as an apparent arbitrator in these disputes (Engels, 1977). The state has, of course, many functions including the efficient running of the 'economy' but, as Miliband notes, 'the description of the system as 'the economy' is part of the idiom of ideology, and obscures the real process. For what is being improved is a <u>capitalist</u> economy: and this ensures that whoever may or may not gain, capitalists' interests are least likely to lose' (Miliband, 1973, 73). Thus the intervention of the elected members of the state, either directly by government intervention or indirectly by economic, urban and regional planning, assume 'the interests of the dominant social class in the whole social formation and the organization of the urban system, in such a way as to ensure the structural reproduction of the dominant mode of production' (Castells, 1977, 432). The way in which these three circuits of capital interact to produce and reproduce the dynamics of the urban environment will be described in detail in the following section.

AN OPERATIONAL MODEL

It is relatively easy to describe a conceptual model of an urban area but it is much more difficult to translate this conceptual model into an operational dynamic model of urban growth. Nevertheless, if progress is to be made in this new direction in urban modelling then it is essential that this particular problem is resolved. The rest of this section translates the conceptual model of urban growth, based on the political-economy of Marx, into a simulation language (DYNAMO) which will permit some of the relationships to be tested empirically.

The operational political-economic model of urban growth for an hypothetical city is presented in figure 2. This model uses the conventional symbols of system dynamics to make the conceptual model operational. The model consists of seven sectors: a Marxian economic base, a demographic sector consisting of three classes, a migration sector, two crude industrial and housing sectors, employment including unemployment and finally an urban land use sector. The seven sectors of this operational model are described briefly below whilst the full details of the model are explained elsewhere (Moffatt, 1979a, 79-118).

Marxian Economic Base

As noted in the previous section the heart of Marxian economic theory assumes that the total productive capacity resides in the hours of toil of the labouring classes. Hence, the total hours worked in the urban area depend on the total employment and the hours worked per person. This latter relationship is described by an exogenous time driven table

function in which the value of the independent variable is fed into the model as a function of simulated time. In this specific example the hours of work have declined from twelve hours per day in 1801 to eight hours in 1961. This decline in working hours is due to the successive and successful struggles of the working class, through organized trade unions, to achieve better conditions for themselves. The data used in the table is derived from British historical sources such as the Factory Acts of 1833 and 1850. In order to survive it is argued that the working class need a minimum number of hours of socially necessary labour to produce consumable commodities from the commodities fund. This socially necessary labour time is obviously less than the total hours worked. It is the difference between the total hours toiled and the socially necessary labour hours which are extracted by the capitalists as surplus value (Marx, 1974; Engels, 1972).

According to Marx the social relationship between the capitalist class and the working class is essentially one based on exploitation. This exploitation is not a moral judgement on the capitalist system but in Marx's economics a precise concept for understanding the dynamics of that specific socio-economic system. The relationship is simply the ratio of the amount of surplus value divided by the amount of variable capital given as wages to the working class. The terms surplus value and variable capital are measured in hours of labour time, not money. Obviously, in the real processes of capital accumulation individual capitalists try to compete with their rivals by increasing the productivity per labourer by introducing technological innovations in the productive process. The injection of constant capital into the productive process increases the productivity per labourer; the latter function is injected into the model as a time driven exogenous function using data derived from a survey of economic development in Britain (M.S.A., 1954). By increasing constant capital into the primary circuit of capital accumulation the individual capitalists increase the rate of exploitation until the rate of profit in this sector diminishes and a business crisis is produced. The falling rate of profit, in this model, comes about because of the tendency of the capitalist system to concentrate on increasing surplus value and to replace variable capital by constant capital (Desai, 1974). The results of this process are to increase unemployment and to switch capital into the secondary and tertiary circuits.

Demographic Sector

The model consists of three demographic groups namely the capitalists, the middle and working classes. Whilst the former are not numerically significant in Britain they do control some of the means of production and, hence, have an exceedingly important economic impact on the urban system.

Only the 1831 census for England and Wales actually identified this class, which in this model is taken as one per cent of the total population of the urban area. This one per cent can increase or decline depending on the way in which the rate of profit changes. If the rate of profit rises then more of the bourgeoisie can become capitalists; conversely, if there is a fall in the rate of profit then the capitalist class decline as several of their firms become bankrupt.

The working and middle classes are modelled in an identical fashion insofar as natural increase, migration and social mobility accounts for movement within and between these two demographic sectors. The upward social mobility was assumed to be a constant proportion set at one in a thousand people. The birth and death rates for both classes are assumed to be identical; although the ravages of early industrialization had a greater impact on the working class it was not possible to obtain the detailed data for differences in the vital rates for these two groups. Hence, in this model the vital rates are estimated from a variety of historical courses and are injected into the model as exogenous time driven functions (Hobsbawm, 1969; Lawton, 1977; Marsh, 1961; Dean and Cole, 1969). Whilst the same vital rates are used for the two classes there are, of course, regional differences which altered the actual numerical values of birth and deaths per thousand for the actual urban areas modelled. Ideally, of course, birth and death rates for individual urban areas would be required but this detail was not available for the simulation model hence only regional figures were used.

Migration Sector

Despite the large number of studies into the pattern of inter-urban and rural-urban migration (Ravenstein, 1885, 1889; Willatts and Newson, 1953; Kennett, 1977) the actual causal processes are by no means well understood. In this model it is assumed that immigration is a function of the condition of the urban labour market. When unemployment exists in the urban area it is hypothesized that outmigration exceeds inmigration; the converse is true when there is a shortage of labour in the urban area. The notion of employing endogenous migration equations is based upon recent research into inter-city migration in the British system of cities (Cordey- Hayes and Gleave, 1973). The numerical values for in and out migration differ from those given by Cordey-Hayes and Gleave and reflect the longer time horizon employed in this study.

Employment and Unemployment Sector

The employment sector includes members of both the middle and working classes living in the urban area. The model assumes that sixty per cent of these two groups would be part of the total labour force at any given time. Under capitalism the total employment, generated by industry, multiplied by

variable capital determines the number of people engaged in employment. As noted earlier, employment is constantly threatened by the introduction of new technological innovations (constant capital) which cause unemployment. Alternatively, unemployment is caused by the take-over and subsequent closure of an industrial unit.

In Marxian economics the industrial reserve army plays an important role in the accumulation of capital by the capitalist class. During times of high unemployment the ranks of the industrial reserve army are swollen by an increase in the number of unemployed. Hence, the capitalists can hire these unemployed people at a lower wage than those in employment and hence increase surplus value. Obviously, if labour was organized so that, at least, a minimum wage was accepted by all employees this avenue of exploitation would be thwarted. At present, however, the lack of strong trade unions permits the capitalists to exploit non-unionized labour, especially female labour, in the tertiary sectors of the economy. In this model, fluctuations in the average urban wage rates are directly related to the ratio of the employed to unemployed in the labour force. When this ratio is low the wage rate is low and vice versa.

Industrial Sector

The industrial sector in this model is crude and does not differentiate between primary, secondary, tertiary and quarternary sectors of the capitalist economy. Each industrial unit employs members of the middle and working classes in the ratio of one to four people. The number of industrial units present in the hypothetical city at any given time depends on the amount of investment injected into industrial activity by the capitalist class. This injection of investment is generated endogenously, with the actual rate of industrial growth being derived from the rate of profits generated in the model's economic base. Generally, when the rate of profit is low the amount of capital invested in industry is also low; conversely, as the rate of profit increases so does the amount available for industrial expansion. This part of the model attempts to capture the complex flow of capital in the primary and secondary circuits.

The model assumes that each industrial unit has a finite life of 100 years. Hence, in normal conditions the industrial stock would decline by one per cent per year if no new units were added to the stock. This overtly simple pattern of industrial dynamics is complicated by the competitive struggle between the capitalists, who seek to increase their capital accumulation by taking over rival industrial firms. This competitive struggle is suggested in Marx's law of

centralization of capital whereby the limit to competition would be, 'united in the hands of either a single capitalist or a single capitalist company' (Marx, 1974, 588). In this model this complex process is written as a take-over factor which accelerates the decline of industry in an urban system as the distance increases in concentric zones from the central markets of London, the financial, political and industrial centre of Britain.

Housing Sector

Housing occupies an important financial and geographical place in urban areas. Financially, it has been argued that when industrial production is less profitable then investment is switched to housebuilding as part of the secondary circuit of capital (Harvey, 1981). Geographically, housing occupies about 43.7 per cent of all urban land in England and Wales circa 1950 (Champion, 1973). Clearly, then, housing is an important aspect of the urban scene and capital accumulation and is, therefore, integrated into this current simulation model.

The housing sector consists of two types of housing corresponding to the middle and working classes. The structure of these two sub-sectors is basically similar with the demand for housing by both social classes depending upon the population size of each class divided by the size of the average household. The size of the average household is derived from historical sources and is fed into the model as an exogenous table function. In 1801, the household size was ten and declines steadily to eight and then six in 1841 and 1881 respectively. By 1961 to 2001 it is assumed that the average household size is four people.

While the demand for housing is identical for the two classes it is clear that the working class are unable to satisfy their needs for decent housing conditions because of poor wages. In times of economic hardship house-sharing was a common feature, especially in the nineteenth century. Fortunately, in the twentieth century, the political struggle which resulted in the formation of the council housing movement has legally prevented house-sharing on council estates and has, to some extent, improved the living conditions of the working class. In this model house sharing occurs in the working class housing sub-sector when unemployment rises in the model. Furthermore, the model also assumes that two per cent of the total housing stock is vacant even in periods of employment. This could be thought of as due to friction in the urban housing market.

The demolition rates for middle and working class housing are modelled identically. The model assumes that the houses have a finite life set at one hundred years. Whilst

this estimate appears reasonable for British housing stock it is acknowledgedthat in any real urban system variations in houselife would be inevitable (Laslett, 1965; Brookbanks, 1973). The demolition rates also depend on the number of vacant houses in the urban system. As noted earlier, when unemployment is high house-sharing is common amongst the working class and hence many houses are vacated. These empty houses, which are not due to friction in the housing market, are no longer providing rental for the landlord or building society. Hence, the landowner or building society, prompted by the property speculator, is encouraged to demolish the houses and rebuild for more profitable enterprise. This concept of house demolition under capitalism is in accord with Marx's theory of differential rent (Marx, 1974). Furthermore, this pattern of behaviour explains the reasons for demolishing houses and erecting empty office blocks in urban areas even when a chronic housing shortage exists (Engels, 1975).

Whilst the processes of demolition are common to both housing groups the model also incorporates house filtering. In this case two per cent of the middle class housing is occupied by the working class as aprocess of filtering (Jones and Eyles, 1977). This process is evident in many British cities, where the working class inhabit the sub-divided larger houses of the inner city whilst the middle class move into the suburbs.

Urban Land Use Sector

Unlike several other system dynamic models (Forrester, 1969; Schroeder, 1974; Brookbanks, 1973) which have a fixed areal extent the current model permits the city area to expand as more housing and industrial units are added to the city. In Marx's Capital it is suggested that speculative building is one aspect of urban expansion (Marx, 1974). As noted earlier, when the rate of profit is low in the industrial sector or primary circuit the secondary circuit witnesses an increase in investment and this is reflected in the physical exapnsion of the city.

Calibration Procedures and Parameter Sensitivity Tests

The model contains eight levels, each of which was initialized for 1801 only. The total population for any city was subdivided into two classes namely the working class and middle class on the basis of a two to one ratio. Whilst this measure of the class structure of any British city may appear crude, nevertheless these figures are broadly consistent with historians' findings (Hobsbawm, 1969). From the total population figure, the employment and unemployment levels are calculated, whilst the total population multiplied by the activity rate normal value set at 0.6 determines the size of the employment level in the hypothetical city. Of this total, two per cent represents the unemployed level. The number of industrial units is then calculated by dividing the total

labour force (employed and unemployed) by twenty, i.e. the number of working and middle class people employed in any one industrial unit. The number of houses for the two population levels is then calculated by dividing the number of people in the working class and middle class level by ten, i.e. the number of people per household in 1801. As noted above an additional two per cent of this total number of houses are included as vacant property in the city. Finally, the areal extent of the city was ascertained by plotting a curve of population size against area for several British cities in 1801 and using the relevant areal extent value for different urban population size. The relevant initial values were calculated and used for each real world city in this study. Ideally, it would be useful to use all the towns and cities in Britain. In this preliminary study, however, only eighteen urban areas were considered namely: London, Birmingham, Bristol, Portsmouth, Sheffield, Nottingham, Stoke-on-Trent, Exeter, Hull, York, Leeds, Manchester with Salford, Wigan, Sunderland, Swansea, Edinburgh, Dundee and Aberdeen.

The model includes seventeen table functions and fifteen constant parameters. Seven of these table functions were derived from historical sources and were injected into the model as exogenous time driven functions. The remaining ten table functions were subjected to several sensitivity tests, so that those sensitive parameters would be identified and altered so that they would not cause unusual behaviour in the model of the city. The fifteen constants were also examined to detect the sensitive parameters especially the impact of changing the activity rate in the model. Clearly, future research is required to restructure the model so that the impact of some of the sensitive parameters can be reduced.

The entire program for this political-economic model of urban growth consists of sixty equations and is written in DYNAMO (Forrester, 1961, 1969; Moffatt, 1979a, 1979b). The model requires 80K memory when run on an IBM 370 computer. Despite the simplicity of this dynamic simulation model it is anticipated that the model's predictions could be tested with available empirical data for the eighteen British towns and cities.

EMPIRICAL VERIFICATION

According to Furtado, 'it is not enough to construct an abstract model and provide an explanation of how it operates, it is just as important to demonstrate the explanatory effectiveness of such a model as applied to historical realities' (Furtado, 1964, 1). Hence, in this section the predictions of the simulation model will be compared with the actual pattern of urban growth for eighteen British towns and cities between 1801 and 1971 in decennial intervals. We begin by discussing the definition and data used in this study.

Definition and Data

It is exceedingly difficult to define an urban area especially when the administrative boundaries have failed to keep up with the pace of urban growth. As Robson points out, 'a city cannot be isolated as a functional operating unit in spatial terms. If it is narrowly defined many of the people intimately involved in its activities will be excluded; if it is generously defined, many of the people included will be involved only marginally, if at all' (Robson, 1973, 12).
In England and Wales, urban researchers are indebted to the empirical work of Law for recalculating urban populations for many urban areas which were underbound by the official administrative areas given in the census returns (Law, 1967). The criteria used by Law, and also by Robson, to define an urban areas consisted of a minimum size of population, a minimum density and a measure of spatial clustering. The minimum population size was taken as 2,500 inhabitants; this excludes many mining villages and small market towns which rarely, if ever, attracted industry to them. The minimum population density was fixed as a figure of one person per acre which, as Law points out, would be a very low figure for urban areas, but rather high for rural areas. The nucleation criterion attempted to define towns as spatially continuous built up areas. This data provides as 'sensitive and accurate a set of estimates as one could hope to devise' (Robson, 1973, 52) for English and Welsh settlements over the period 1801 to 1911

in decennial intervals. In the case of Scotland, However, no such data was readily ascertainable and hence Law's criteria were used to define Scottish towns and cities based on the Scottish census returns and a study of the historical geography of Scotland (Lythe and Butt, 1975).

Whilst Law's data is arguably the best British data source for nineteenth century urban studies it does not cover any decade beyond 1911. Hence, for the bulk of the twentieth century data for all British Standard Metropolitan Labour Areas was used. This data defines urban areas in a more generous fashion than in Law's study and covers the whole of Britain from 1931 to 1971 (Hall, et al, 1973). Since no census returns were made available for 1921 and in 1941 an arithmetic mean was used to determine the total urban population size of the eighteen towns and cities used in this study, inevitably the data set used in this study is not consistent throughout the period 1801 to 1971 for all the British settlements. In particular, since the change of definition makes it exceedingly difficult to test the model's predictions for the period 1931 to 1971, more emphasis will be placed on the first one hundred and ten years of the simulation (1901 to 1911) rather than on the later period (1931-1971). Clearly, the approach adopted in collecting data in this particular study may be criticized, but it merely reflects a problem of much greater magnitude, to form a

consistent basis for comparing urban growth over an extended time horizon. This is a problem which must be solved if long-range dynamic models are to be used effectively in empirical urban research.

Predicted and Actual Patterns of Urban Growth

If we consider London first, the predicted pattern of London's growth (table 1a; figure 3a) between 1801-1911 consistently overpredicts the actual pattern by approximately 10 per cent. This predicted pattern of urban growth is quite reasonable until the decade 1901-1911, when the model overpredicts by 23.2 per cent or 1,514,086 people. After the change of definition in the urban area of London, the model continues to overpredict by 32.5 per cent on average between 1921-1971, partly reflecting the outflow of migrants from the inner city of London to the surrounding M.E.L.A. The pattern of Birmingham's urban growth (table 1b; figure 3b) contrasts quite sharply with that of London's. Except for the overprediction for the first two decades of the nineteenth century and also for 1911, the model underpredicts for the rest of the period. The largest absolute difference for nineteenth century Birmingham occurs in 1881, when the predicted and actual city size differ by 105,410 people or 18.4 per cent. After the change in the definition of the urban area the model underpredicts throughout the twentieth century.

In contrast, throughout the entire simulated period, 1801-1971, the predicted and actual patterns of urban growth for Bristol are very close (table 1c; figure 3c). During the early decades of the nineteenth century the model tends to underpredict by approximately 3.4 per cent. By 1861 the model overpredicts, but, with the exception of 1911, the average value is only 4.1 per cent. Clearly, the model gives a very accurate simulation of urban growth for Bristol throughout the nineteenth century. The change of definition of the urban area causes a certain amount of overprediction, with the largest deviation occurring in 1941, with an over-estimated population size of 61,850 or 10.7 per cent. The simulated total population size keeps within approximately 10 per cent of the actual population size of Bristol, and does not greatly over or under-estimate the twentieth century pattern of city growth, unlike the patterns for London and Birmingham. Whether or not this result reflects a chance occurrence or is an indication of the success of the model is difficult to ascertain until other good results are obtained.

The simulated pattern of urban growth for Portsmouth gives some further support to the empirical validity of the model (table 1d; figure 3d). For the nineteenth century. the model tends to keep within 8.7 per cent of the actual total except for the overprediction for the decade 1841 of 30.8 per cent or 20,528 people. As in the case of Bristol,

the predictions of Portsmouth's urban growth in the twentieth century are remarkably close to the actual population size, despite the change of definition of the urban area.

Similarly, the simulated pattern of urban growth for Sheffield during the first two decades of the nineteenth century almost parallels the actual pattern (table 1e; figure 3e). For this period, the largest deviation occurs in 1821, with an absolute overprediction of only 2,397 or 3.7 per cent. Throughout the rest of the nineteenth century the model underpredicts, although only for three decades 1961-1881 does it differ by more than 10 per cent from the actual total. After the change of definition the model continues to underpredict, with a maximum value of 19.4 per cent occurring in 1931, with an underestimate of 159,300 people. The results of the closing two decades of the simulation are encouraging, with the actual and predicted figures being within approximately 3 per cent of each other. As in the case of Sheffield, the predicted pattern of urban growth for Nottingham underestimates the actual population throughout most of the nineteenth century (table 1f; figure 3f). The model overpredicts by 1911, with a value of 30.8 per cent or 83,667 people. As with Sheffield, the model underpredicts the actual population size of Nottingham after the change in the urban boundary. Clearly, this administrative factor complicates the problem of dynamic modelling over an extended time horizon and can be illustrated most clearly in the cases of Stoke-on-Trent and Exeter.

Throughout the nineteenth century, the predicted pattern for Stoke-on-Trent underestimates the actual pattern of growth (table 1g; figure 3g), with the exception of 1891 when the model temporarily overpredicts by 12.2 per cent or 2,463 people. For most of the nineteenth century the results of the model are quite reasonable, with the predicted pattern being less than 10 per cent under the actual pattern of growth - although in 1841 the model underpredicts by 13.1 per cent. After the change of definition of the urban area, the predicted pattern of urban growth falls below 40 per cent of the actual total. Similarly, in the case of Exeter, the nineteenth century predictions tend to be greater than the actual pattern of urban growth, with the exception of 1831-1851 (table 1h; figure 3h). Again, with the change in definition of the urban area, the model underpredicts by about 40 per cent of the actual total.

The simulated pattern of urban growth for Swansea is very good for the first three decades of the nineteenth century (table 1i, figure 3i). However, from 1841 to 1911 the model underpredicts, with values as low as approximately 17 per cent. Again, with the change of definition the predicted pattern of growth underpredicts, then overpredicts by 16.5 per cent or

35,300 people by 1971. The case of Hull is much more encouraging, with the simulated pattern of urban growth resembling closely the real world (table 1j; figure 3j). During the period 1811-1881 the model underpredicts the actual pattern by approximately 4.3 per cent, whilst from 1891 until the end of the simulation the model overpredicts the actual population size. Clearly, the predicted pattern of growth for Hull is almost as close empirically as the Bristol simulation: Hull, however, does overpredict by about 20 per cent for the final three decades of the simulation, 1951 to 1971. Nevertheless, the model does give very good results for the period 1801 to 1911 and is a further source of support for the model.

During the nineteenth century the model tends to overpredict the pattern of urban growth for York and Leeds. In the former case (table 1k; figure 3k) the largest deviation is given in 1871, when the model overpredicts by 8,474 or 19 per cent. However, during the rest of the nineteenth century the model is often within 10 per cent of the actual population. After the change in the urban boundary the model tends to underpredict the actual population of the S.M.L.A. by about 18 per cent in 1971. In the case of Leeds, the model tends to overpredict the actual growth pattern, with the exception of 1831 to 1851 when the model underpredicts by only 107 people, or a deviation of 0.1 per cent (table 1l;

figure 31). Again, the model is within 10 per cent of the actual population size for seventy years in the first century. Despite the missing data for 1911 and 1921, the model continues to overpredict after the change of urban definition.

The two urban systems in North-West England, Manchester with Salford and Wigan, show a broadly similar pattern of urban growth. The model underpredicts the growth of Manchester with Salford from 1821 to 1881, with the largest deviation being almost 25 per cent below the actual figures in 1851, or 107,606 people (table 1m; figure 3m); the model then overpredicts from 1891 to 1911. After the change of definition of the urban boundary, the model's predictions tend to approach the actual population size in 1931, when a difference of only 1.1 per cent, or 23,300 people, is recorded; however, the model continues to overpredict, with the 1971 total being almost 45 per cent in error. This pattern is somewhat similar for Wigan (table 1n; figure 3n), although the predicted results are much nearer to the actual total population size during the nineteenth century. During the first seventy years of the simulations the model underpredicts by about 2,000 people per decade, on average less than 10 per cent of the total: by 1881 a perfect result is recorded, with an underprediction of only 57 people. The model then continues to overpredict throughout the rest of the simulation. The

nineteenth century results provide further empirical support for the model.

In North-East England, the pattern of urban growth for Sunderland is represented (table 1o; figure 3o). During the first thirty years of the simulated period the model overpredicts, with a difference of only 1.4 per cent or 602 people in 1831, but is followed by a period of underprediction until 1911. The lowest value is recorded in 1871, when the model underestimates by almost 20 per cent or 22,951 people. However, after the change of definition of the urban boundary, the model overpredicts the absolute growth of Sunderland, with the larges deviation of 38 per cent occurring in 1971.

Three Scottish cities, Edinburgh, Dundee and Aberdeen, were included in the sample. During the nineteenth century, the model overpredicts the actual pattern of urban growth of Edinburgh, with the exception of the two decades, 1821 and 1831 (table 1p; figure 3p). After 1851 the deviation of the predicted results from the actual are quite large, with the largest deviation of 110,100 people, or 27.4 per cent, occurring in 1911. A more reasonable fit is shown in the pattern of urban growth of Dundee (table 1g; figure 3q). After an overprediction for the first three decades of the nineteenth century the model underpredicts until 1911, with an underestimate of 26,500 people or 19 per cent, in 1881.

However, the best simulation run of urban growth in Scotland is that of Aberdeen (table 1r; figure 3r). During the first fifty years of the nineteenth century, the model underpredicts by a maximum of 13.1 per cent, or 7,430 people: for the next forty years it overpredicts by only about 10 per cent, with an absolute difference of 9,700 people. This difference is reduced in the first two decades of the twentieth century, when the model is 3,400 below and then 2,500 people above the actual population size. After the change of definition of the boundary all three simulated patterns of urban growth for the Scottish cities overpredict. The difference in the case of Edinburgh is quite large, with an overprediction of up to 30 per cent, or about 150,000 people, whilst the simulations for Dundee and Aberdeen overpredict by only 7.3 per cent or 12,666 people, and 10.1 per cent, or approximately 19,000 people. respectively. Again, the problem of the changing definition of city size affects the results of the model. Clearly, the three case studies of Scottish cities give varied results: whilst Edinburgh's growth pattern is somewhat unconvincing, the simulated patterns of urban growth for Dundee and, especially, Aberdeen give further positive support for the model.

CORROBORATIVE EVIDENCE

It could be argued that it is a crude measure of the value of a conceptual and operational model of urban growth

to compare its predictions with the actual aggregate population total of the eighteen British towns and cities. Yet it is exceedingly difficult to examine the finer details of the model with actual historical data, since this demands collating and relevant data from such historical sources as rate books, birth and death registers, old maps and census returns. However, using the available detailed historical data for Wigan, and using exogenous urban rather than regional vital rates, the model was re-run for the period 1841 to 1911.

The results of this simulation run are presented in table 2. The total population of Wigan grew throughout the simulated period. Apart from 1851 and 1861 the predicted pattern of population growth is quite reasonable both in magnitude and timing with a difference of about five per cent over or under the actual population total. This accuracy underlines the need for detailed urban rather than regional vital rates in the model. The predicted housing stock in Wigan, including empty housing, also shows a close correspondence with the actual pattern. The simulated areal exapnsion of Wigan is the least satisfactory aspect of the model insofar as overprediction occurs in all periods, although the data source itself could be in error by as much as ten per cent. Clearly, this example offers further corroborative evidence in support of this new political-economic approach to dynamic modelling. More research into the finer detail of the model's predictions is continuing (Moffatt and Jackson, 1984).

CONCLUSIONS

It is obvious from the above results that the attempt to build a dynamic model or urban growth based on Marxian economics is relatively successful. Using a consistent definition or urban area for the period 1901 to 1911 the results of the model are encouraging, especially the patterns of urban growth for Bristol, Portsmouth, Hull, Stoke-on-Trent, York, Aberdeen and Dundee. Similarly, the predicted pattern of growth for Wigan, including changes in the housing stock and areal expansion, provides further empirical support for this new approach to dynamic modelling. It is anticipated that this preliminary model will be further refined and developed so that more accurate detailed predictions could be tested on a larger sample of British towns and cities.

As noted in the introduction, constructing a dynamic simulation model of urban growth in Britain based on Marx's methodology has highlighted both the advantages and weaknesses of his methodology. The first major advantage of using Marxian political economy for building models of urban growth is that this methodology is essentially dynamic. Thus, there is no need to dynamize a static, or comparatively static, model derived from neo-classical economics. Next, by stressing the laws of motion of capitalism as essentially social relationships between classes of people it is possible to cast light upon the social structure of cities and their

relationship with the dominant mode of production. Third, by illustrating the various ways in which the three circuits of capital interact in the commodities fund it is possible to examine the contradictions in capitalist urban areas such as the rise of unemployment, the demolition of houses at times of housing shortages and building of huge tower blocks for profit, not for use. Fourth, by attempting to examine the complex workings of capitalism this political economic approach to urban modelling has the major advantage of directing attention to the real causes of urban change rather than deflecting research into spurious analogies based on quantum physics or biological processes.

There are, however, several limitations in the use of Marx's economics as a basis for model building. At a theoretical level it is clear that the use of the labour theory of value cannot go unchallenged. In the present simulation model all the economic terms are given in terms of units of labour. It is, however, important to make an isomorphic transformation from value terms to monetary units and vice versa in order for an analytical, dynamic model to be produced. In some special cases, the profits and prices of the capitalist system can be derived from value terms - but only if very restrictive assumptions are made (Bortkiewicz, 1974). The general solution to this crucial theoretical problem remains the unfinished task of Marxian economics. Closely related to this theoretical problem is the need for fine data on the prices and profits of all capitalist enterprises over an extended time horizon and on changes in ownership. Such evidence would substantiate the findings of the model which indicate that there is a tendency for greater accumulation by fewer capitalists in Britain which leads to a decline of urban areas and the quality of life in peripheral locations. A third criticism of this approach to urban modelling is that it can all too easily become a mechanistic interpretation of the real world rather than a guide to understand and radically change it.

Despite the limitations inherent in both Marx's economics and in this model of urban growth it is clear that the preliminary results appear quite encouraging, especially with regard to the nineteenth century patterns of urban growth. The present model is, however, based on aggregate categories and could be refined by disaggregating the various economic, industrial, housing and demographic sectors. Obviously, further refinement of the model would increase the complexity of the model's structure and make sensitivity tests, calibration and verification even more difficult. Similarly, the hypothetical urban model could be interconnected to form a national system of cities, although this would involve using FORTRAN or CSMP rather than the restricted DYNAMO computer language. This gargantuan task still remains to

be undertaken but if this avenue of research is explored the, perhaps, the role of cities in the dynamics of capitalism would be better understood. Whether or not this understanding will lead to repressive, planned capitalism or a radical transformation to socialism remains a matter of conjecture.

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Date	London Actual	London Predicted	London %	Birmingham Actual	Birmingham Predicted	Birmingham %
1801	982,156	982,156	100.0	73,670	73,670	100.0
1811	1,176,021	1,265,000	107.5	85,753	93,000	108.4
1821	1,435,364	1,577,000	109.8	107,642	118,100	109.7
1831	1,737,535	1.918.000	110.3	151,213	149,100	98.6
1841	2,051,380	2.291.000	111.6	197,680	185,900	94.0
1851	2,490,199	2,721,000	109.2	258,186	231,200	89.5
1861	3,000,844	3,255,000	108.4	356,273	289,700	81.3
1871	3,606,135	3,922,000	108.7	445,205	366,000	82.2
1881	4,432,592	4,759,000	107.3	573,610	468,200	81.6
1891	5,228,371	5,764,000	110.2	675,035	599,700	88.8
1901	6,056,565	6,862,000	113.2	813,602	753,300	92.5
1911	6,512,914	8.027,000	123.2	910,896	926,900	101.7
1921	7,570,257	9.220,000	121.7	1,529,348	1,116,000	72.9
1931	8,627,600	10,370,000	120.1	2,147,800	1,311,000	61.0
1941	8,870,000	11,390,000	128.4	2,317,950	1,496,000	64.5
1951	9,112,400	12,210,000	133.9	2,488,100	1,656,000	66.5
1961	9,156,700	12,760,000	139.3	2,693,100	1,781,000	66.1
1971	8,634,200	13,070,000	151.3	2,818,000	1,863,000	66.1
1981		13,170,000			1,901,000	
1991		13,060,000			1,892,000	
2001		14,000,000			1,890,000	

LONDON BIRMINGHAM

Table 1a,b. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	62,890	62,890	100.0	44,521	44,521	100.0
1811	75,188	74,910	99.6	53,799	52,920	98.3
1821	90,444	89,230	98.6	57,915	62,630	108.1
1831	113,508	106,400	93.7	63,026	73,930	117.3
1841	136,276	127,000	93.1	66,542	87,070	130.8
1851	154,916	151,900	98.0	89,004	102,100	114.7
1861	177,151	182,700	103.1	117,452	119,100	101.4
1871	217,314	221,200	101.7	136,206	138,500	101.6
1881	262,519	269,300	102.5	149,569	160,700	107.4
1891	307,694	325,700	105.8	184,683	186,000	100.7
1901	359,870	386,700	107.4	219,154	214,800	98.0
1911	379,750	451,200	118.8	266,873	247,500	92.7
1921	455,875	517,100	113.4	301,036	284,600	94.5
1931	532,000	580,600	109.1	335,200	323,200	96.4
1941	574,550	636,400	110.7	352,500	356,800	101.2
1951	617,100	680,900	110.3	369,800	382,600	103.4
1961	661,200	710,600	107.4	410,400	398,200	97.0
1971	718,100	726,300	101.1	462,200	404,700	87.5
1981		730,800			404,000	
1991		723,600			398,200	
2001		723,000			398,000	

BRISTOL — PORTSMOUTH

Table 1c,d. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	42,987	42,987	100.0	31,181	31,181	100.0
1811	52,365	53,800	102.7	45,419	39,020	85.9
1821	64,263	66,660	103.7	50,002	48,350	96.6
1831	90,657	82,020	90.4	72,929	59,500	81.5
1841	109,690	100,900	91.9	83,102	73,160	88.0
1851	133,811	124,700	93.1	99,064	90,440	91.2
1861	189,123	155,600	82.2	122,089	112,900	92.4
1871	245,729	196,200	79.8	140,033	142,300	101.6
1881	292,151	251,600	86.1	186,575	182,500	97.8
1891	349,465	322,900	92.3	216,422	233,700	107.9
1901	424,592	406,200	95.6	246,761	291,900	118.2
1911	474,381	500,400	105.4	271,533	355,200	130.8
1921	670,690	603,100	89.9	424,116	420,800	99.2
1931	867,000	707,700	81.6	576,700	484,600	84.0
1941	891,750	804,500	90.2	630,950	541,900	85.8
1951	916,500	885,800	96.6	685,200	588,400	85.8
1961	949,500	944,400	99.4	731,400	620,100	84.7
1971	958,300	981,500	102.4	793,100	638,500	80.5
1981		1,002,000			647,700	
1991		1,006,000			647,700	
2001		1,007,000			640,000	

SHEFFIELD — NOTTINGHAM

Table 1e,f. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	3,000	3,000	100.0	17,412	17,412	100.0
1811	3,851	3,754	97.4	18,896	20,700	109.5
1821	4,915	4,652	94.6	23,479	24,490	104.3
1831	5,997	5,724	95.4	32,450	28,900	89.0
1841	8,091	7,039	86.9	38,425	34.030	88.5
1851	9,346	8,702	93.1	41,506	39,630	95.4
1861	11,118	10,860	97.6	41,489	45,260	109.0
1871	15,300	13.700	89.5	43,654	50,840	116.4
1881	19,027	17,576	92.3	48,105	56,220	116.8
1891	20,027	22,490	112.2	52,484	61,360	116.9
1901	30,458	28,080	92.1	54,217	66,290	122.2
1911	36,357	34,180	94.0	59,092	70,920	120.0
1921						
1931						
1941						
1951						
1961						
1971						
1981						
1991						
2001						

STOKE EXETER

Table lg,h. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	6,099	6,099	100.0	27,609	27,609	100.0
1811	8.055	8.127	100.8	36,009	34,550	95.9
1821	10,613	10.620	100.0	44,905	42,810	95.3
1831	14,016	13,800	98.4	53,744	52,680	98.0
1841	24,364	17,880	73.3	67,606	64,770	95.8
1851	37,307	23,230	62.2	86,781	80,070	92.2
1861	45,903	30,540	66.5	101,444	99,910	98.4
1871	64,528	40,670	63.0	131,365	126,000	95.9
1881	85.491	54,820	64.1	172,241	161,600	93.8
1891	97,170	73,650	75.7	200,472	206,500	103.0
1901	117,177	96,770	82.5	240,259	256,000	106.5
1911	143,997	124,300	86.3	277,991	307,800	110.7
1921	190,848	156,100	81.7	332,395	358,500	107.8
1931	237.700	190,300	80.0	386,800	405,600	104.8
1941	234,450	223,000	95.1	394.800	447,800	113.4
1951	231,200	251,300	108.6	403,100	482,300	119.6
1961	235,700	272,200	115.4	419,500	506,800	120.8
1971	245,300	286,000	116.5	426,600	521,700	122.2
1981		294,500			529,100	
1991		297,200			528,500	
2001		297,000			526,800	

SWANSEA HULL

Table li,j. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	16,846	16,846	100.0	47,916	47,916	100.0
1811	19,099	20,020	104.8	55,431	63.670	114.8
1821	21,711	23,700	109.1	77,968	82,460	105.7
1831	26,260	27,960	106.4	119,005	105,400	88.5
1841	28,842	32,920	114.1	146,523	133,600	91.1
1851	36,303	38,580	106.2	168,907	168,800	99.9
1861	40,433	44,960	111.1	207,165	214,500	103.5
1871	43,796	52,270	119.3	259,212	275,100	106.1
1881	61.789	60,620	98.1	309,119	356,200	115.2
1891	67,841	69,830	102.9	436.072	459,200	105.3
1901	77,914	79,480	102.0	454,155	579,700	127.6
1911	82,282	89,430	108.6	n.a.	715,500	-
1921	99,891	99,480	99.5	n.a.	863,200	-
1931	117,500	109,000	92.7	1,051,100	1,015,000	96.5
1941	138,100	117,000	84.7	1,096,150	1,159,000	105.7
1951	158,700	123,100	77.5	1,141,200	1,285,000	112.6
1961	146,900	127,000	86.4	1,163,500	1,383,000	118.8
1971	155,200	128,800	82.9	1,204,700	1,455,000	120.7
1981		128,500			1,507,000	
1991		127,000			1,539,000	
2001		126,800			1,530,000	

YORK LEEDS

Table 1k,1. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
1801	94.995	94.995	100.0	10,989	10,989	100.0
1811	116,071	126,200	108.7	16,994	14,690	86.4
1821	184,575	163,500	88.5	21,395	19,030	88.9
1831	257,793	208,900	81.0	25,050	24,170	96.4
1841	340,708	264,900	77.7	32,476	30,280	93.2
1851	442,206	334,600	75.6	40,863	37,740	92.3
1861	529,355	425,200	80.3	52,794	47,450	89.8
1871	606,788	545,400	89.8	61,473	60,450	98.3
1881	730,739	706,100	96.6	77,963	78,020	100.0
1891	835,628	910.400	108.9	92.667	100,100	108.0
1901	934,367	1,149.000	122.9	103,690	124,500	120.0
1911	1,034,690	1,418.000	137.0	114,414	149,900	131.0
1921	1,511,695	1,711,000	114.0	148,407	174,800	117.7
1931	1,988,700	2,012,000	101.1	182,400	198,400	108.7
1941	2,000,550	2,297,000	114.8	182,600	220,700	120.8
1951	2,012,400	2,547,000	126.5	182,800	240,900	131.7
1961	2,041,700	2,742,000	134.2	180,100	257,700	143.0
1971	1,991,300	2,884,000	144.8	223,900	270,300	120.7
1981		2,988,000			261,800	
1991		3,050,000			263,400	
2001		3,030,000			267,800	

MANCHESTER WITH SALFORD WIGAN

Table 1m,n. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
	SUNDERLAND			EDINBURGH		
1801	24,444	24,444	100.0	83,000	83,000	100.0
1811	25,180	29,120	115.6	103,000	103,200	100.2
1821	30,437	34,680	113.9	138,000	126,200	91.4
1831	40,738	41,340	101.4	162,000	152,100	93.8
1841	54,740	49,330	90.1	166,000	181,200	109.1
1851	68,753	58,970	85.7	194,000	214,800	110.7
1861	84,510	70,900	83.8	203,000	253,900	125.0
1871	106,692	85,770	80.3	242,000	299,400	123.7
1881	127,351	104,400	81.9	295,000	352,000	119.3
1891	144,649	126,200	87.2	332,000	408,400	123.0
1901	161,585	150,000	92.8	394,000	462,300	117.3
1911	168,056	175,100	104.1	401,000	511,100	127.4
1921	189,278	200,800	106.0	420,000	551,500	131.3
1931	210,500	226,100	107.4	439,000	581,900	132.5
1941	208,650	249,900	119.7	453,000	601,700	132.8
1951	206,800	270,900	130.9	467,000	609,300	130.4
1961	218,100	288,100	132.0	449,000	604,100	134.5
1971	216,900	300,400	138.4	453,000	591,700	130.6
1981		306,900			577,900	
1991		307,300			562,800	
2001		307,000			560,780	

SUNDERLAND EDINBURGH

Table lo,p. Actual and Predicted Patterns of Urban Growth, 1801-1971

Date	Actual	Predicted	%	Actual	Predicted	%
	DUNDEE			ABERDEEN		
1801	27,000	27,000	100.0	27,000	27,000	100.0
1811	30,000	33,550	111.8	35,000	33,640	96.1
1821	31,000	40,720	131.3	44,000	41,140	93.5
1831	45.000	48,910	108.6	57.000	49.570	86.9
1841	63,000	58,260	92.4	63,000	59,060	93.7
1851	79,000	69,120	87.5	72,000	70,000	97.2
1861	90,000	81,780	90.8	74,000	82,750	111.8
1871	119,000	96,490	81.0	88,000	97,560	110.8
1881	140,000	113,500	81.0	105,000	114,700	109.2
1891	154,000	131,800	85.6	125,000	133,100	106.4
1901	161,000	149,100	92.6	154,000	150,600	97.8
1911	165,000	164,800	99.8	164,000	166,500	101.5
1921	168,000	177.700	105.7	159.000	179,700	113.0
1931	176,000	187,400	106.4	170,000	189,600	111.5
1941	176,500	193,600	109.6	176,500	196,100	111.1
1951	177,000	196,000	110.7	183,000	198,600	108.5
1961	182,000	194,300	106.7	178,000	196,900	110.6
1971	182,000	190,500	104.6	182,000	192,800	105.9
1981		186,200			188,300	
1991		181,400			183,400	
2001		180,000			185,000	

DUNDEE ABERDEEN

Table lq,r. Actual and Predicted Patterns of Urban Growth, 1801-1971

	Population			Housing			Area		
	Actual	*Pre-dicted	%	Actual	*Pre-dicted	%	Actual	*Pre-dicted	%
1841	25517	25520	-	4941	4950	-	285	285	-
1851	31941	28220	88.3	5857	5793	98.9	325	376	115.6
1861	37658	32550	86.4	6834	6937	101.5	430	484	112.5
1871	39110	38740	99.0	7486	8026	107.2	570	607	106.4
1881	48194	45720	94 8	10115	9143	90.4	720	745	103.4
1891	55013	53470	97.2	10390	10380	99.9	860	899	103.7
1901	60764	61550	101.2	na.	11820	-	975	1046	107.2
1911	65510	69550	106.1	na.	13470	-	1100	1208	109.8

*(Predicted/Actual) x 100

Table 2. Actual and Predicted Patterns of Wigan's Growth, 1841-1911

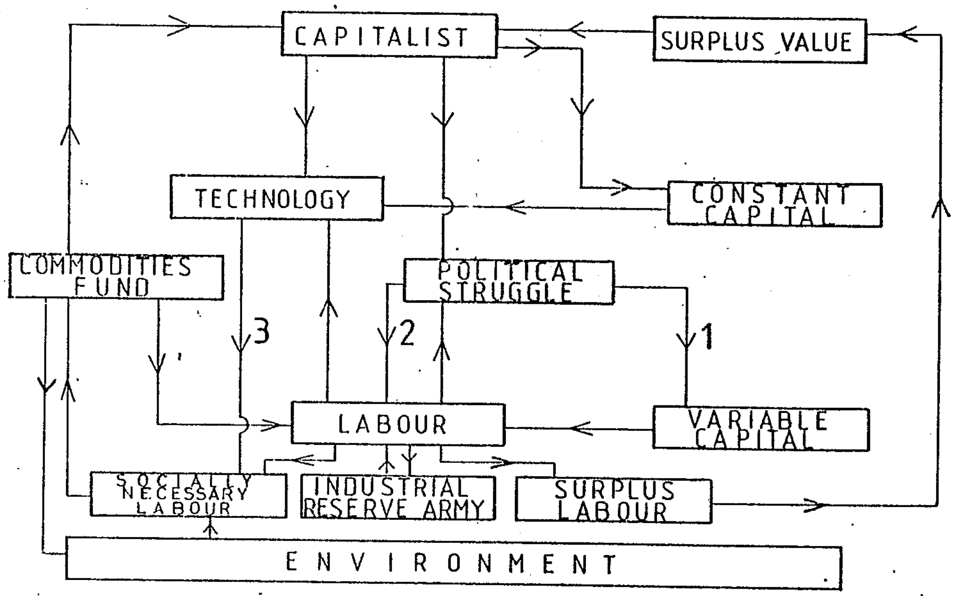

Figure 1: A Model of the Capitalist Economic System

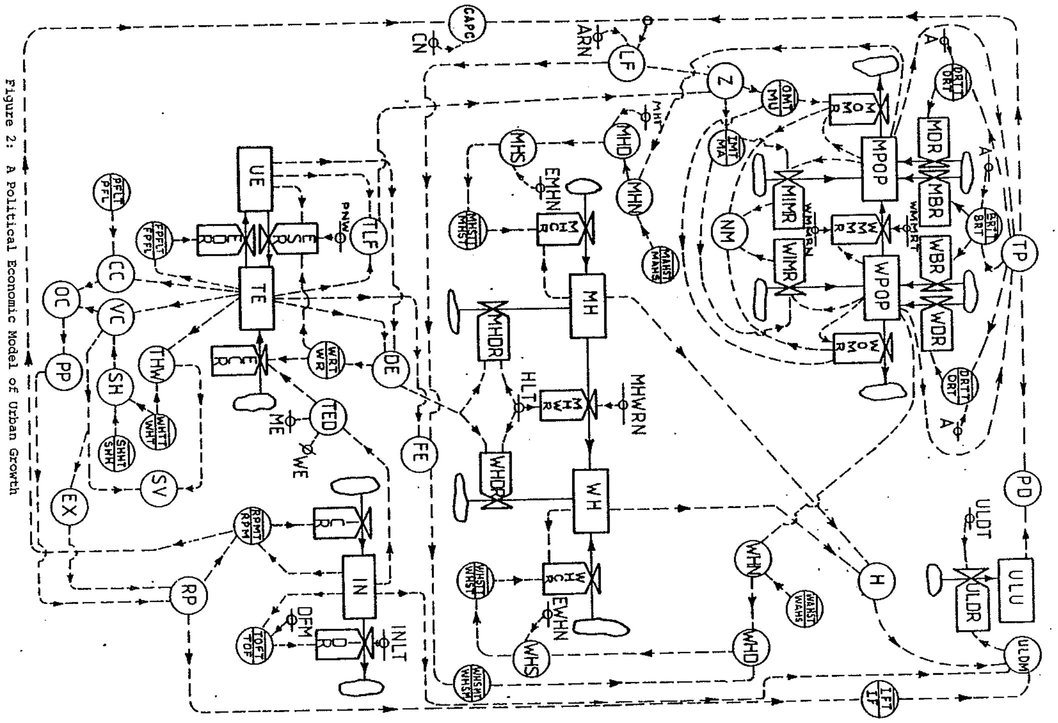

Figure 2: A Political Economic Model of Urban Growth

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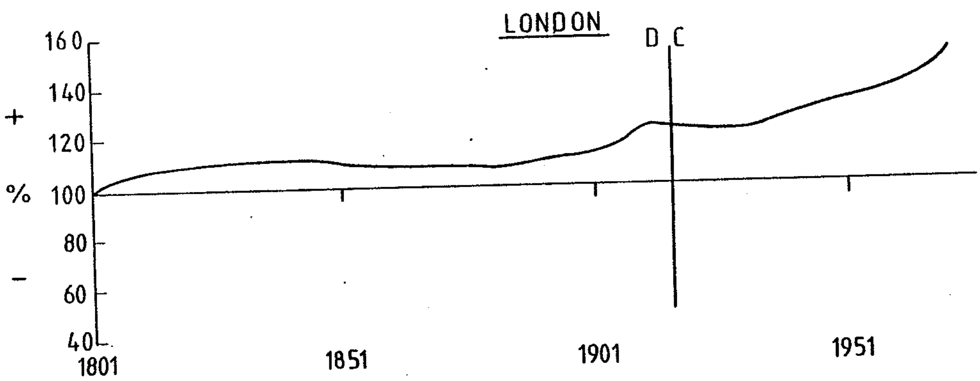

DC - Definition of urban area changed

% - (Predicted/Actual) x 100

Figure 3a. Predicted Pattern of Urban Growth, 1801 - 1971

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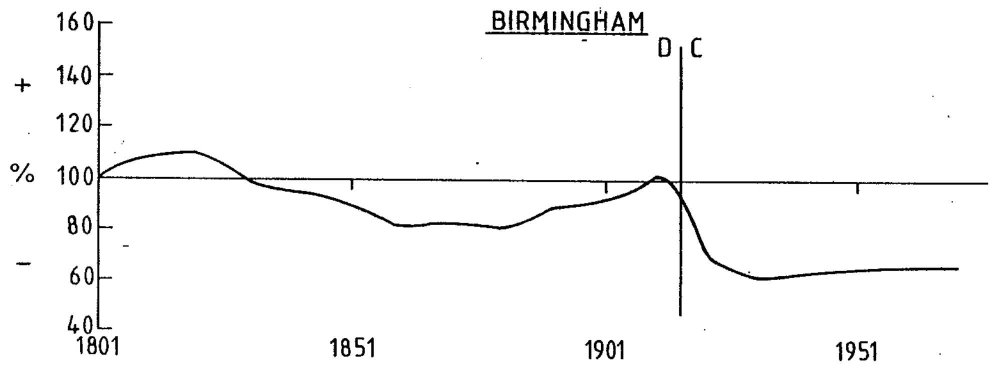
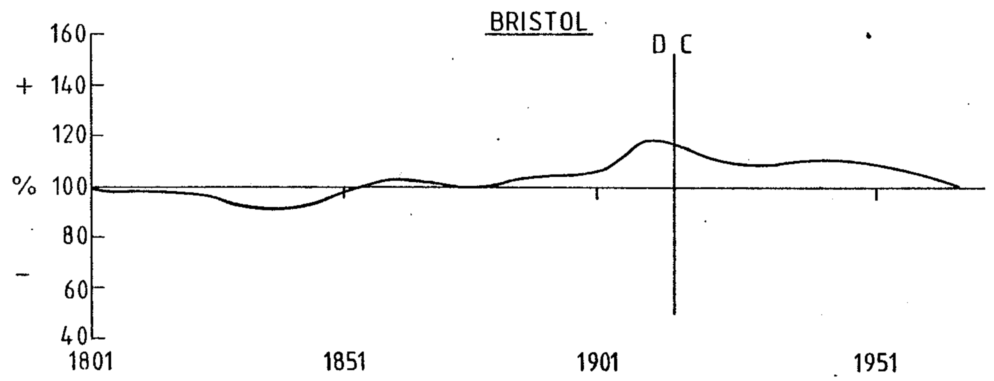


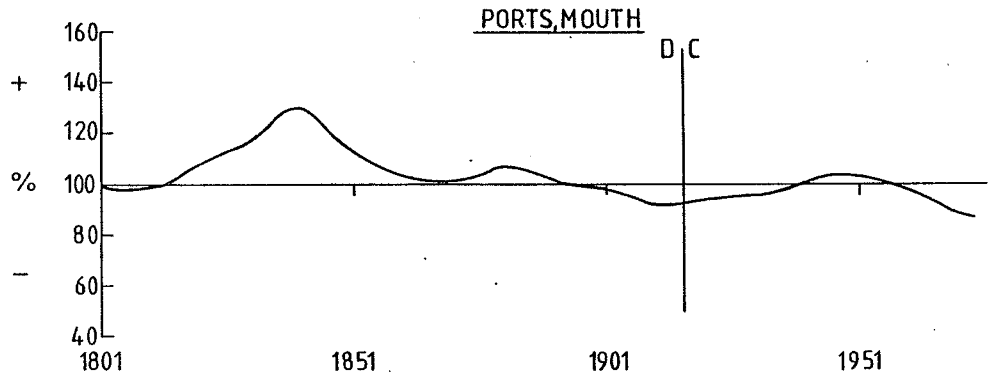
53

Figure 3b. Predicted Pattern of Urban Growth, 1801-1971



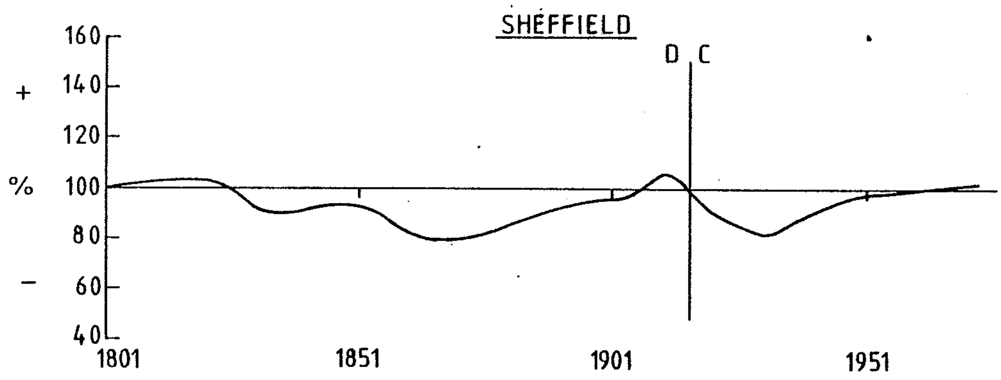
54

Figure 3c. Predicted Pattern of Urban Growth, 1801-1971



55

Figure 3d. Predicted Pattern or Urban Growth, 1801-1971



56

Figure 3e. Predicted Pattern of Urban Growth, 1801-1971

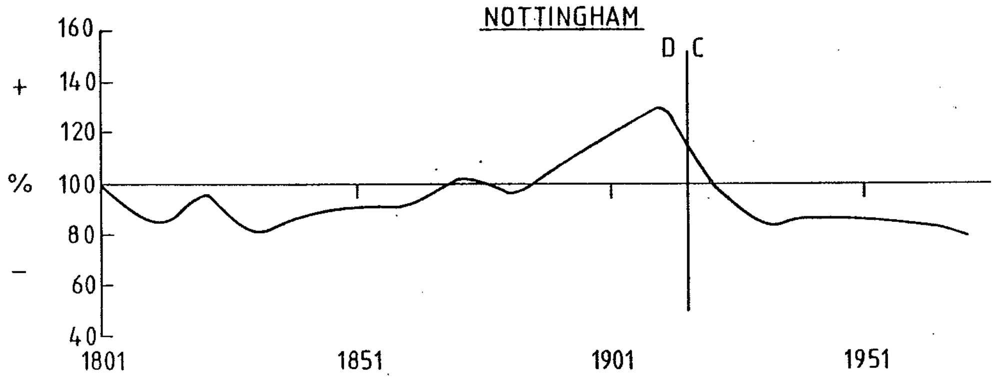


Figure 3f. Predicted Pattern of Urban Growth, 1801-1971

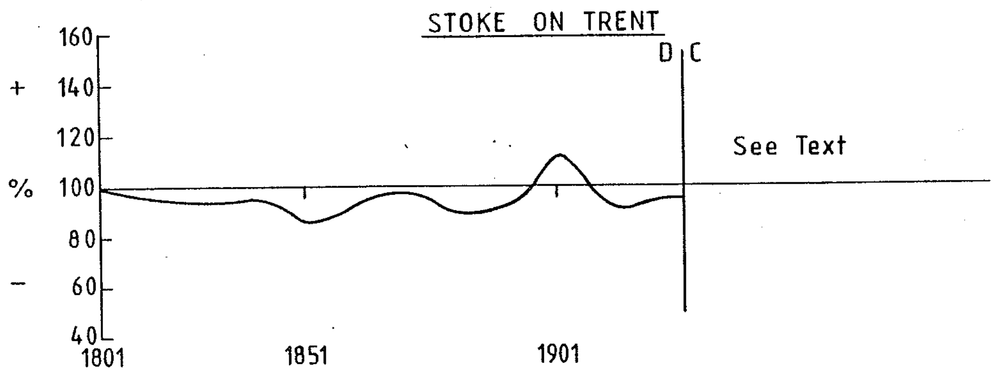


Figure 3g. Predicted Pattern of Urban Growth 1801-1971

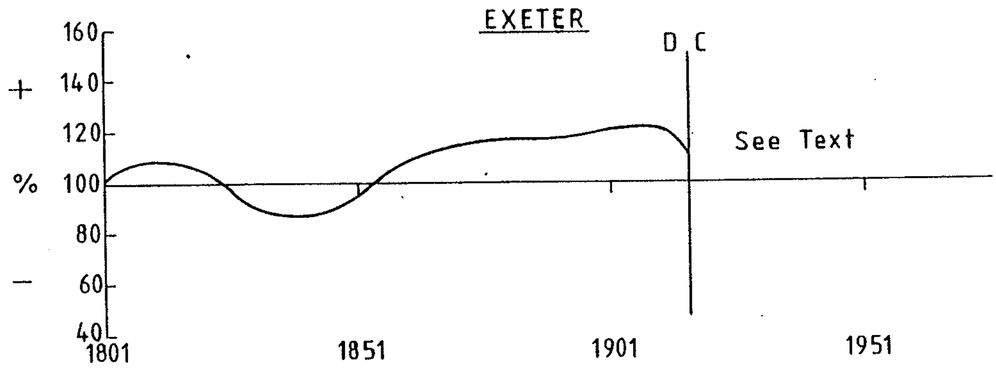


Figure 3h. Predicted Pattern of Urban Growth, 1801-1971

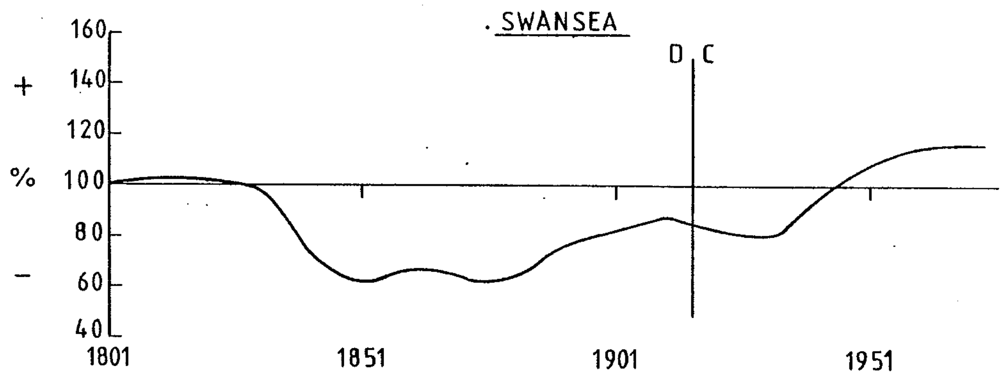


Figure 3i. Predicted Pattern of Urban Growth, 1801-1971

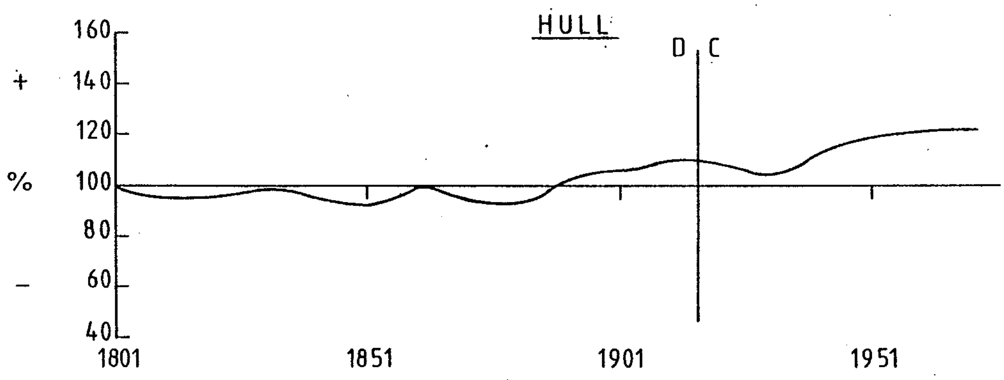


Figure 3j. Predicted Pattern of Urban Growth, 1801-1971

61

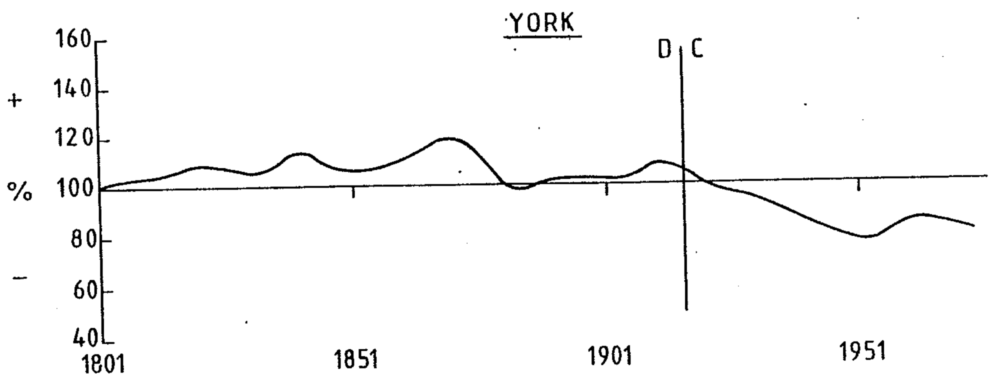


Figure 3k. Predicted Pattern of Urban Growth, 1801-1971

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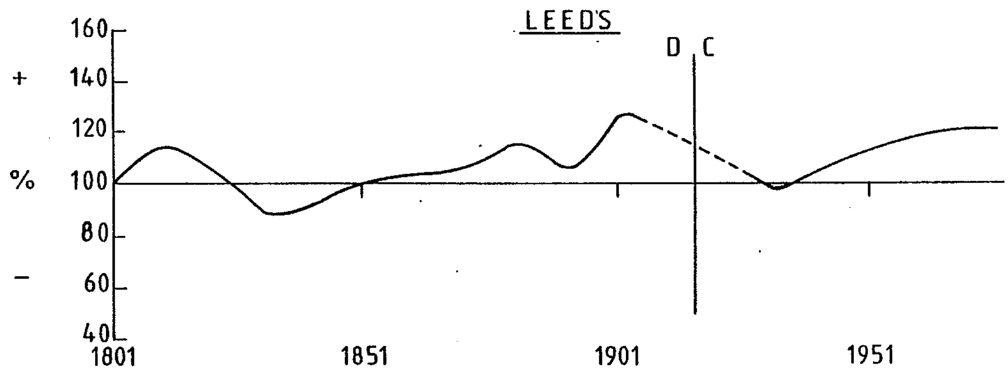
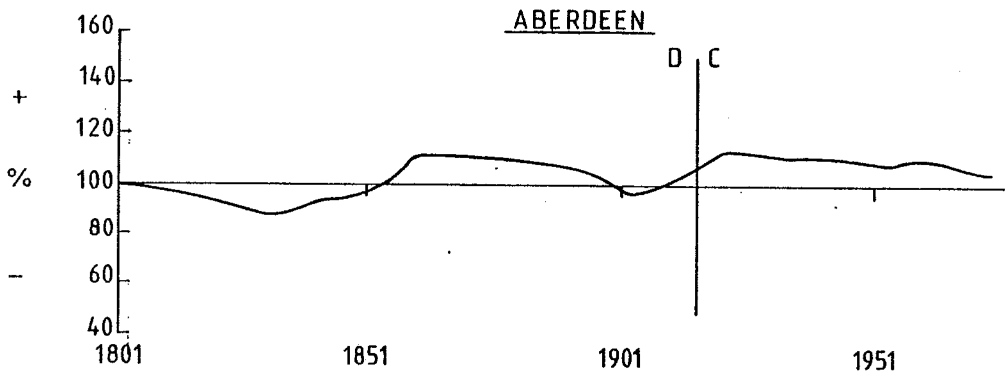


63

Figure 31. Predicted Pattern of Urban Growth, 1801-1971



64

Figure 3r. Predicted Pattern of Urban Growth, 1801-1971

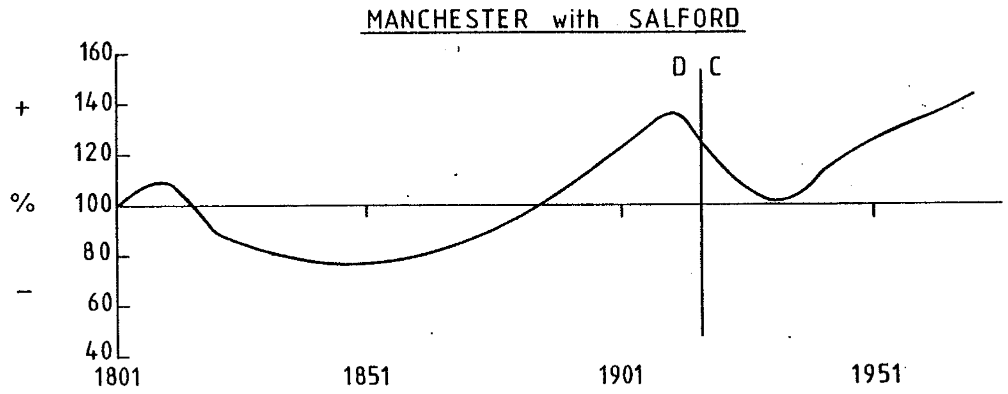


Figure 3m. Predicted Pattern of Urban Growth, 1801-1971

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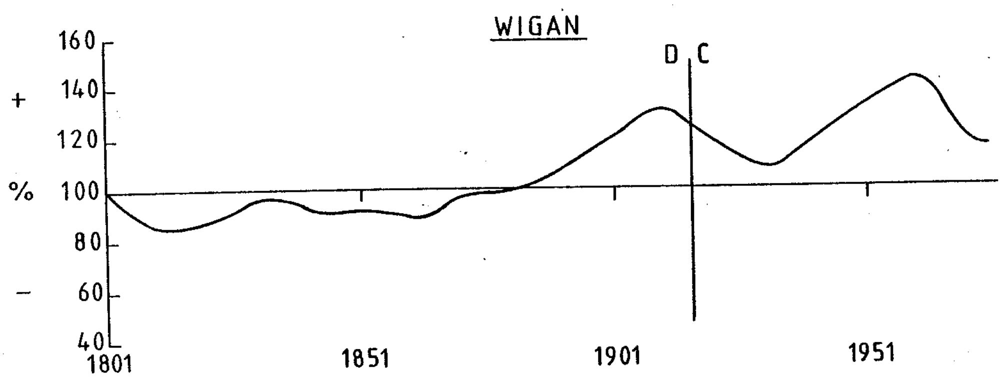

Figure 3n. Predicted Pattern of Urban Growth, 1801-1971

66

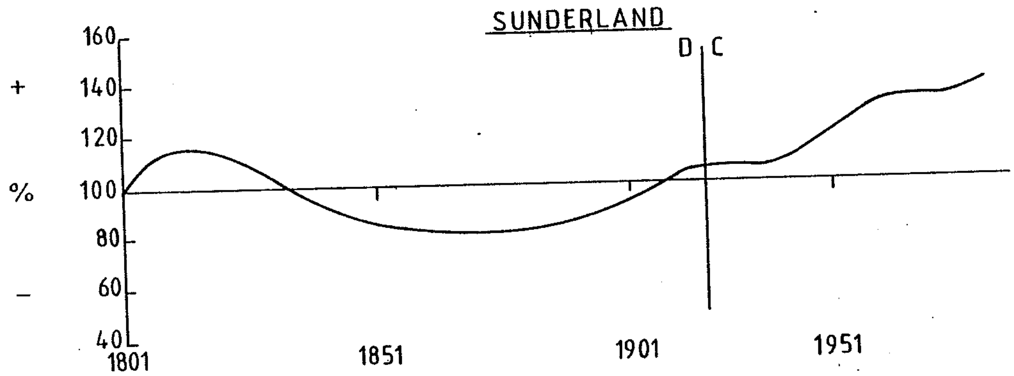

Figure 3o. Predicted Pattern of Urban Growth, 1801-1971

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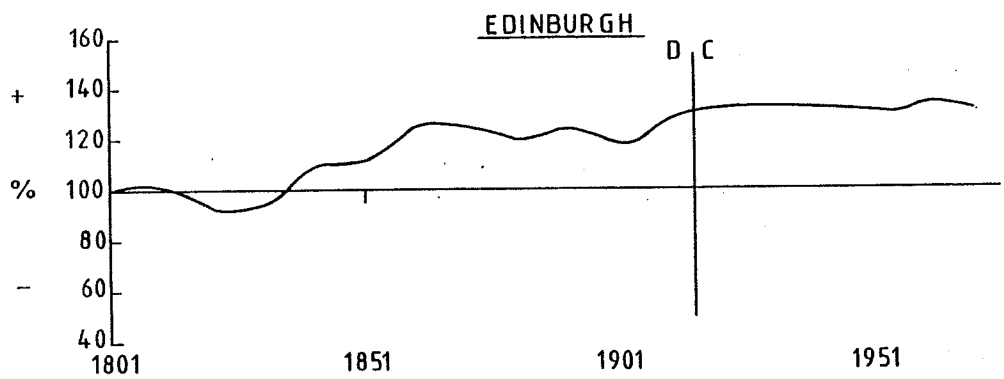

Figure 3p. Predicted Pattern of Urban Growth, 1801-1971

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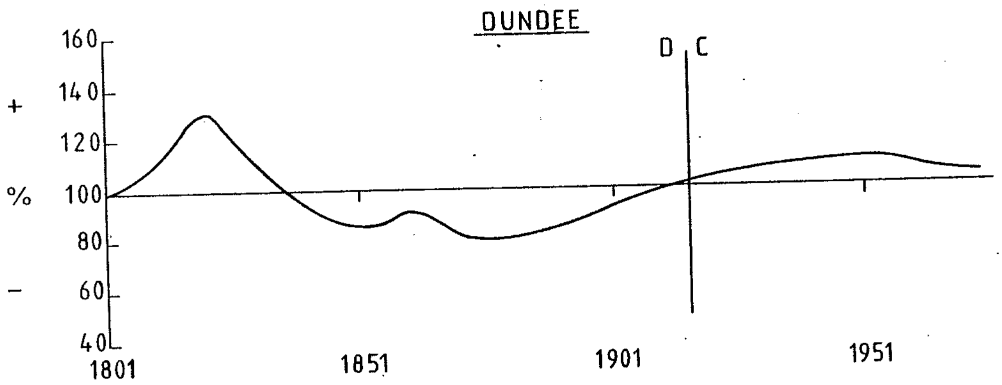

Figure 3q. Predicted Pattern of Urban Growth, 1801-1971