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SPATIAL IMPACTS OF GROWTH CENTRES

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by

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ABSTRACT: The paper indicates, by a review of the early growth centre literature and the later spatial analysis literature, how little is known, particularly in quantitative terms, about the spatial impacts of growth centres. A regression model is then presented by which several aspects of the spatial impacts of growth centres in Ontario are investigated. Generally, it was found that growth was polarised around a set of designated growth centres and this growth diffused away from the growth centres quite gradually. The exceptions were for large centres, growing slowly, where growth rates increased sharply as distance to growth centres increased and for small centres, growing rapidly, where growth rates decreased rapidly with distance from growth centres.

From the regression model, a further model was derived which was used to investigate the extent of spread effects from growth centres in Ontario. The approximate mean maximum distance of the diffusion of spread effects from growth centres was found to be 163 miles. This

could have important implications for the spacing of growth centres and government policies relating to growth centres.

The analysis also investigates the relationship between growth rates and population size and this was found to be non-linear. Generally, for small centres, population size and growth rates were negatively related: for intermediate-sized centres the relationship was positive; and for large centres the relationship was again negative.

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Dianne Laskowski deserves thanks also for typing the manuscript and bravely facing up to several daunting equations.

Finally, I would like to thank Mr. Jim Unger for producing the following cartoon which kept me smiling even through the times I least felt like smiling.

"See that! I forgot to tighten the nut."

The "Globe and Mail"
April 19th, 1977.

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PREFACE

The basic idea underlying growth centre concepts is the alleged superiority of decentralised concentration of development efforts as a strategy for speeding up the process of economic growth and interregional integration and equalisation. The popularity of such an idea is illustrated by the fact that its validity is assumed to be independent of the economic and social systems of the counties within which it is applied.[1] However, the popularity of growth centres in practice has not been matched by an analytical understanding that would be expected of such a popular, and such an expensive, tool of regional planning. Many of the earlier works on growth centres, for example, consisted of vague theories, often untested at the time, about how growth was transmitted, or else they simply described a region's experience in using growth centre policy. It was not until the 1970's that more questions were asked about the analytical content of growth centre theories, and articles such as the one by King, Casetti and Jeffrey [1969] and the one by Casetti, King and Odland [1971] pioneered a new phase of spatial-temporal awareness.

Even throughout the 1970's, however, the number of such works on what appears to be an important topic in regional planning has not been great

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[1]Hence their use in countries such as the U.S.S.R., the U.S.A., Britain, France, India and Venezuala.

and the state of the science has not advanced greatly since Perroux's ideas in the early fifties. There are still many concepts which have not been tested properly or have not been tested at all. This paper attempts to indicate, by a review of the existing literature, in which directions further research could be aimed. Firstly, the general concepts of growth centre theory from the early beginnings will be reviewed and the distinction will be drawn between growth centres and growth poles. Secondly, some of the later literature relating to the spatial-temporal aspects of growth centres will be stated and some of their failings noted. Thirdly, a model will be presented by which several aspects of growth centre theory can be examined more carefully and new information provided. From this model, a fourth section will be presented which will comment briefly upon the spatial extent of growth centre impacts in Ontario - the area in which the model was tested. Mainly from these latter two sections, conclusions will then be drawn regarding some of the present theories and new directions for research will be proposed.

CHAPTER 1

THE EARLY GROWTH CENTRE LITERATURE

"Growth is necessarily unbalanced in a geographical sense".

-Tolosa & Reiner
[1970, p. 454]

CHAPTER 1

THE EARLY GROWTH CENTRE LITERATURE

1.1 INTRODUCTION

A growth centre is a place whose growth stimulates growth in surrounding areas. A growth pole is an industry whose growth stimulates growth in related industries. This paper is primarily concerned with growth centres, although the development of growth centre theory is closely tied to that of growth pole theory, and in fact there was some confusion during the 1950's and 60's as to what the exact distinction between the two was.

Much of this confusion has been attributed to the fact that a lot of the early works on growth pole theory were published by French authors, such as Perroux [1950, 1955] and Boudeville [1957], and misunderstandings arose out of the translations into English. Also, perhaps more importantly, was the fact that Perroux's original article on the subject of growth poles[1], was slightly misleading. At the outset he defines growth poles in relation to abstract economic space and not in relation to geonomic space, which he describes as "banal". Geonomic space is defined as being "bounded and defined by the geonomic relations between points and lines and volumes" and hence the geonomic space of a firm is that in which the material means and manpower of

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[1]"Economic Space, Theory and Applications." Quarterly Journal of Economics. 64, pp. 89-104.

the firm are situated when it functions. Economic space is defined as being "unbounded and defined by the economic relations which exist between economic elements" and the economic space of a firm is then a function of the relationship a firm has with the economies of other firms. To draw the difference between the two types of spaces, Perroux [1950] gives the example of the Michelin firm in France:

> "The geonomic zone of influence of Michelin is inscribed in a region, but its economic zones of influence, like that of all large firms, defies cartography."
> -p. 98

Thus, when Perroux talked about a firm in economic space he meant a growth pole - a firm which transmits growth through economic space and not necessarily through geonomic space. However, misunderstandings with growth centres probably arose out of some of Perroux's later statements in his 1950 article when he began considering spatial aspects of growth poles. Thus, he said:

> "As a field of forces, economic space consists of centres (or poles or foci) from which centrifugal forces emanate and to which centripetal forces are attracted .....
> The firm considered as a centre releases centrifugal and centripetal forces. It attracts men and objects into its banal space (personal and material aggregations around the firm), or it removes them (diverting tourist activity, land reserved for further expansion etc.)
> -p. 97

The confusion between poles and centres is perhaps taken further in Perroux's article[1] in which he deals with linkage effects and cumulative

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[1]"Note sur la notion de 'pole de croissance'" in McKee, Dean & Leahy [1970].

causation - a theme developed a year earlier by Scitovsky[2]. Perroux states that a new industry does not generally appear alone and as expansion in new industries overlap, the total increase in output from a system can be represented by the following equation:

$$G = f(A) + f(B) \qquad (1.1)$$

where G represents the increase in total production;
A represents the 'amount' of the additional products themselves of the new industries taken as a whole;
and B represents the 'amount' of the additional products induced by the new industries taken as a whole.

Perroux goes on to mention that territorial agglomeration occurs because of various types of economies of scale and,

> "the complex industrial pole, geographically agglomerated, modifies not only its immediate geographical environment but, if it is sufficiently powerful, the entire structure of the national economy where it is situated. As the centre of accumulation and agglomeration of human resources and of fixed and definite capital, it brings into being other centres of accumulation and agglomeration of human means and fixed and definite capital".
>
> -pp. 101-102 in McKee, Dean & Leahy [1970]

It is understandable then, how some of the confusion between growth poles and growth centres has arisen. As Darwent [1969] remarked in his excellent literature review:

> "The distinction which it is necessary to preserve in growth pole notion, between economic space in which poles are defined, and geographic space in which they happen to have a location, is a basic and important one which has all to often been neglected. The semantic confusion of attributing to a location, the growth characteristics of the pole (industry) which happens to be there has been made repeatedly".
>
> -p. 541

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[2]Scitovsky, T. "Two concepts of External Economies" - Journal of Political Economy. p. 143 ff. Vol. 62. April 1954.

A practical example of the difference between growth poles and growth centres, which is given by Darwent as evidence of the confusion between the two concepts, is worth repeating here. This is the discovery of the gas field in Lacq, S.W. France. The gas field has acted as a good growth pole because it has induced growth in the economy of France: but it has been a poor growth centre because it has failed to affect or induce any other industries to its locality. It so happens that greater external economies exist in other locations in France and because of this gas is transported to those locations. Growth has taken place - but not in S.W. France.

Hansen [1972] also gives an example to differentiate between growth in economic space and growth in geographic space. He cites the setting up of the Kaiser Aluminum and Chemical Corporation at Ravenswood, West Virginia, which created more growth in Ohio, where the plant derived its power from, and in Louisiana where the bauxite came from, than it did in Ravenswood. Thus the plant acted as more of a growth pole than a growth centre.

Before such semantic confusion between growth centres and growth poles permeates this work it is useful here to define what will be meant by a growth centre and why this study will concentrate on growth centres as opposed to growth poles.

There are several definitions of growth centres in the literature. Some writers have defined and discussed growth centres in a very restricted sense. Fox [1966], for example, defines a growth centre as "an urban place which can act as a focal point for development planning" and is only related to the development regions and districts as defined by the U.S. government's Economic Development Act. In this context, "a growth center is typically an urban place of less than 250,000 population which acts as the vital heart of its development district." Fox defines several criteria by which a distinction might be made between urban areas which are growth centres, and those which are not. Such criteria for growth centres included:

1) Strong Linkages to the National Economy.
2) Centre of a labor market.
3) Major retail trade area.
4) High level tertiary functions.
5) Large volume of wholesale trade.
6) Good communications.

However, as Darwent [1969] notes, these criteria hold for almost all large urban areas.

A slightly less vague definition is that given by the Appalachia Regional Commission in 1968, which states:

> "By a growth center or centers is meant a complex consisting of one or more communities or places which, taken together, provide or are likely to provide, a range of cultural, social, employment, trade and service functions to itself and its associated rural hinterland. Though a centre may not be fully developed to provide all these functions it should provide, or potentially provide, some elements of each, and provide a sufficient range and magnitude of these functions to be readily identifiable as the logical location for many specialized services to people in the surrounding hinterland."
> -p. 12

However, this defintion could again be applied to almost all fairly large urban centres. It does give the impression though that "something" is transmitted from a centre, outwards into the periphery. This is said more explicity in a third defintion of growth centres given by the European Free Trade Association (EFTA) in 1968:

> "A growth centre is an urban core (however small) and its surrounding area is defined by an acceptable journey - to - work, and capable either of spontaneous growth - both of population, economic activity and income level together - or of potential growth (which could, if required, be stimulated by government intervention). Another important feature ... is that the benefits of its growth are likely to be felt also in the surrounding area."
>
> -p. 21

All three definitions given above imply that growth is transmitted from the growth centre to the periphery and this growth is some form of economic activity. Thus, for the purposes of this paper, a growth centre will be defined in simpler terms to those definitions previously stated and in similar terms to that used by Nichols [1969, p. 163]. *For the purposes of this study a growth centre is an urban centre of economic activity which can achieve self-sustaining growth to the point that growth is diffused outward into the surrounding region.* Under this definition, the existence of a growth pole in a centre implies that the centre is a growth centre only if the industries whose growth is stimulated by the growth pole are concentrated in the hinterland of the growth centre. One of the main aims of regional planning is to stimulate growth in specific underdeveloped areas and consequently it is growth centre development, rather than growth pole development, which is of interest to regional planners and of interest to this paper. Thus, most of the literature which deals with growth poles will not be mentioned here, except where ideas are deemed to be coincidential with growth centre theory.

One such coincidential idea which applies to growth centres and to growth poles is the effect of linkages between industries. Hirschmann [1958] discusses backward and forward linkage effects in relation to unbalanced growth and with reference to problems of under-development. Backward linkages (links to suppliers of inputs) are developed by all non-primary activities, and forward linkages (links to consumers of outputs) can be developed in all sectors other than that supplying final demand. Hirschmann also speaks of the 'strength' and 'importance' of the link. The total linkage effect can be measured by the product of these two. In Hirschmann's terms the 'importance' of links from a polar industry to a satellite industry is the potential net output of satellite industries which might be induced by the polar industry and the 'strength' is the probability that such induced outputs will actually occur. Although these ideas were developed primarily in economic terms, and hence in growth pole terms, they can help explain how growth centres can be established and how growth can eventually be transmitted into the environs of a growth centre. Generally, the strongest linkages will be those that are the shortest, *ceteris paribus*, and this leads to the idea of cummulative causation which was to be later developed by such workers as Pred [1966], Keeble [1967] and Moseley [1974]. Once a centre is established and cummulative growth has taken place over a time period, diseconomies of scale may develop in that centre and firms may move to the peripheral areas.[1] In very simple terms then, growth is transmitted from a centre to a surrounding area.

Thus, from Perroux's early ideas, the interaction between a propulsive firm, or pole, and others, was seen only in relation to the matrix of a theoretically open economy where bounds are arbitrarily limited to a nation or region. Locations in geographic space will now be dealt with solely

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[1]see for example Fotheringham, A.S. "Time Space Divergence and Spatial Reorganisation in Cleveland." Unpublished Batchelor's thesis. University of Aberdeen. 1975.

and a concentration will be made upon the spatial impacts from growth centres.

1.2 SPREAD AND BACKWASH EFFECTS

Growth in the space economy does not appear at all places with equal intensity at the same time and many authors haved stated this fact. Perroux [1955] said:

> "Growth does not appear everywhere at the same time".
> -p. 94 in McKee, Dean & Leahy [1970].

Hodge [1966] amplified this point:

> "It is almost axiomatic that not all urban places in a region can expect to share in the limited possibilities for economic development or in the limited public resources for capital investment. Many, whose urban accoutrements are meagre and whose quality of physical development is not high, start with a handicap in attracting populations and investment."
> -p. 2

Thus it is reasonable to assume that the places where growth is taking place rapidly, such as growth centres, will have some effect upon surrounding places where growth is not taking place so rapidly.

Myrdal [1957] and Hirschmann [1958] were early contributors to this aspect of growth centre literature. Independently, they both talk of a process whereby one region (called "North" by Hirschmann) is the growth centre, being advanced and developed, which influences or controls the rest of the nation ("South") by two processes - called 'spread' and 'backwash' by Myrdal. Hirschmann's terms, exactly analogous to these, are 'trickling down" and "polarisation' respectively. Backwash effects, exercised by the North on the South, tend to be to the South's disadvantage, and are due to the North's stronger economic position. Backwash effects could include such things as severe competition for the South's relatively inefficient industries, and a tendency for selective migration of the young, skilled, educated people from South to North in search of the greater opportunities and apparantly higher salaries available in the latter. Because the North's industry is probably more productive than that of the South's, what little capital the South possesses may also migrate to the North, where interest rates are probably higher and investments are more secure. Hansen [1971] states that the process by which the core regions consolidate their dominance over peripheral regions (backwash), tends to be self-reinforcing as a consequence of 6 principal feedback effects of core-periphey growth:

(1) the dominance effect, or the weakening of the periphery by resource transfers to the core.

(2) the information effect, or increased interaction and innovation in the core.

(3) the psychological effect, or a higher rate of innovation due to higher expectations and lower risks in the core.

(4) the modernisation effect, or social and institutional change favouring innovation.

(5) Linkage effects, or the tendency of innovations to induce yet other innovations; and

(6) Production effects, which increase scale and agglomeration economies.

Opposing these backwash effects, the growth centre, North, emits spread effects to the surrounding area, South, which are to the South's benefit. Such 'spread' effects could be the increase of Northern purchases and investments in the South and the absorption by the North of some of the South's underemployed thereby raising per capita incomes in the South.[1] Nichols [1969] said that in theory spread effects should, after a while, begin to diffuse out from a centre for any one or more of the following reasons:

(1) Diminishing marginal returns to investment set in at the centre making investment in the surrounding areas relatively more attractive.

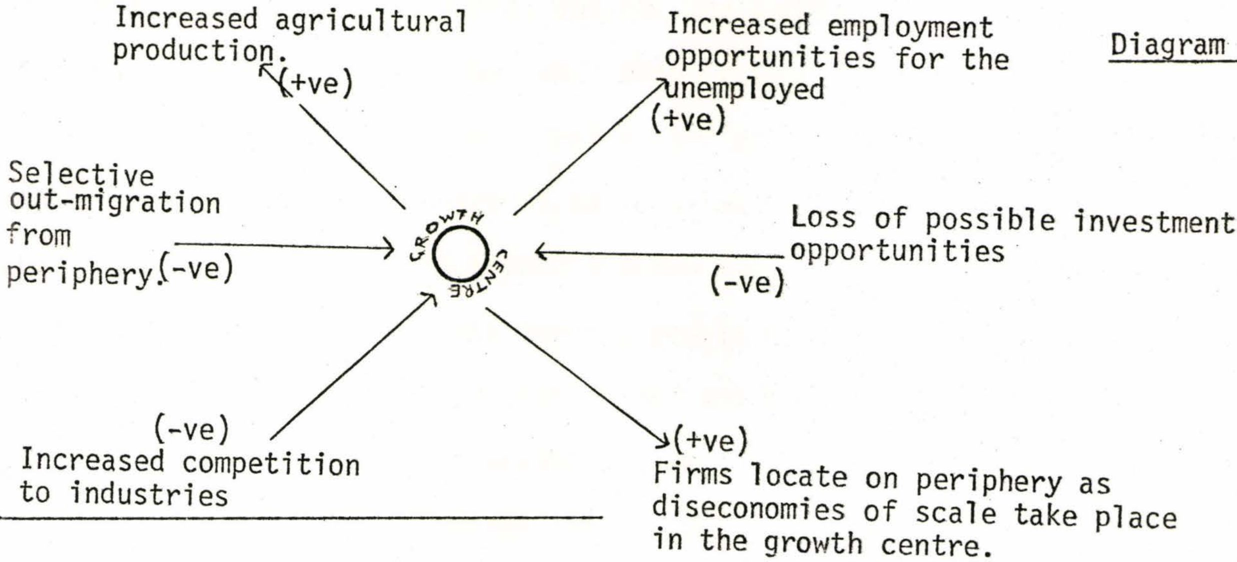
(2) New ideas demonstrated in the centre are taken up by local investers in more distant locations.

(3) Excess labour is drawn off the land into the growing centre and this allows reorganisation of the land holding system and forces mechanisation.

(4) Increased income in the centre raises the level of demand for the products of the surrounding area.

The following diagram represents a theoretical distribution of spread and backwash effects.

Diagram 1



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[1] It is useful at this point to distinguish between "pure" and "relative" spread and backwash effects. "Pure" backwash effects, for example, occur when a centre is suffering an absolute decline such as a net loss of population. "Relative" backwash effects occur when a centre is declining relative to all other centres. Its population may still be increasing yet, compared to other centres, its rate of increase is very low and it can be said to be relatively declining. Similarly, "pure" spread effects occur when a centre is growing while "relative" spread effects occur when a centre is growing at a relatively rapid rate: relative to all other centres, that is.

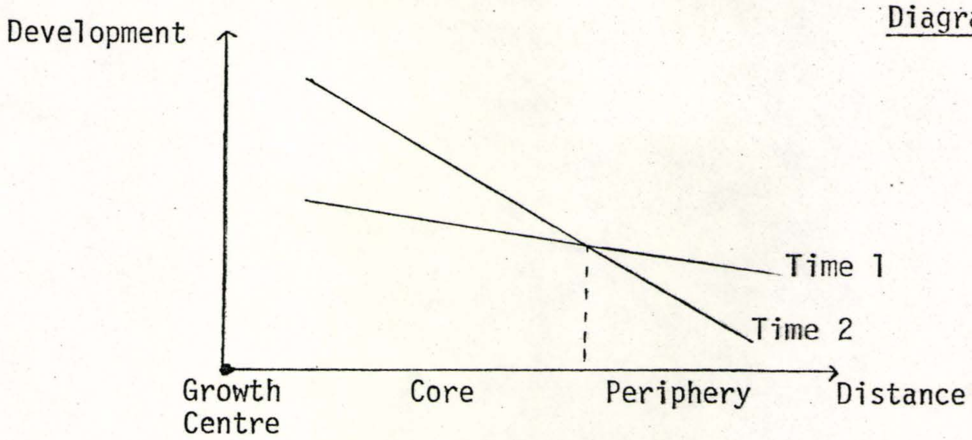
Most of the later analyses in this paper use the concept of "relative" spread and backwash effects.

It should be noted here that what one calls a 'spread' or 'backwash' effect changes with the perspective one looks at the effect from. Is migration, for example, a 'spread' effect, in the sense that migrants have better employment opportunities in the growth centre, or is it a 'backwash' effect in that the growth centre will increase in population while the surrounding areas will decrease? The confusion here is analagous to the confusion between growth poles and growth centres and depends upon how one classifies groups of people. For all people the overall effect of a growth centre may be positive, that is, they are receiving spread effects, but for the people who remain in the periphery the effect may be negative, that is they are receiving backwash effects. The analogy with growth centres and growth poles is clear. If the example of the Lacq gas industry is again taken, this industry had positive effects for all the people in France grouped together, yet it had negative (or negligible positive) effects for the people in Lacq itself.

It should also be noted that spread and backwash effects, although mentioned frequently in the literature, have not been very well defined. Are such processes actually operating? If so, what is the spatial extent of such processes from growth centres? Do spread effects travel further than backwash effects? Where do spread effects stop and backwash effects begin? Both Myrdal and Hirshmann were doubtful about the strength of the possible spread effects from growth centres and felt that backwash effects are likely to be much stonger. However, little testing of their ideas has been undertaken.

Two of the earliest comments on the spatial extent of spread and backwash effects were those made by John Friedmann in 1963 and 1966, when he developed a core-periphery model of growth centre impacts which could be applied to any scale (see 1966, p. 10-11). Briefly, his very simple model envisages spread effects spreading rapidly outwards from a growth centre until a certain distance (the core) and then backwash effects becoming dominant (the periphery). This situation can be represented by the following diagram:

Diagram 2



All of the region nearest the growth centre receives spread effects, while the parts of the region furthest away receive backwash effects.

This theory has intuitive appeal because of the probable distance - decay effect of growth impulses, and as mentioned earlier, the core-periphery model has been interpreted in many real-life situations. Darwent [1969], for example, mentions the case of France in which the Paris region can be considered a core while the rest of France is the periphery. In Ontario, the Toronto-centered region could be considered the core while Northern Ontario is the periphery.

However, echoing Moseley's words [1974, p. 121], "*how far* [author's italics] geographically does the growth centre's effective hinterland extend? Is it in fact true that the spatial incidence of economic growth is a function of distance from the central city and troughs of backwardness lie in the most inaccessible areas?"

Brewis [1968] asks similar, relevant questions but does not answer them;

> "No one will question the extremely important role that towns play in the growth processes and the stimulus that they give to innovation and enterprise, but how far are they likely to have a "spin-off" effect encouraging growth in out-lying areas and how far are they likely to attract industry away from these areas? "Growth centre" advocates are apt to assume the former effect will be dominant but this may not always be the case. In many instances, rather than inducing growth in the region as a whole, expanding urban centres will rob other localities of what growth they had and lead to a decline in their industry and the migration of their populations".
>
> -p. 58

Questions such as these have often been asked in the growth centre literature but most authors appear to be satisfied in asking the questions and leaving the answers for others. Consequently, few answers have arisen while many questions have been asked.

Some answers that have been given such as those by Richardson [1976], Gaile [1973] and Moseley [1973] have been either contradictory or vague and consequently much work still remains to be done in this area. Gaile and Moseley both doubt the presence of substantial spread effects around growth centres, while Richardson says that they are likely to be the dominant effect over a period of time. Gaile's growth centre test of the Milwaukee area led to his finding that "the concept of concentric spread" of growth from the growth centre has not been proven. Moseley's studies of the spatial impact of Rennes, France and of spatial flows in East Anglia also cast doubt on the notion that spatial concentration of investment will inevitably benefit much wider geographic areas. Moseley said it may benefit other sections of the economy but not necessarily the surrounding area and "in fact it may be to the disadvantage of the surrounding area". In contradiction to these latter two views, Richardson concludes that a well-located growth centre "promoted with vigor in appropriate economic conditions and resistant to political trimming should pay off as a regional policy investment if the planning term is long enough". Thus, with this contradiction in mind, it is worth investigating further the spatial extent of spread and backwash effects to clarify the existing vagueness in the current literature.

It is worth mentioning at the end of this section, which has touched briefly upon the core-periphery model and its relevancy to growth centre theory, that there appears to be a basic contradiction in thought here. Growth centres are seen in regional planning terms as instrumental to the stimulation of depressed areas and the securing of balance in the development process among regions to avoid political rifts and the emergence, or maintenance, of economic dualism. That is, growth centre policies are seen as equalisation policies. Yet, the core-periphery notion indicates that growth centres would promote central growth and peripheral decline. Thus, the peripheral areas of newly established growth centres would presumably be worse off after the establishment of growth centres than they were before. Growth centre policies, then, encourage spatial imbalance in some areas by chanelling investments to the new regional growth centres and away from the periphery, while at the same time they support regional balance by the creation of regional centres in the periphery of the main centre of ecomomic growth. A growth centre policy may help to reduce inter-regional disparities but at the same time increase intra-regional disparities.

1.3 THE IDENTIFICATION OF GROWTH CENTRES

In the growth centre literature, population size has been the most widely used and most discussed identifier of growth centres. There has probably been discussion over the size of growth centres since the concept of such a centre came into being. This has perhaps been a beneficial thing because the size of a centre, if it is to succeed as a growth centre, is of vital importance in regional planning where time and money could be wasted on investment in too small or too large a centre. However, as Darwent [1969] notes:

> "There is ..... little agreement on the size of growth centres, and in the planning field, on the optimum size, given a set of goals and constraints. Clearly if a theory of the spatial incidence of growth is to be developed, it must include some postulates about the size of growth centres, and the relationship between size and rate of growth, at a given state of development and in a given socio-cultural system. Unfortunately, this is very close to the issue of the optimum size of a city, which is a problem replete with hypotheses, many of them ill-founded, and notably lacking in evidence."
>
> -p. 558 in Friedmann & Alonso [1975]

One of the earliest mentions of the size of growth centres came from Boudeville [1961, 1968] when he described three types of regions: homogeneous; polarised; and planning regions. Polarised regions were defined to be that collection of geographic spaces in which connections and flows of goods and services are predominantly in one direction - towards a central point which dominates the region. The boundary of a polarised region is therefore that line beyond which flows and connections are predominantly in some other direction. As Darwent [1969] notes, these concepts are very similar to Derwent Whittlesley's 'nodal region' and John Friedmann's 'core-periphery' model. The polarised region can exist at any scale, and smaller ones, polarised around smaller centres, will tend to 'nest' within larger ones. The idea of the polarised region is therefore compatible with the central-place structure of a hierarchy of cities of ascending size and function, with the 'growth centre' normally being the larger city or cities in the region, at whatever scale being discussed. Thus, a growth centre is here described as being one of the largest cities in the region. Later authors have given more exact definitions of the size a growth centre should be.

Hoover [1968], in a classical formulation, explained why larger centres would make better growth centres. According to Hoover, larger centres could attract more growth, that is, more industries, because of 3 main reasons:

(1) Increased specialisation by firms. Certain operations that would normally have to be carried out by a firm can be contracted to other firms specialising in such operations at a lower cost.

(2) In a large city firms can carry proportionally smaller stocks of materials than they can in an isolated location, since they are able to depend on their ability to secure more at short notice.

(3) There are often reductions in unit cost when many firms are consuming large quantities of basic materials such as electricity. This is more likely to occur in large centres than in small ones.

Thus, industries are likely to be attracted to, or near, already existing large centres, and hence large centres are more likely to be successful growth centres. Alonso [1968] and Hirschmann [1958] both agree that investors concentrate upon established centres. Alonso says that this is a rational decision as "nothing succeeds like success", while Hirschmann claims that large centres need not necessarily be good growth centres and claims that this is an irrational decision and urges investors to look at the periphery more.

How large these 'large centres' have to be to be termed growth centres has varied in the literature and various advocates have claimed sizes between 10,000 and 1,000,000 to be optimum. Brian Berry [1967, p. 18], for example, found that above a population of 250,000, "the necessary conditions for self-sustaining growth seem satisfied", and he suggests that the greater payoff in terms of increasing employment and reducing unemployment would be to use "the public treasury to enable centers close to this point to achieve self-sustaining growth" rather than to put resources into places much smaller than this maximum.

Wilbur Thompson [1965, p. 24] also proposed a threshold of 250,000, while Hansen [1972] suggested a threshold for self-sustaining growth in the 150,000-200,000 population range and Werner Hirsch [1968, pp. 509-511] estimates that the greatest economies of scale occur in the 50-100,000 population range. Finally, it is useful to note the conclusion drawn by participants at a conference sponsored by the International Economics Association in response to the question "How large must a successful growth point be?" E.A.G. Robinson [1969] reports:

> "the general sense of our discussions was that the minimum size of growth points that experience had shown to be successful was nearer to a population of 100,000 than to one of 10,000 and that even 100,000 was more likely to be an underestimate than an overestimate. It must be large enough to provide efficiently the main services of education, medical facilities, banking, shopping facilities ... Above all, it must be large enough both to provide an efficient infrastructure of public utility services, and to permit the early and progressive growth of external economies for its local industries."
> -p. xvi

Thus, there are almost as many proposed levels of optimum growth centre size as there are articles about it and there are no definite conclusions to be drawn from the existing literature.

In practice, the sizes of growth centres have been as diverse as those proposed in theory. In the United Kingdom, New Towns, which are used as growth centres in some cases, were designated optimum populations of between 45,000 and 60,000. More recently the thinking has been to encourage Expanded Towns of between 150,000 and 250,000 population. In Eire, "regional growth centres" were defined as towns having between 10,000 and 30,000 inhabitants[1], and in India the population of growth centres varies from 50,000 to 500,000 depending upon the stage of the regional economy[2].

The optimum size of centres in which to initiate growth in has often varied between that proposed in theory and that resulting from practice. For example, Hansen [1975] says that larger centres are likely to receive growth transmitted to them more quickly than small places because of their more frequent contact, although this point is not proven, and he argues for initiating growth in smaller centres, as larger places are more likely to adopt such growth. If growth is induced primarily in larger places, smaller places will be slow to adopt it.

Nichols' conclusion [1969] was similar in that she thought that although it is probably advisable to concentrate investment in that town in a region that had the strongest links, there are also advantages to be gained from injecting capital into lower order centres, or even the agricultural base, because increases in incomes in these places will generate strong income multipliers in higher order centres but not the other way around. However, the U.S. Economic Development Administration (E.D.A.) attempted to apply this strategy on a national scale. It was not successful because development funds were too widely and thinly dispersed. The Department of Commerce, in a report

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[1] see Moseley [1974, p. 39]

[2] see Kuklinski [1972, p. 161]

proposed jointly with the Office of Management and Budget, pointed out that:

> "The policy of dispersing assistance rather than focusing on those [places] with the greatest potential for self-sustaining growth has resulted in much of the E.D.A.'s funds going to very small communities. Over a third of its public works funds have gone to towns with less than 2500 people, and over half to towns with less than 5000 population. There are relatively few kinds of economic activities which can operate efficiently in such small communities, so the potential for economic development in the communities is relatively small."
>
> -Report to the Congress on the Proposal for an Economic Adjustment Program, 1974.

The optimum size of growth centres is thus a very difficult subject to deal with theoretically and empirically and every region may have its own optimum population size for growth centres. However, it is pertinent to note here that in the analysis undertaken in this paper, a minimum size of 100,000 was used to define growth centres. This figure is closely related to that used by Robinson.

There have been several identification procedures, generally more recently, that has not been based upon size. Carol [1966] identified growth centres in Southern Ontario as simply being high and middle order central places defined by the level of their retail sales which was taken as a surrogate for centrality. Semple et al. [1972] sought growth centres within the state of Sao Paulo, using composite indices of growth related to each centre in that state. Their objective was to identify a centre such that the reciprocals of the distance from it to each of the other centres were positively and significantly correlated with the growth rates of those centres. In other words, they hypothesized that the state's surface of growth resembled a series of interlocking cones, and they used trend surface analysis to find the peaks of these cones.

Casetti et al. [1970, 1971] began with the hypothesis that Los Angeles was the dominant growth centre in Western U.S.A., and then tested its ability to influence the growth rates of twelve cities within 1000 miles of it over 12 years, using regression analysis. Proximity to Los Angeles played a significant role and so the former's growth centre status was confirmed.

Berry [1969] factor-analysed the economic structure of 105 Chilean towns, separately for 1952 and 1960. Grouping these towns on the basis of their scores on the major factors, he identified five groups in each of the two years. Those towns which "moved up a group" between 1952 and 1960, he termed growth centres.

Other methods that have been used to identify growth centres include shift and share analysis by Kuehn and Bender [1969] and Principle Components Analysis by Hodge [1966]. Kuehn and Bender attempted to identify growth centres in the Ozarks Economic Development Region of Arkansas, Missouri and Oklahama, by looking at the competitive and comparative elements of the industrial structure of various-sized population centres. The competitive component, C, for each sector i, and county j, was computed by:

$$C_{ij} = E'_{ij} - [(E'_{i.} / E_{i.}) E_{ij}] \qquad (1.2)$$

where, E' = employment in the latest time period.
E = employment in an initial time period.
subscript . = national employment.

The net competitive component for sector i is $\sum_j C_{ij}$. The comparative component, M, was computed as follows,

$$M_{ij} = [(E'_{i.} / E_{i.}) - (E'_{..} / E_{..})] E_{ij.} \qquad (1.3)$$

and the net comparative effect for county j is $\sum_i M_{ij}$.

Basically, Kuehn and Bender's ideas were that if the analysis is restricted to depressed areas, then those counties exhibiting trends that are different from the rest of the area should have a different competitive and comparative advantage and hence be more suitable for growth.

Hodge used principle components analysis to identify characteristics of growth poles and put these main characteristics into a regression model, using data from Eastern Ontario. The main factors he identified in distinguishing 'growth centres' from 'non-growth centres' were that a growth centre generally had a relatively young population; an economic base devoted to commerce rather than industry; and a low adult education level.

In this paper, as mentioned earlier, an *a priori* identification of growth centres in Ontario is made by selecting all centres over 100,000 population in 1966. However, one of the purposes of the analysis is to determine if any of the centres selected are not acting as true growth centres by not diffusing growth into their environs and thus the analysis presented in a later chapter in this paper can be considered as another method of identifying growth centres. The advantage of the method to be outlined later is that it considers a multi-growth centre landscape and accessibility factors are calculated for all places to all of the growth centres. This is closer to reality than most of the analyses mentioned above which have generally attempted to identify growth centres singly.

Chapter 1 has thus mainly discussed the early works or growth centres which were generally non-mathematical and which perhaps "laid the ground rules" for further studies to proceed on. The later studies on growth centres have generally been concerned to a much greater extent with spatial awareness of growth centre impacts, particularly the extent and character of spread and backwash effects and these studies will now be reviewed in Chapter 2.

CHAPTER 2

THE SPATIAL ANALYSIS LITERATURE PERTAINING TO GROWTH CENTRES

"When you can measure what you are speaking about and express it in numbers, you know something about it."

-Lord Kelvin

CHAPTER 2

THE SPATIAL ANALYSIS LITERATURE PERTAINING TO GROWTH CENTRES

Spatial analyses have tended to dominate the growth centre literature since the early 1970's. Such analyses have generally taken the form of applying diffusion theory to growth centres and the directions taken by various authors can be roughly divided into three groups:

(1) Those mainly concerned with the diffusion method of growth from growth centres. Research in this area has tended to dominate that carried out in the other two groups.

(2) Those mainly concerned with time aspects of diffusion from growth centres.

and (3) Those concerned with spread and backwash effects independently.

Each of these groups will now be discussed separately and the main purpose in reviewing them will be to indicate where research has been weakest and where improvements could be made.

2.1 DIFFUSION OF GROWTH FROM GROWTH CENTRES

One of the earliest analyses that mentioned the diffusion of growth away from growth centres was that by Nichols [1969] who studied the spread of growth in Georgia, using per capita income change as a surrogate for growth. A map of the residuals from a regression analysis indicated that higher than usual increases were clustered around the major cities.

Visual inspection of this map suggests that perhaps 40 miles marks the maximum extent of these zones of particularly rapid increases in property. Nichols commented:

> "It is of course difficult to tell whether the disproportionate increase in income around the main centres in Georgia is due to the propulsive influence of Atlanta spreading via the urban network, or whether it is a demonstration of independently generated growth in these towns. The fact, however, that the small towns of the north have demonstrated much faster income growth rates than similar sized towns in the south would seem to suggest that this growth was at least partially attributable to the influence of Atlanta."
>
> -p. 199

Nichols thus raises two points here regarding the diffusion of growth. The first is that growth could be diffused "via the urban network" or hierarchically from higher-ordered centres to lower order centres. The second is that, as Nichols reports for Georgia, "small towns of the north have demonstrated much faster income growth rates than similar sized towns in the south", that is, growth could also be transmitted by a neighbourhood effect, from the larger centres to their environs, in much the same way as in the core-periphery model discussed earlier. These two ideas of growth diffusion-hierarchic and neighbourhood - result from Hägerstrand's original ideas on diffusion in 1953 in which a 2-stage diffusion process was outlined. As Nichols [1969] says:

> "...it seems probable that the propulsive influence of a growth pole[1] is felt in other major towns in the region and in the rural area immediately surrounding the growth pole, and then eventually spreads from these urban centres to the other interstitial rural areas."
>
> -p. 199

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[1]Nichols' use of the word 'pole' is synonomous with the use of the word 'centre' in this paper.

A good distinction between hierarchic and neighbourhood effects of diffusion has been expressed by Cohen [1972, pp. 14-15] as follows:

> "The neighbourhood effect means that.....the closer a potential adoption unit to the source of innovation or to another unit that has already adopted...the greater the probability that it will adopt...The hierarchical effect implies that....the higher the ranking of a potential adoption unit in a Hierarchy, the greater the chance that it will adopt...."

Nichols' evidence of possible hierarchic and neighbourhood effects in operation stimulated various other authors to expand upon theories of growth diffusion from growth centres. Berry [1972], for example, argues that:

> "the development role of growth centres involves the simulataneous *filtering* of the innovations that bring growth down the urban hierarchy and the *spreading* of the benefits accruing from the resulting growth, both nationally from core to hinterland regions and within these regions from their metropolitan centres to the intermetropolitan periphery."
>
> -p. 108

Berry then reviews and amplifies several diffusion models that could be used to test for hierarchic growth and then attempts to identify, by regression analysis on information on the spread of T.V. stations in the U.S., various factors which may be important in describing the diffusion process. For example, he cites such things as the population size of receiving towns, population potential, percentage of workers commuting to the city, etc. as influencing which places growth diffuses to. However, some of the factors he identifies are specific to the spread of T.V. stations and do not apply to growth in general: for example, college towns and towns with lower median incomes were found to be resistant to T.V. station diffusion. From his results, Berry concluded that hierarchical growth occurs first, followed by the spatial diffusion of this growth, though whether this applies to growth, measured in income or population terms, transmitted by growth centres in a regional sense, is not tested but simply implied. However, Berry did postulate four reasons why a hierarchical filtering of growth could be expected from growth centres. These were as follows:

(1) a 'market-searching' process in which an expanding industry exploits market opportunities in a larger-to-smaller sequence.

(2) a "trickle-down" process in which an activity faced with rising wage rates in larger cities moves to smaller cities in search of cheaper labour.

(3) an "imitation" process in which entrepreneurs in smaller centres mimic the actions of those in larger centres, or,

(4) a simple probability mechanism in which the probability of adoption depends upon the chance that a potential entrepreneur residing in a given town will learn of an innovation, a probability which declines with the size of town.

Odland, Casetti and King [1973] attempted to identify hierarchical growth more precisely in a regional sense. From an earlier paper, (see Casetti, King and Odland [1971]), a model was tested for the existence of single or multiple growth centres. z (s,t) was defined as being the intensity of some phenomena z at a location with distance s from the growth centre at time, t, and an expression for z (s,t) was given as follows:

$$z(s,t) = a_0 + a_1 t + a_2 s + a_3 st \qquad (2.1)$$

where a_0, a_1, a_2, a_3 = parameters to be estimated by stepwise regression.

Polarised growth occurs when the conditions:

$$\frac{\partial z}{\partial t} = a_1 + a_3 s > 0 \qquad (2.2)$$

and

$$\frac{\partial^2 z}{\partial t \partial s} = a_3 < 0 \text{ are met.} \qquad (2.3)$$

For example, if z is a measure of income and $\frac{\partial z}{\partial t}$ is positive, then the levels of income are growing over time in the region. If $\frac{\partial^2 z}{\partial t \partial s}$ is negative, then the growth rates of income are highest close to the growth centre and decrease with distance from it. This then indicates a positive polarisation of growth around the growth centre. If the cross-partial derivative, $\frac{\partial^2 z}{\partial t \partial s}$, is positive, this indicates that income growth rates increase with an increase in distance from the growth centre and there is a negative polarisation of growth around the growth centre.

It is interesting to note that if the cross-partial derivative is positive then the centre "pulls up" the periphery and the "strength of the pull" decreases with increasing distance from the centre.[1] An unfortunate corollary regarding the measurement of growth centres in these terms is that the disparities between periphery and centre must, by definition, increase and the periphery can never hope to catch up to the centre.

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[1] for evidence of this, see Jozsa, J.M. [1975] Master's Research Report, McMaster University.

In the later model developed by Odland et al. in 1973, designed to test for hierarchical growth in a multiplicity of growth centres, z was defined simply in terms of t, initially:

$$z(t) = a + bt \tag{2.4}$$

However, the parameters a and b of equation (2.4) were then expanded as linear functions of s_i, where s_i was the distance from an ordinary centre to a growth centre and there were as many distance terms as there were growth centres:

$$a = a_o + a_1 s_1 + a_2 s_2 + ... + a_n s_n \tag{2.5}$$

$$b = b_o + b_1 s_1 + b_2 s_2 + ... + b_n s_n \tag{2.6}$$

Substituting these expressions into (2.4) yields:

$$z(s_1, s_2 .... s_n, t) = a_o + \Sigma a_i s_i + b_o t + t\Sigma b_i s_i \tag{2.7}$$

Again, positive polarisation for any of the n growth centres is confirmed if:

$$\frac{\partial^2 z}{\partial t \partial s_i} = b_i < 0 \tag{2.8}$$

where s_i is the distance to growth centre i.

To test for hierarchical polarisation, for every point in the region, Odland et al. defined k distances, where k is the order of the hierarchy and they let s_j be the distance to the nearest jth order centre. Then each ordinary centre is associated with a set of distances (s_1, s_2 .... s_n) to the k order centres each of which is the nearest centre of its particular order. Hypotheses concerning the propulsive effect of centres of any given order, j, may be tested by using a model expanded in terms of the s_j variable. To effect this, equation (2.4) is expanded in the manner suggested by equations (2.5), (2.6) and (2.7) but with the s variables now indicating distance to the nearest jth order centre.

The method outlined above was used to test for hierarchial polarisation among retail sales in small mid-western towns in the U.S. during the 1948-1967 period. In the first instance, the s_j variable was defined as being the distance to a defined major centre, such as Chicago-Gary, Cincinnati, Columbus, Detroit, Indianapolis or Cleveland. It was hypothesized that growth would be polarised around these very large centres and

$$\frac{\partial^2 z}{\partial s_1 \partial t} \quad \text{would be} < 0$$

Where s_1 is the distance to one of the designated major centres.

Thus growth rates were expected to decline as distance to large centres increased.

In a second instance, the s_j variable was defined to be the distance to the nearest higher order centre: all the centres being ordered into eight size groupings. For this s_j variable it was thought that the larger centres may act as secondary growth centres and exert a positive effect on growth so that:

$$\frac{\partial^2 z}{\partial s_2 \partial t} < 0$$

where s_2 is the distance to the nearest larger centre.

Alternatively, these larger centres may compete for retail sales with smaller centres and act as negative centres. In which case:

$$\frac{\partial^2 z}{\partial s_2 \partial t} > 0$$

That is, as distance increases from these secondary growth centres, growth rates, would increase.

The results for small mid-western towns indicated that growth did take place in the region since $\frac{\partial z}{\partial t}$ was positive. The hypothesis of positive polarised growth with respect to the designated major centres was confirmed, since $\frac{\partial^2 z}{\partial t \partial s_2} = -.00128$

Subregional or local positive polarisation effects were also present since the cross-partial derivative with respect to larger centres was also negative:

$$\frac{\partial^2 z}{\partial t \partial s_2} = -.00137$$

This indicates that growth rates (Odland et al. used retail sales) increased more rapidly in centres which were nearer to the designated major centres of the region and in centres close to sub-regional growth centres. In Odland et al.'s own words, "the example above has provided confirmation of a set of hierarchical spatial-temporal trends in the polarisation of growth."

In using this method, Odland et al. hypothesized that distance to larger centres is an important variable in explaining growth rates. Also they realized that distance to a number of such centres is important. However, where their method is weak is that the populations of larger centres were not considered and so distance to a place of 100,000 population would be treated equally with distance to a place of 1 million population, if both these sizes were included within one group. Thus, instead of simply defining growth rates as a function of distance to a higher order centre, growth rates should be related to some function of the population of a larger centre and the distance to that centre. The paper by Odland et al. is also unclear about differentiating between neighbourhood and hierarchical effects and sometimes the two appear confused. Both neighbourhood and hierarchical diffusion are proven in the article but it is not mentioned which is dominant.

Although several authors, such as those mentioned above, have favoured both hierarchic and neighbourhood growth and have attempted to explain growth in terms of a central place structure, some authors have not. Moseley [1974], for instance, states that central place theory, being essentially static, cannot explain something which is as obviously dynamic as growth:

> "Traditional theories of the location of central places and of industry sought to explain the spatial patterns of service and manufacturing activity respectively but in an essentially static context. While central place theory elegantly explains the typical spacing, size and hierarchy of settlements, it says little about how the system is likely to react to the onset of further development initially taking place in only one or a few of these settlements. And not only is it not dynamic, but by assuming in a very deterministic way that all localised decisions made by the firms concerned are designed to maximise profits, and that all businessmen are fully informed and rational in their decision-making, it abstracts from reality to a degree which further reduces it value for studies of the process of development."
>
> -p. 6

Moseley's empirical work, the year ëarlier, 1973, had shown that in Brittany, France, neighbourhood diffusion seemed to be dominant over hierarchical diffusion. The proximity to Rennes was shown to be the main determinant of the level of development in the region, although other towns of over 25,000 inhabitants "pushed-up" the surface in their vicinity. Moseley concluded that:

> "the possibility of daily journey-to-work to "large" towns is the most important single determinant of the level of prosperity in rural areas."
> -p. 131

It is useful to note here that Casetti [1973] proposed a similar model to Odland et al. [1973], but with some refinements, which could test for neighbourhood diffusion of growth over space and time. He defined D (s) as being the intensity of some phenomena at distance s from a centre, and it was assumed to be greater than 0. An estimation of D (s) was then given by such a quadratic exponential as suggested by Newling [1969]:

$$D(s) = \exp(a + bs + cs^2) \tag{2.9}$$

where a, b, c are parameters to be estimated.

This can be expanded as a function of time if time series data is available by using the following polynomial expansion:

$$a = a_o + a_1 t \tag{2.10}$$

$$b = b_o + b_1 t \tag{2.11}$$

$$c = c_o + c_1 t \tag{2.12}$$

By substituting (2.10), (2.11) and (2.12) into (2.9) the following is obtained:

$$D(s,t) = \exp(a_0 + a_1 t + b_0 s + b_1 st + c_0 s^2 + c_1 s^2 t) \quad (2.13)$$

Casetti originally proposed that D was density of population from a centre but if a dependent variable such as income/person; number of jobs per person or population growth rate was used, then this function could test the hypothesis that the dependent variable will generally be larger closer to a growth centre, and will decline with distance.

Thus, there appear to be some basic difference of opinion in the existing literature as to whether growth is diffused hierarchically or by a neighbourhood effect, or by a mixture of both methods, away from growth centres. If both methods are occurring which one is dominant and to what extent is one dominant over the other? No models, reviewed by this author, have so far satisfactorily tested for both diffusion methods and many models seem to ignore the population size of the sending centre. Distance from a receiving centre to a sending centre, which is a commonly used variable in explaining diffusion, should be "weighted" by some function of the population size of the sending centre because the population size of the sending centre is likely to determine the speed and spatial extent of impulse from it. Also, most present models have not fully explained the effect of the population size of receiving centres upon their growth rates and there appears to be some differences of opinion on this topic. By means of the model outlined in Chapter 3 it is hoped to clarify many of the above points.

2.2 TIME ASPECTS OF GROWTH DIFFUSION

Although time is not treated in the analysis given in Chapter 3, it is expedient to mention here two studies which have dealt with the time aspect of growth diffusion. Such an aspect is important in practical terms because it would be of obvious benefit to know when regional growth policies are going to become effective. It could be, for example, that a newly established growth centre emits predominantly backwash effects at first before spread effects become dominant. Obviously, one would like to know the time period that elapses before spread effects do become dominant.

An early model which investigated the time aspect of growth diffusion explicitly was given in a paper by Casetti, King & Williams [1972] in which they were concerned with identifying and measuring modalities and relevant parameters of the spatial spread of economic growth, particularly its speed. Basically, their method was to add a spatial dimension to the following aspatial model of income growth over time:

$$Y(t) = \exp(a + bt) + v \quad b,v > 0 \qquad (2.14)$$

where y(t) is income per capita at time t and is taken as a surrogate for growth. a, b, v, are parameters.

Equation (2.14) indicates that income per capita has a base level of v and increases exponentially with time above this base level: y tends to an asymptotic low level of v as $t \to -\infty$. The parameter b measures the rate of increases of y over time: the larger is b, the faster the growth of y over time. The parameter, a, simply positions the y curve on the time axis.

If s is the distance from the origins then equation (2.14) can be expanded by redefining its coefficients a and b as linear functions of s:

$$a = a_o + a_1 s \qquad (2.15)$$

$$b = b_o + b_1 s \qquad (2.16)$$

Substituting equations (2.15) and (2.16) into (2.14) yields a model in which income per capita is a function of its spatial temporal coordinates:

$$y(s,t) = v + \exp(a_o + a_1 s + b_o t + b_1 st) \qquad (2.17)$$

For appropriate values of its parameters, equation (2.17) represents the outward spatial spread from an origin. As an example, Casetti, King & Williams set y equal to a given constant level, h, and then replaced h for y in equation (2.17) to give:

$$H = a_o + a_1 s_h + b_o t + b_1 s_h t \qquad (2.18)$$

where $H = \log_n(h-v)$

The speed of the spread of economic growth, $\frac{\partial s_h}{\partial t}$, may be obtained by taking the implicit derivative of s_h in equation (2.18) with respect to t and solving. Thus,

$$\frac{\partial s_h}{\partial t} = \frac{(-b_o - b_1 s_h)}{(a_1 + b_1 t)} \qquad (2.19)$$

Solving equation (2.18) for s_h and substituting into (2.19) gives:

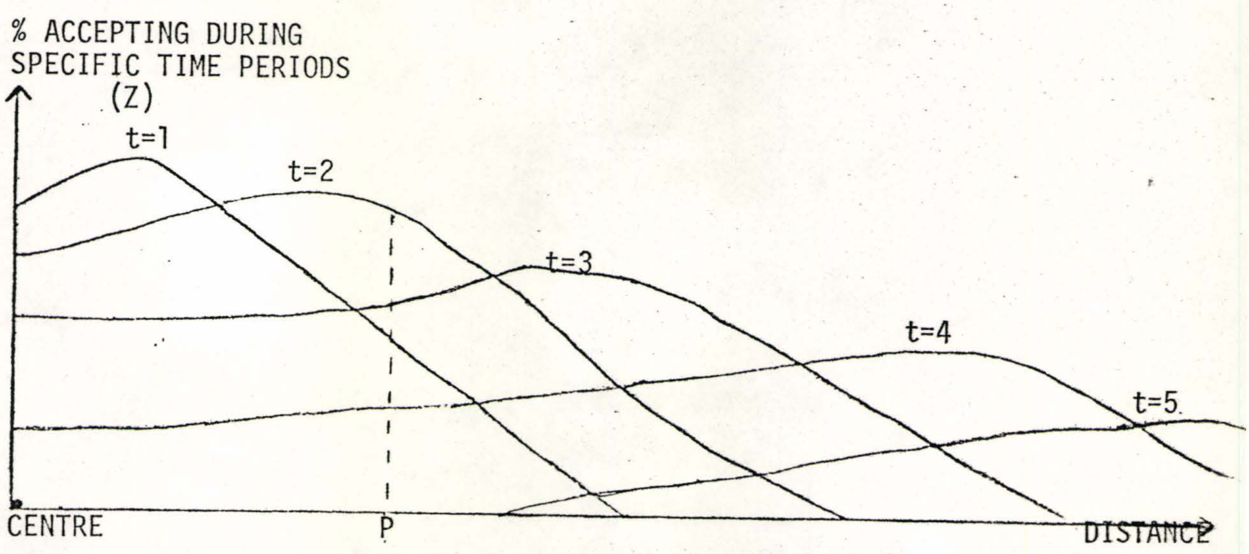
$$\frac{\partial s_h}{\partial t} = \frac{(a_o b_1 - b_o a_2 - Hb_1)}{(a_1 + b_1 t)^2} \qquad (2.20)$$

This model was tested by Casetti et al. on the speed or economic development into Europe between 1860 and 1913 where the velocity of the spatial spread of economic growth from England into Continental Europe was approximately 21km/year.

The model could be applied to growth centres on a smaller scale, that is, in a regional sense, if time series data is available. By estimating the past speed of growth diffusion one could estimate the future rate for the same centres or one could estimate the time period spread effects would take to diffuse outwords from a new growth centre.

Morrill [1968], relating the diffusion of growth to time, suggested that the eventual spatial distribution of innovation acceptance is the product of a process of innovation adoption in which the zone of maximum acceptance moves progressively away from the origin as time proceeds, until the "wave" eventually peters out. This can be represented by the following diagram:

Diagram 3



Morrill's model is closely related to the ideas mentioned earlier regarding hierarchic and neighbourhood diffusion. At time t=1, for example, Morrill's "wave" can be represented by one growth centre diffusing growth via a neighbourhood effect to its environs. At time t=2, growth has been diffused hierarchically to surrounding large centres that also transmit growth to their environs and hence there is a peak of acceptance at the distance these centres are away from the main centre.

Hanham and Brown [1976] attempted to put Morrill's ideas into more precise mathematical terms and they presented the following model to investigate how growth can diffuse outwards from several growth centres in waves:

$$A(s_1, s_2 \ldots . s_n) = \exp - (\alpha + \sum_{i=1}^{n} \beta_i s_i) \qquad (2.21)$$

where A represents the proportion of the population of potential adopters located at distance s_1, s_2, ... s_n away from n centres who have adopted an innovation during time period t. s_i is the distance from the location in which adoption is taking place to diffusion centre i. α and β are parameters.

This model was expanded to include time by expressing α and β as quadratic functions of time and then substituting back into the original equation to give:

$$A(s_1, s_2 \ldots s_n, t) = \exp-[\alpha_0 + \alpha_1 t + \alpha_2 t^2 + \sum_{i=1}^{n} (\beta_{io} + \beta_{i1} t + \beta_{i2} t^2) s_i] \qquad (2.22)$$

From this, Hanham and Brown stated that if spatial diffusion had taken place from a particular centre, i, then,

$$\frac{\partial A}{\partial t} > 0 \quad \text{and} \quad \frac{\partial A}{\partial s_i} < 0$$

Identifying various stages in diffusion with respect to a particular centre was accomplished in the same manner and,

$\frac{\partial^2 A}{\partial s_i \partial t} < 0$ implies a primary stage[1]

$\frac{\partial^2 A}{\partial s_i \partial t} > 0$ implies a diffusion stage[2]

$\frac{\partial^2 A}{\partial s_i \partial t} \lesseqgtr 0$ implies one stage followed by the other.

Using this model, Hanham and Brown were able to show how, in Southern Sweden, the adoption of artificial insemination has spread out in waves from two centres.

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[1] Following Hagerstrand's notation [1952], a primary stage is one in which diffusion centres are established.

[2] A stage characterised by spread into the hinterland of these centres.

Relating this method to Morill's waves of diffusion given in diagram 3, at point P, $\frac{\partial z}{\partial t}$ is positive and $\frac{\partial^2 z}{\partial s \partial t}$ is negative at time t=1. Thus point P is experiencing a primary stage of diffusion at this point in time. At time t=3, however, $\frac{\partial z}{\partial t}$ is negative and $\frac{\partial^2 z}{\partial s \partial t}$ is positive, indicating point P is then experiencing a diffusion stage. In Morill's diagram, at any one point in time, any place "in front of" the crest of a wave would be experiencing backwash effects (that is, $\frac{\partial^2 z}{\partial s \partial t} < 0$) while any place "behind" the crest of the wave would be experiencing spread effects (that is, $\frac{\partial^2 z}{\partial s \partial t} > 0$). It is again interesting to note that under this hypothesis the centre must always be dominant over the periphery. As each innovation disperses outwards from the centre, the periphery can never hope to be ahead of the centre.

Thus, this brief section on the time aspects of growth diffusion has raised some interesting points. Morill's ideas, in particular, proven to a limited extent by Hanham and Brown, could be very useful if they apply to the diffusion of growth from growth centres. In policy terms, it could mean that growth centres produce predominantly backwash effects in their initial stages, except for a small annulus around the centre itself, while after successive time periods spread effects become dominant. At what time period this transition occurs, or in fact whether it does, has not been adequately investigated. How the results of the diffusion of artificial insemination can be applied to the general diffusion of growth in the space economy is also not clear. It is very important to note the difference between diffusion of one item where there are clear adopters and the diffusion of growth which is difficult to define. How far can one say that a place has suddenly adopted "growth"?

Although as previously mentioned, the analysis to be presented in Chapter 3 in this paper does not include a time variable, this could be included fairly easily by expanding the parameters in terms of time, if further research is undertaken in this area.

The concluding section in this chapter on the spatial analysis literature pertaining to growth centres is concerned with the diffusion of spread and backwash effects and is primarily concerned with the work of Richardson [1976].

2.3 THE DIFFUSION OF SPREAD AND BACKWASH EFFECTS

In chapter 1 it was mentioned that Myrdal and Hirschman both conceptualised spread and backwash effects at approximately the same time. However, neither author was very specific in the identification and quantification of these effects. Their models were devoid of explicitly spatial content although they did make some general observations on changes in spread and backwash during the course of development (implicit time). Myrdal held that backwash effects predominate and indeed may intensify due to cumulative causation forces, though he conceded that they might weaken in the later phases of development. Hirschman, on the other hand, argued that net backwash usually gives way to net spread at some time, perhaps reinforced by regional economic policies.

Richardson [1976] attempted to express these thoughts in a more mathematical way and tried to discover more specific aspects concerning the diffusion of spread and backwash effect, mainly related to time. He expressed the distance decay effect of spread and backwash via a negative exponential function, analagous to those used in density gradient analysis:

$$s_d = s_o e^{-u_1 d} \tag{2.23}$$

and

$$b_d = b_o e^{-u_2 d} \tag{2.24}$$

where s_o and b_o represent spread and backwash at the pole itself: d is distance and u_1, u_2 are distance decay coefficients.

Richardson reasoned that if the diffusion of spread over space can be represented in terms of the intensity of spread at the pole (s_o), and if s_o can be expressed as a function of time, then it is possible to measure spread over space and through time:

$$s_{o_t} = k\ (1 + ae^{-ct})^{-1} \tag{2.25}$$

where $s_{o_{t_o}} = k/(1 + a) \geq 0$

Similarly, backwash can be represented as a quadratic function of time:

$$b_{o_t} = x_o + x_1 t - x_2 t^2 \qquad (2.26)$$

where $b_{o_{t_o}} = x_o \geq 0$

Net spillover effects, g, can then be obtained by substracting backwash from spread, and can be expressed at a point in space and an interval of time, as:

$$g_{dt} = s_{dt} - b_{dt} \qquad (2.27)$$

Substituting (2.25) and (2.26) into (2.23) and (2.24), and (2.23) and (2.24) into (2.27) gives:

$$g_{dt} = k(1 + ae^{-ct})^{-1}e^{-u_1 d} - (x_o + x_1 t - x_2 t^2)e^{-u_2 d} \qquad (2.28)$$

Equation (2.28) indicates that as t increases, so does g_{dt}. When t is low, that is, at early time periods, then backwash effects will dominate and g_{dt} will be negative. As t increases, g_{dt} will become positive indicating that spread effects will be dominant.

will be dominant. This is an interesting result because as Richardson concludes:

> "The analysis suggests that a well-located growth pole[1], promoted with vigor in appropriate economic conditions and resistant to political trimming, should pay off as a regional policy investment if the planning horizon is long enough".
>
> -p. 7

Richardson's approach in trying to identify spread and backwash effects as seperate entities is enlightening. However, his analysis falls short because of his poor treatment of space and he makes only a small mention of the extent of spread and backwash effects. How far they emanate from the growth centre is undefined. Also as Richardson himself, comments, the time aspect of his model can be improved upon:

> "...the net spillover function (g) is obtained by subtraction of the b [backwash] from the s [spread] function. The precise time path of g depends not only upon the general shape of s and b but on their slopes at different phases of time. These are hard to determine exactly".
>
> -p. 4

Thus, although Richardson's analysis is useful, it could be improved upon, to some extent, by concentrating on space more. What is perhaps needed is a model which can identify the spatial extent of spread effects from a growth centre. This extent will be the point at which backwash effects equal spread effects and the system will be in equilibrium. Such a model will be presented in Chapter 4, following the analysis of growth centre impacts in Ontario now presented in Chapter 3.

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[1] "pole" is synonomous with "centre" here. It is interesting to note that this basic misconception has still carried on to the most recent literature.

CHAPTER 3

AN ANALYSIS OF GROWTH CENTRE IMPACTS

"The shortest distance between two points is approximately seven inches".
-Ephraim Ketchall

CHAPTER 3

AN ANALYSIS OF GROWTH CENTRE IMPACTS

From the review of the growth centre literature given in Chapters 1 and 2, several aspects of growth centre analysis would appear to be uncertain or unfounded or untested. The most relevant points which need further testing would seem to lie in the following four areas:

(1) The transmission of growth from growth centres. More specifically, are hierarchical effects or neighbourhood effects dominant? What is the relationship between distance to growth centres and growth rates? Does this relationship change for different size categories of receiving centres?

(2) The spatial extent of growth centre impacts, especially the spatial extent of spread effects. How close to growth centres on average does an ordinary centre have to be in order to receive spread effects?

(3) The relationship between the size of the receiving centres and the spatial extent of spread effects. Does the distance from a growth centre at which spread effects equal backwash effects vary with the size of the receiving centre?

(4) The relationship between the size of the receiving centres and their growth rates. Do smaller centres have lower rates of

growth than larger centres or vice versa?

The points raised above will be investigated by using the model presented in this chapter. It will be assumed that the region in which the model is tested has several growth centres - a different approach to many of the previous growth centre analysts who have used the simplifying assumption that regions only have one growth centre. Thus, from this analysis, growth centre impacts from a number of growth centres can be tested. It will also be shown that the model can be used as a method to identify growth centres, or, more exactly, to identify those centres which are not true growth centres.

3.1 THE MODEL

Early empirical studies on diffusion such as Bowers [1937], McVoy [1940], Crain [1966] and Berry and Neils [1969] have indicated that both urban size and distance from earlier adopters are important factors in explaining the diffusion of innovations. In similar fashion one of the basic aims of the model presented here is to relate diffusion to accessibili and population size. However, in this case, it is the diffusion of growth that will be of concern and not the diffusion of specific innovations, and the distance measures will be formulated as accessibility measures because a multi-growth centre region is assumed and hence there is more than one distance to an early adopter. A basic measure of accessibility was derived as follows:

$$A_i = \sum_{j=1}^{N} P_j d_{ij}^{-\gamma} \quad (3.1)$$

and from this, γ was set at ½ and 3 to give two separate accessibility measures:

$$A_i^1 = \sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}} \quad (3.2)$$

and,

$$A_i^2 = \sum_{j=1}^{N} P_j d_{ij}^{-3} \quad (3.3)$$

where A is the accessibility of an ordinary centre, i: P_j is the population of a growth centre, j: and d_{ij} is the distance from ordinary centre i to growth centre j. By summing $P_j d_{ij}$ over the total number, N, of growth centres in the region, a measure of accessibility is given for an ordinary centre to each growth centre weighted by the population of the growth centre. Distance to a larger growth centre will then be a more important contributing variable to the measure of accessibility than will be distance to a smaller growth centre. This seems to be a reasonable representation of reality.

The accessibility measures are thus of 'gravity-model type', which, although fairly simple, have been shown to be accurate estimators of flows. Pedersen [1971], for example, has suggested that the flow of information is likely to accord closely to the gravity model with the exchange of information between two towns depending upon their size and spacing and, as Berry [1972] notes, Wilson [1967] has given justification for the gravity model. A similar justification for using the gravity model to describe growth diffusion is given in Appendix I.

The reason why two accessibility functions were included in the model is that by comparing the order of entry and significance values of both functions from a stepwise multiple regression, more information can be gained as to the role of distance in explaining growth rates. Also the significance of hierachic and neighbourhood diffusion can be compared. The accessibility measure given in equation (3.2), where distance is to the power of $-\frac{1}{2}$, can be taken as a surrogate for hierarchical growth since accessibility decreases only slowly with increasing distance. In equation (3.3), where distance is to the power of -3, the accessibility measure can be taken as a surrogate for neighbourhood diffusion since accessibility decreases rapidly with increasing distance. To demonstrate the different potential explanatory roles played by both of these variables, a simulation of each accessibility function was produced. A computer program was devised (see Appendix II) to produce both accessibility measures for every square in a 54 x 35 grid matrix placed upon a map of Ontario and from this, isoline maps were drawn indicating lines of equal accessibility in Ontario. Accessibility was measured as a function of distance to, and population, of, eleven designated growth centres.[1] The simulation maps are reproduced in Figures 1 and 2.

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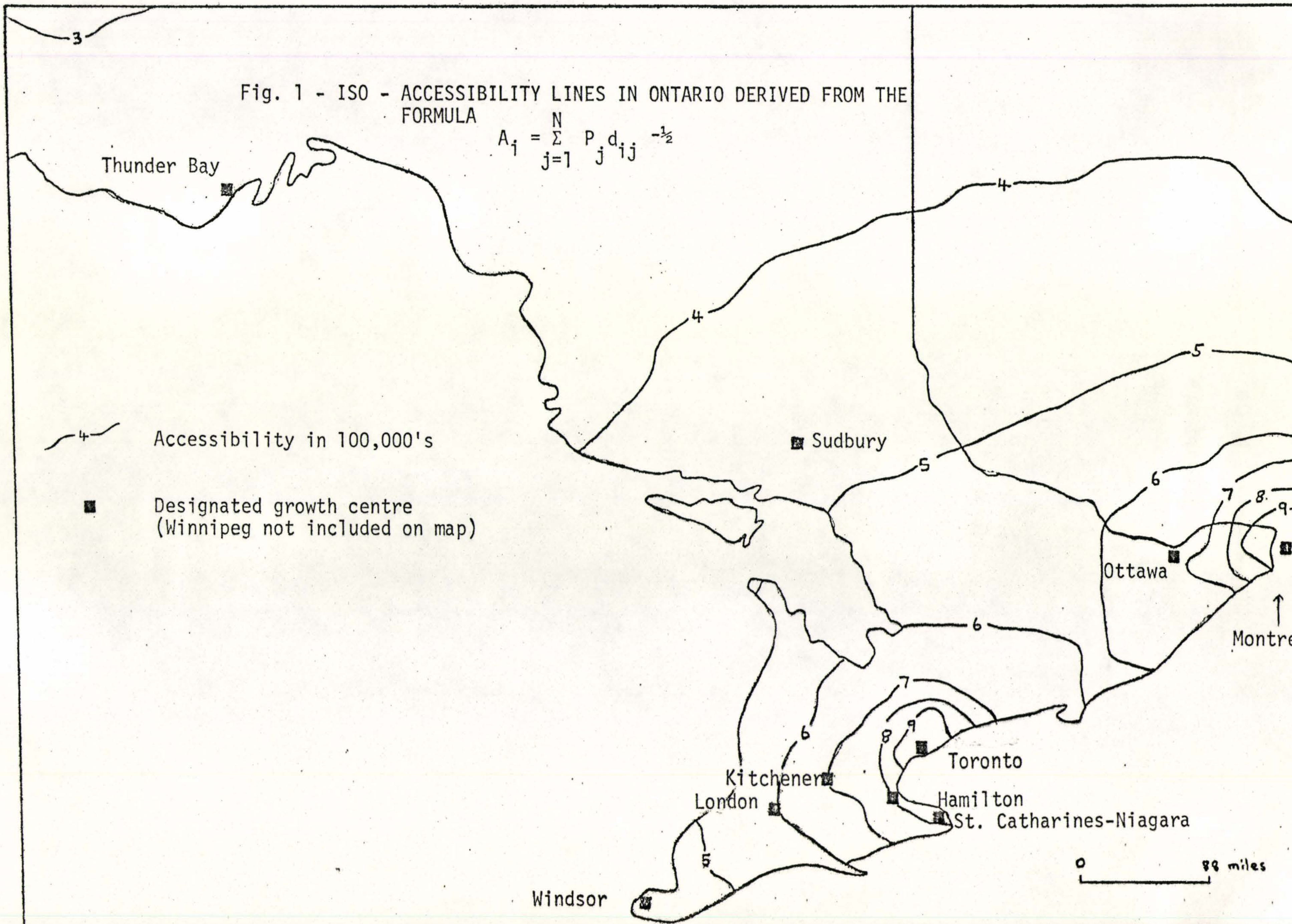
[1] How these centres were chosen is described in section 3.2. A list of the 11 centres, plus their populations, is given in Table 1.

Fig. 1 - ISO - ACCESSIBILITY LINES IN ONTARIO DERIVED FROM THE FORMULA

$$A_i = \sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$$



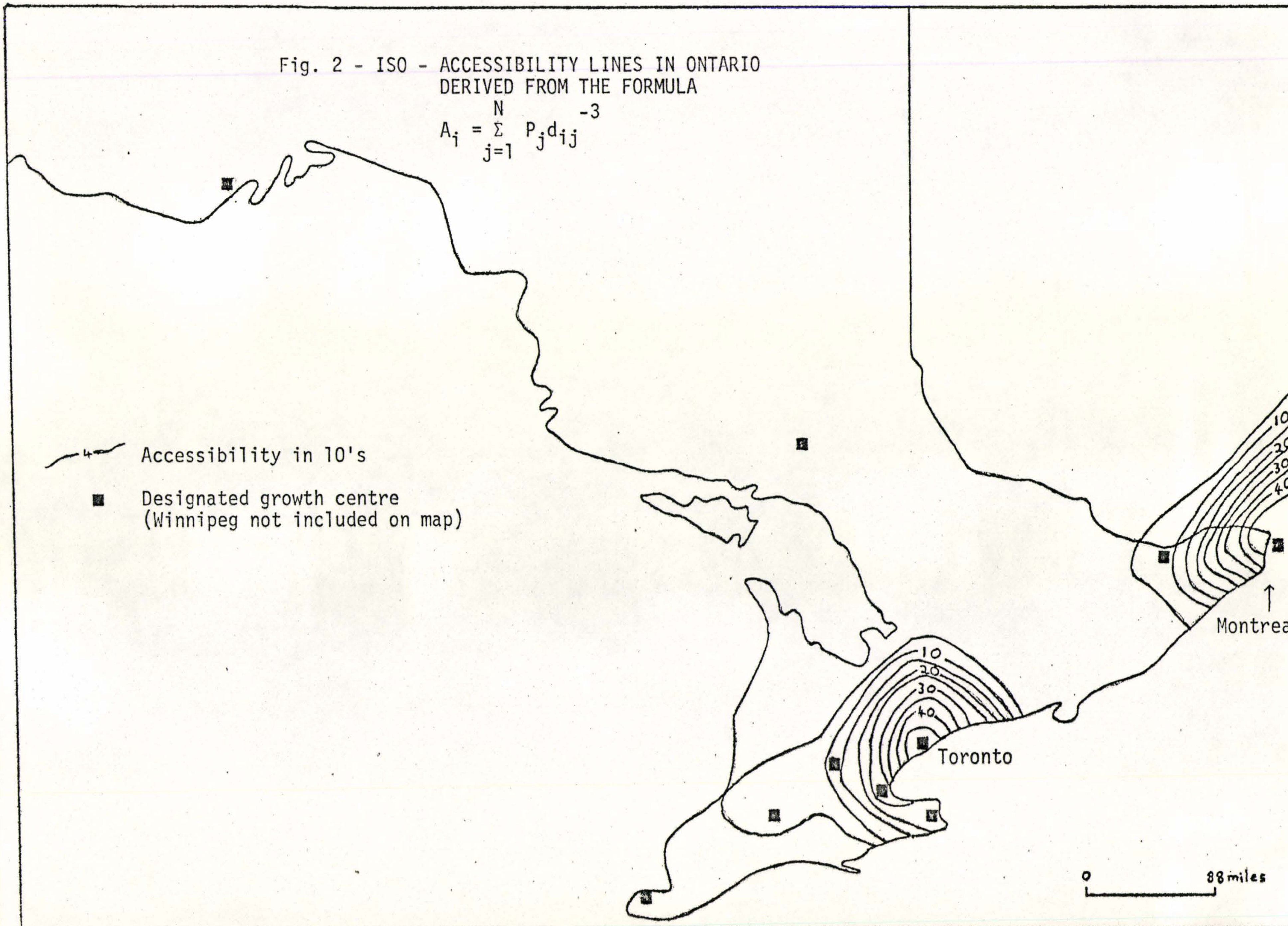


Fig. 2 - ISO - ACCESSIBILITY LINES IN ONTARIO
DERIVED FROM THE FORMULA

$$A_i = \sum_{j=1}^{N} P_j d_{ij}^{-3}$$

Figure 1 indicates lines of equal accessibility derived from the function:

$$A_i = \sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$$

The isolines are spaced well apart indicating that accessibility declines gradually with distance from growth centres. Figure 2 indicates lines of equal accessibility derived from the measure:

$$A_i = \sum_{j=1}^{N} P_j d_{ij}^{-3}$$

and here distance from growth centres is much more important in determining accessibility (being to the power of negative 3) and accessibility declines sharply with distance from growth centres. The maps can be compared since each line represents a tenth of the highest accessibility figure. In both cases, the points of highest accessibility are centered upon Toronto and Montreal and accessibility generally decreases with distance from these centres.[1]

A brief note can be mentioned about the role of the two measures in indicating how growth is diffused. If growth diffusion is more closely related to Figure 1 than to Figure 2, then it would be assumed that distance is a less important explanatory variable of growth diffusion

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[1]Accessibility actually goes to positive infinity at each growth centre because the distance to that growth centre is obviously 0 and hence deriving the accessibility measure for each growth centre involves dividing by 0. These accessibility figures are not shown on Figures 1 and 2.

than if diffusion was more closely related to Figure 2. Hence, growth rates would be expected to decline only gradually as distance to growth centres increases and a hierarchical effect of diffusion may be present as well as a neighbourhood effect. However, if growth diffusion is more closely related to Figure 2, then it would be assumed that distance is a very important contribution variable in explaining diffusion. Growth rates would be expected to decline rapidly as distance to growth centres increases and hence a neighbourhood diffusion effect would be dominant. The size of the receiving centres would be relatively unimportant in explaining growth. One way to see this is to refer back to the equation (3.2) and (3.3). If all distances from a given ordinary centre to all growth centres increased in identical proportions, then the exponent in the accessibility function would be the elasticity of accessibility with repect to distance . Thus the elasticity of accessibility with respect to distance is $-\frac{1}{2}$ in the case of equation (3.2) and -3 in the case of equation (3.3).

Although it is not shown on Figure 2, accessibility decreased very sharply from growth centres such as Thunder Bay, Windsor and Sudbury. The local peaks of accessibility around these centres are not shown on the map because the highest values did not reach '50' which was the minimum iso-accessibility line.

The third independent variable used in the model was that of the population size of the receiving centre. From this it was hoped to gain more information upon which population size categories of centres were growing most rapidly. Also if hierarchical growth diffusion was taking place without neighbourhood diffusion, then the population size of the receiving centre would obviously be an important explanatory variable of growth rates. Thus the form of the final model was as follows:

$$\hat{r}_i = \alpha + \beta_1 \sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}} + \beta_2 \sum_{j=1}^{N} P_j d_{ij}^{-3} + \beta_3 P_i \qquad (3.4)$$

where, $\hat{r}_i$ and P_i are the estimated rate of growth and population size of ordinary centre, i, respectively. α, β_1,β_2 and β_3 are parameters to be estimated by stepwise multiple regression.

The model as presented in equation (3.4) will be useful for the following purposes:

(1) to see which factors are significant in explaining growth rates.

(2) to compare the significance of the independent variables, especially the two accessibility measures, in order to make conclusions regarding the rates of growth diffusion.

(3) to investigate how relevant is the population size of a receiving centre in explaining its rate of growth.

(4) to see if the growth centres assumed in the analysis are in fact true growth centres.

(5) By an analysis of the residuals from the model, further variables which may explain growth rates can be deduced. In terms of public policies, areas of lower than average and higher than average growth rates can be analysed in order to see why such growth rates occur in certain areas.

(6) By manipulating the equation, one can determine the distances from growth centres where growth rates have average values and hence make comments on the spatial extent of growth centre impacts.

3.2 TEST DATA

Before the results of the model can be described it is useful to mention details of the data used in testing the model.

Eleven centres were designated as being growth centres for the Province of Ontario. Nine of these centres were actually in Ontario and these were all the centres with a population of greater than 100,000in 1966. The two other centres hypothesized to be promoting growth in Ontario were Winnipeg, because of its close connections with towns in North-Western Ontario, and Montreal which because of its size and the fact that it is located only 15 miles from Ontario's eastern border, was hypothesized to affect growth rates in Eastern Ontario. The population of all the growth centres in 1966 was obtained from the 1971 Census of Canada and this information formed the "P_j" variable in the regression model. A list of all eleven designated growth centres and their 1966 populations appears in Table 1.

Table 1 - Designated growth centres and their 1966 populations.

Growth Centre	Population (1966)[1]
Montreal	2,575,252
Toronto	2,289,900
Winnipeg	525,786
Hamilton	457,410
Ottawa	398,387
St. Catharines-Niagara	285,453
London	253,701
Windsor	238,323
Kitchener	192,275
Sudbury	136,739
Thunder Bay	108,035

[1]Obtained from the Census of Canada, 1971.

The 1971 Census of Canada also yielded data for the "P_i" variable which is the population of the receiving centre in 1966. A receiving centre was defined as any incorporated city, town, village or hamlet that was not already defined as a growth centre. 243 such centres were defined and the population of these centres is given in appendix III.[1]

[1]Centres which had changed their boundaries between 1966 and 1971 were excluded from this analysis unless their population was greater than 25,000 which was thought to be a suitable level at which small boundary changes would no longer greatly affect the population growth rates of these centres - a variable needed for the regression. Also, six centres with exceptionally high growth rates - over 100% - were excluded from this analysis as they would bias the regression equations too much. These centres were generally very small and this is perhaps the reason for their rapid growth rates. Sturgeon Point, for example, one of these centres, had a population of only 16 in 1966.

To calculate the functions:

$$\sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}} \text{ and } \sum_{j=1}^{N} P_j d_{ij}^{-3},$$

the distances from each ordinary centre i, to every growth centre j, had to be found and for ease of computation straight line distances between points were used. Coordinates for each point were read from a digitiser and a 249 x 11 matrix of distances was computed from these coordinates. For each centre i, the distance to a growth centre j, to the power of $-\gamma$ where γ equalled $-\frac{1}{2}$ or 3, was multiplied by the population of j and then the resulting matrix was summed across the rows to give the accessibility functions for each ordinary centre. Both accessibility values for each ordinary centre are given in appendix II.

The independent variables were thus relatively easily defined. The dependent variable, rate of growth, however, posed three main questions. First, if growth is to be intrinsic to the concept, then growth of what? Some writers have meant growth "generally": others have been more specific. Boudeville [1966], Carol [1966] and Tolsa and Reiner [1970] all used the growth of industry; Hodge [1966] and Allen and Hermansen [1968] used the growth of population plus a composit index of growth using such variables as incomes, commercial facilities, economic activity etc.; and Kuehn and Bender [1969] and Casetti, King and Odland [1971] used employment growth. Second, does 'growth' mean absolute increments of growth or growth rates? Quite different spatial patterns are likely to emerge on the basis of this decision. The former will probably accord high growth to the largest regional centres while the latter may accord high growth to certain small towns which have the advantage of growing from a small base. Third, how much growth? If, as usual, growth rates are preferred, then against what base-line are rates compared (regional average, national average or what?).

The second and third questions are relatively easily answered: the first needs some discussion. In this study, growth rates were used as opposed to absolute increases of growth. Absolute increases of growth would be very large for large centres and very small for small centres - making comparison very difficult. Rates of growth are expected to be more equal between centres of differing sizes and hence more useful for comparison purposes.

In answer to the third question, the rates of growth when used in Chapter 4 to identify the extent of spread and backwash effects will be measured against the regional average growth rate for all centres. Places having growth rates above this average will be assumed to be receiving spread effects while those places having lower rates of growth will be assumed to be receiving backwash effects.

Returning to the first question - the growth of what? In this study, growth rates were measured in terms of population and were calculated by the following formula:

$$r_i = \frac{P_{i(t)} - P_{i(t-1)}}{P_{i(t)}} \times 100 \qquad (3.5)$$

where, r_i is the rate of growth at centre i.

$P_{i(t)}$ is the population of centre i at time t,

and $P_{i(t-1)}$ is the population of centre i at time t-1 i.e. a preceeding time period.

t in this case was 1971

t-1 was 1966

Population growth was deemed to be the most useful measure of growth for several reasons:

(1) If a centre's population is growing rapidly then it can be assumed that its economy is also growing rapidly.

(2) Population growth can be considered as a reflection of the composite growth in all other possible indices. For example, if a centre's manufacturing employment increases but its number of commercial facilities declines, then the sum of these actions will be represented by population growth figures.

The growth rates for all i centres are given in Appendix III.

3.3 EMPIRICAL RESULTS

In this section the results of the regression analysis will be stated and a summary table of the main results will be presented. Comments regarding these results will be made in section 3.4.

The model given in equation (3.4) was first run in a multiple regression program using 243 ordinary centres i, and 11 growth centres j. The full equation then became:

$$\hat{r}_i = -12.46932 + .0000342 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .00105932 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.6)$$

where $\hat{r}_i$ is the estimated value of r_i.

The variable, population size of the receiving centre (P_i), was not of sufficient significance for inclusion into the regression. The two accessibility variables were significant for inclusion into the regression with significance values of < .001.[1] The order of entry

---

[1] The significance value represents the probability that the sample was drawn from a population where $\beta=0$ i.e. the variable would not be of any explanatory value. The significance is derived from the following F ratio:

$$F = \frac{\sum_i (\hat{r}_i - \bar{r}_i)^2/1}{\sum_i (r_i - \hat{r}_i)^2/N-2}$$

where $\hat{r}_i$ is the fitted r-value, r_i is the true r-value and $\bar{r}_i$ is the mean of r_i. 1 and N-1 are the degrees of freedom.

The closer is the significance value of a coefficient to 0, the "better" is the explanatory power of the term that the coefficient describes. In terms of the F ratio, the larger is its value, the larger is the "explained" sum-of-squared deviations from the mean relative to the sum-of squared deviations of the true values from the fitted values. Thus a large F value and consequently a small significance value, means that the observed values were unlikely to have come from a statistical population in which $\beta=0$.

into the regressions, which can be taken as a measure of the order of importance of the variables, was that the accessibility variable, $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$, was entered first and $\sum_{j=1}^{11} P_j d_{ij}^{-3}$ was entered second.

In a separate program, the rates of growth for all centres were plotted against each of the independent variables in equation (3.4) to see if anything could be discerned about the nature of the relationships that was not given by the regression coefficients. An extra plot was computed for rates of growth against population size for those centres below 10,000 population because these centres were virtually undifferentiated on the earlier plot containing centres of all population sizes. These plots are given in Figures 3 through 6.

Figures 3 and 4 indicate that as the accessibility of an ordinary centre to all growth centres increases, the rate of growth of that centre increases and thus the highest rates of growth could be expected in those centres very close to growth centres. This indicates that growth is polarised around the growth centres chosen. The plot of the accessibility index, $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$, against growth rates (Figure 3) shows this fact more clearly than the accessibility index, $\sum_{j=1}^{11} P_j d_{ij}^{-3}$: the latter producing a large number of centres with virtually zero accessibility due to the importance of the distance factor.

Figure 5, which shows the plot of the rate of growth of a receiving centre against its population, is interesting. There appears to be a marked division at about a population of 10,000, where centres with larger populations than this figure appear to have higher growth rates with larger populations, that is, the relationship is positive.

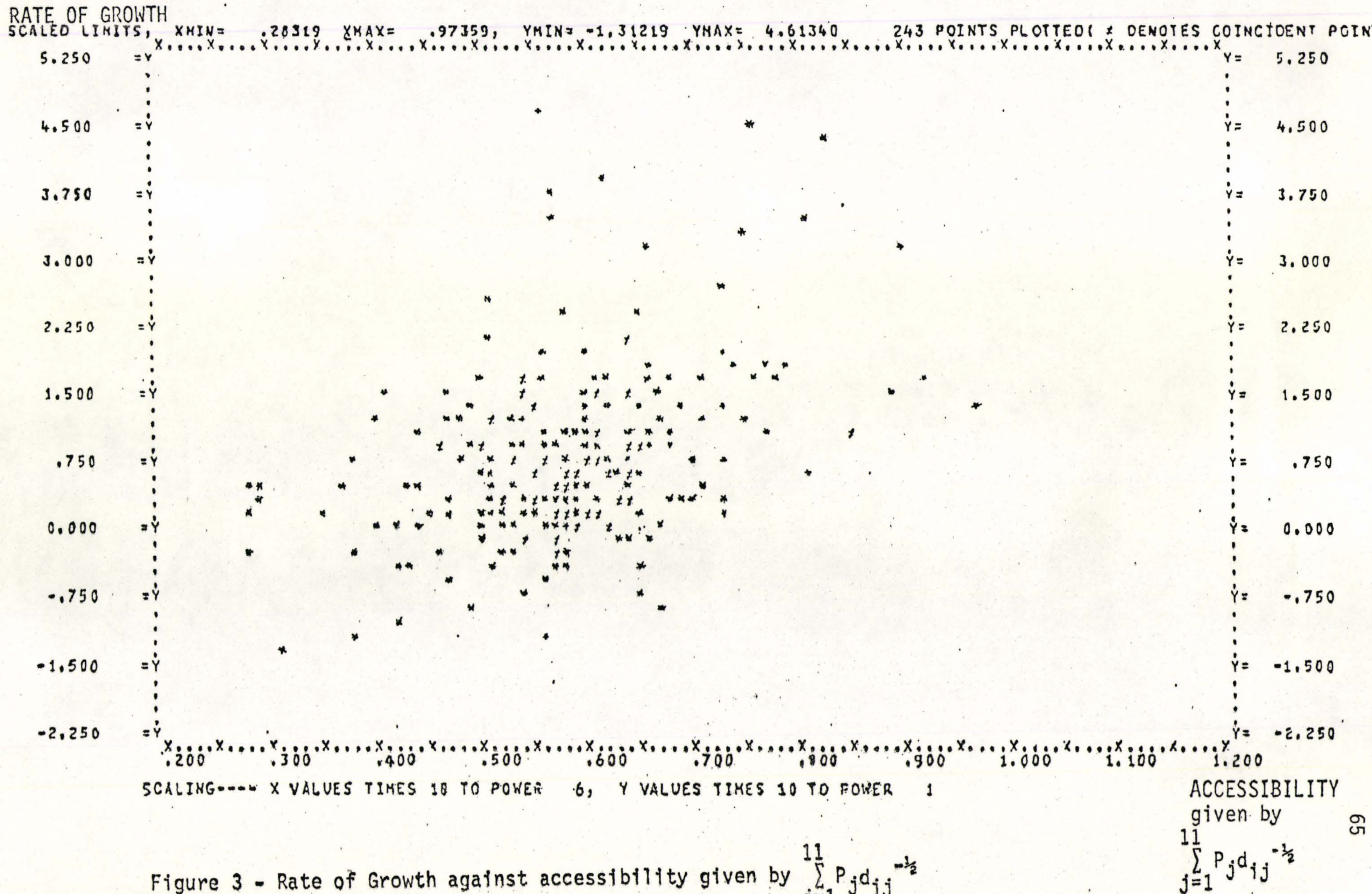


Figure 3 - Rate of Growth against accessibility given by $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$

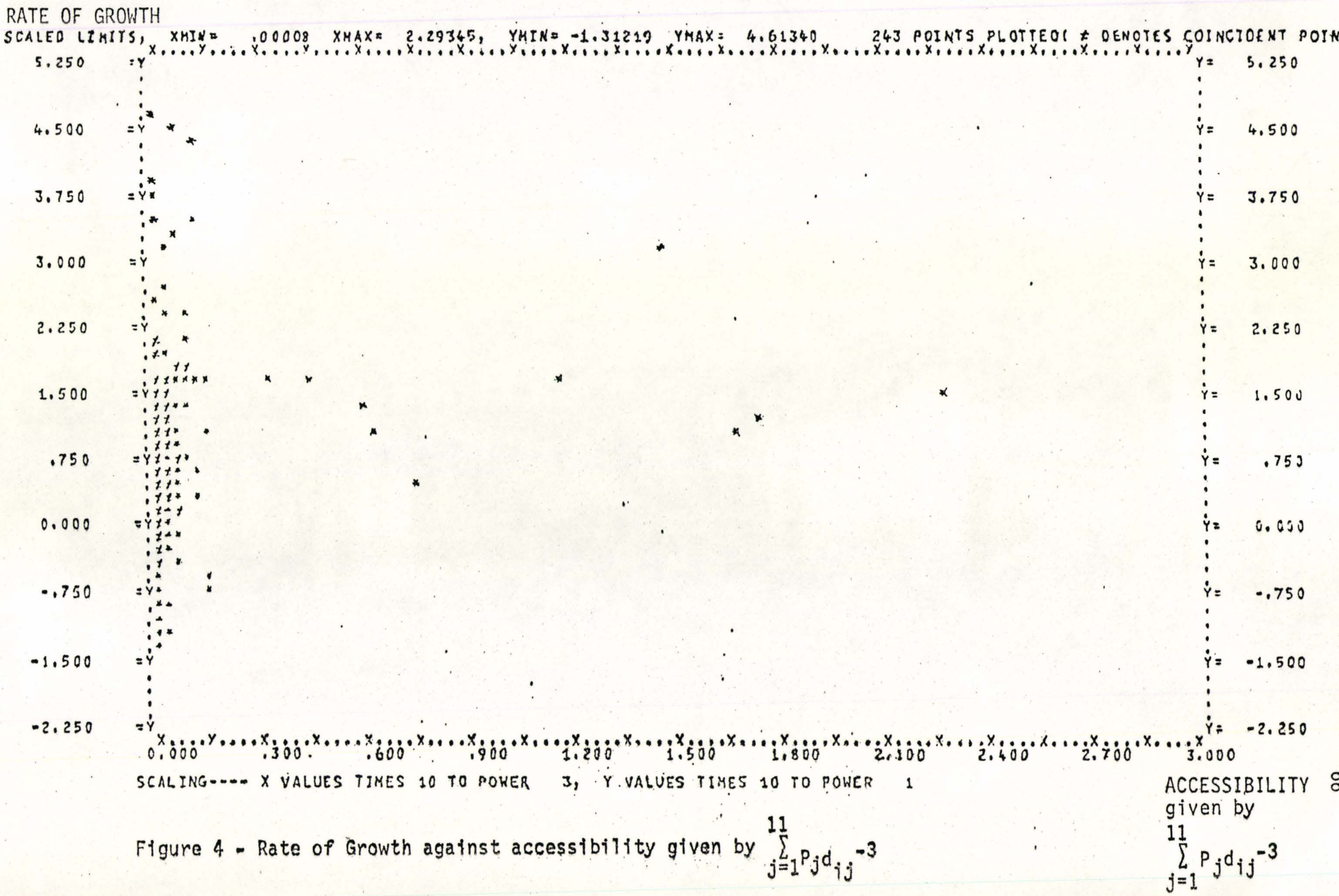


Figure 4 - Rate of Growth against accessibility given by $\sum_{j=1}^{11} P_j d_{ij}^{-3}$

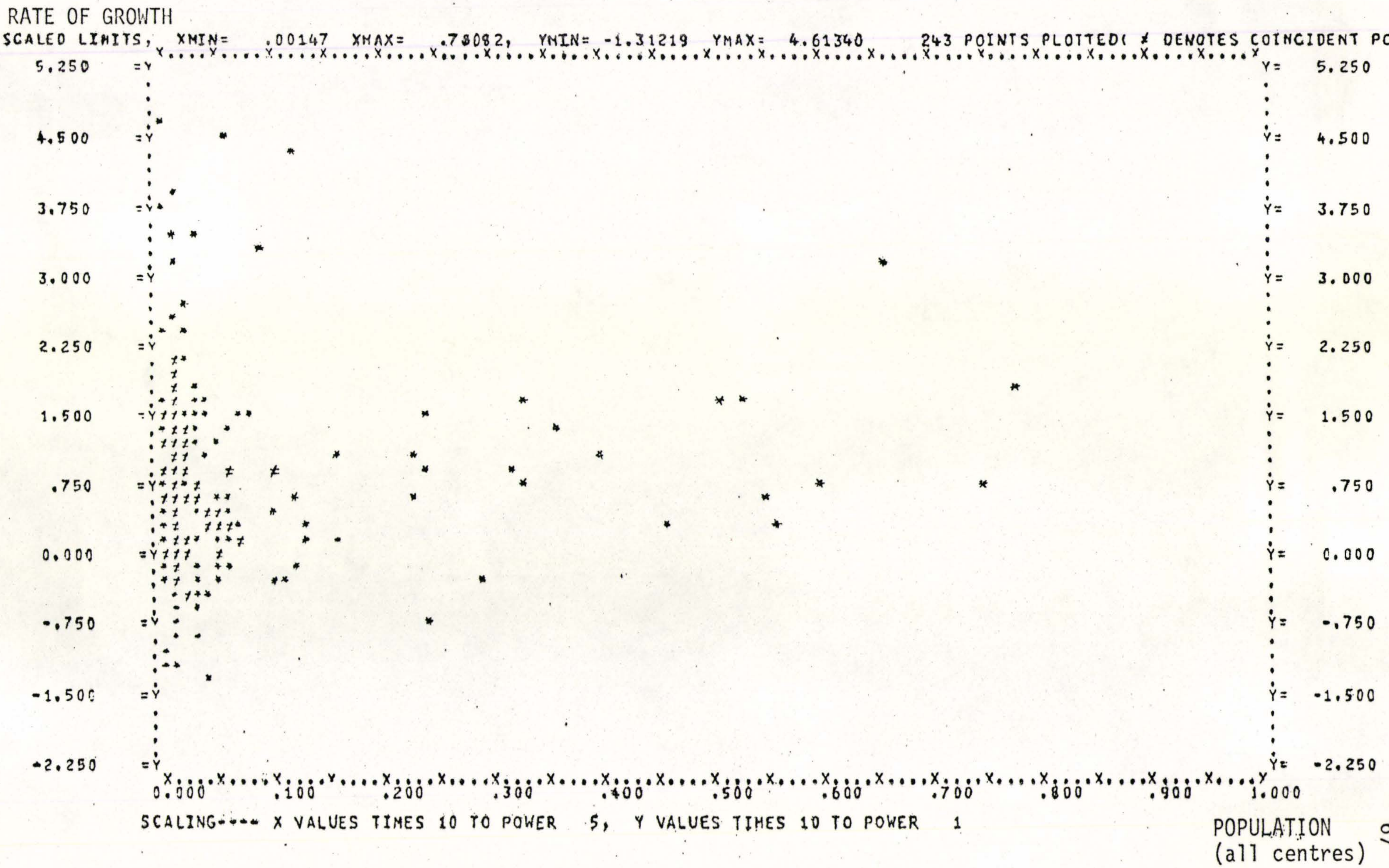
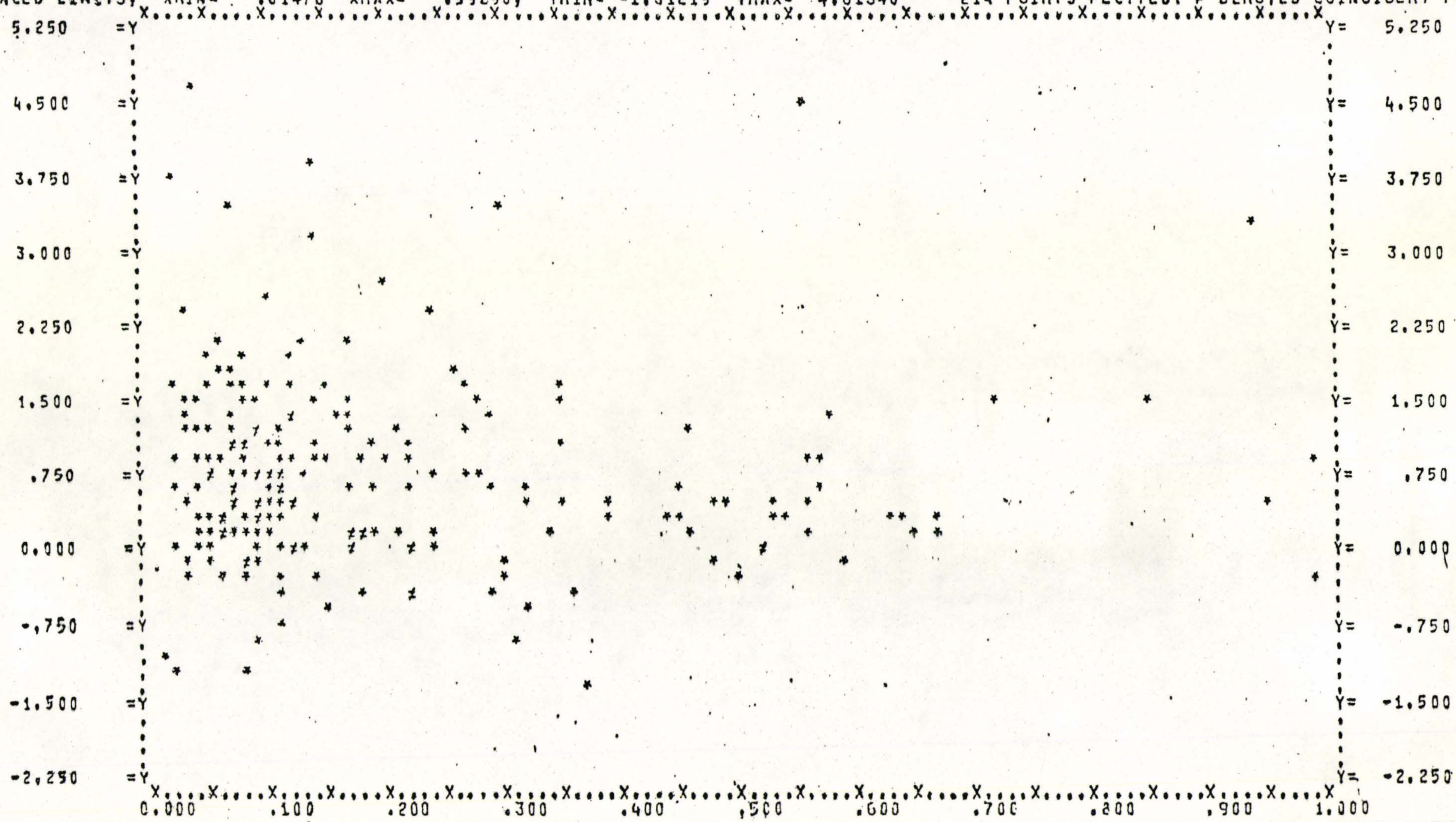


Figure 5 - Rate of Growth against Population for all centres

RATE OF GROWTH

SCALED LIMITS, XMIN= .01470 XMAX= .99290, YMIN= -1.31219 YMAX= 4.61340 214 POINTS PLOTTED(≠ DENOTES COINCIDENT POINTS



SCALING---- X VALUES TIMES 10 TO POWER 4, Y VALUES TIMES 10 TO POWER 1

POPULATION SIZE (for centres below 10,000)

Figure 6 - Rate of Growth against Population for centres of less than 10,000

Centres with less than 10,000 population, however, as shown by Figure 6, which is a plot of rates of growth against population size for centres below 10,000, appear to have lower rates of growth as the figure of 10,000 population is reached. The relationship can be shown schematically as follows:

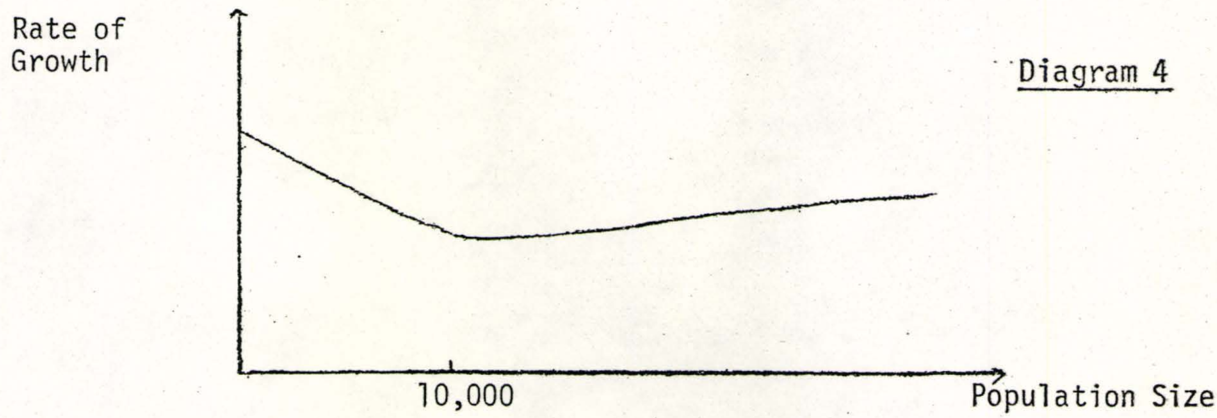


Diagram 4

Because of this apparent dichotomy of relationships, it was decided to disaggregate the data by population size class and run the model for each data set. Thus the receiving centres were divided into the following 3 categories:

(i) centres below 1,000 population.

(ii) centres between 1,000 and 10,000 population

(iii) centres above 10,000 population.

The regression equations derived from using these data sets were as follows:[1]

---

[1]The order of the independent variables given in each of equations (3.7)-(3.9 is equal to their order of entry into the stepwise regression.

For 83 small centres (below 1,000 population):

$$\hat{r}_i^S = -7.5623 + .00003657 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} - .0104181 P_i + .0469 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.7)$$

For 131 intermediate centres (between 1,000 and 10,000 population):

$$\hat{r}_i^I = -11.8937 + .00003322 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .00121015 \sum_{j-1}^{11} P_j d_{ij}^{-3} - .00007513 P_i \qquad (3.8)$$

and for 29 large centres (above 10,000 population):

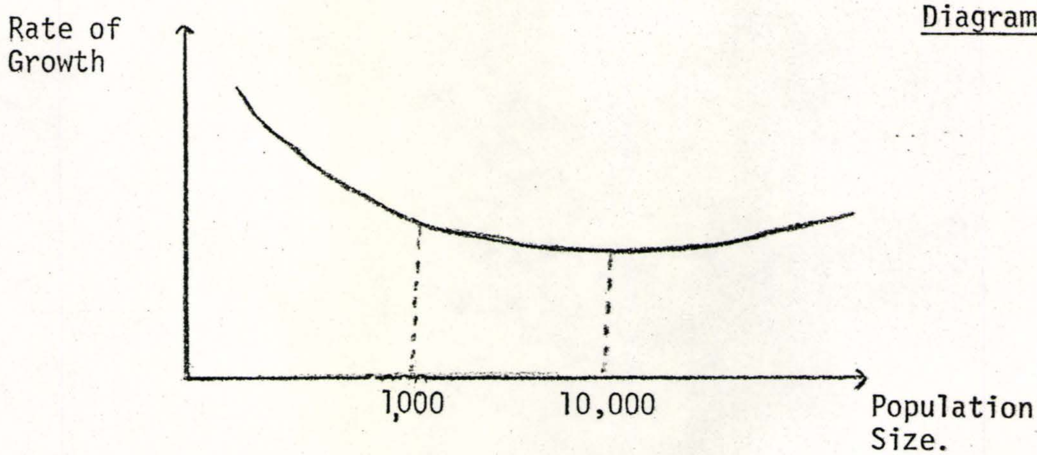
$$\hat{r}_i^L = -15.31375 + .00003526 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .00004592 P_i + .0012262 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.9)$$

The signs of the coefficients of the population variable, P_i, indicate a relationship as in diagram 4. For small and intermediate-sized centres the relationship between rate of growth and population size of a centre is negative, whereas for large-sized centres the relationship is positive. Thus it would appear that as population increases, up to 10,000, growth rates decrease, while beyond 10,000, growth rates increase with population.

For all three groups, the accessibility variable, $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$, was entered into the regression first, indicating its importance. The other two independent variables varied in their order of entry into the regressions. This variation could have been due to the correlation coefficients between the two accessibility variables being relatively high for both small and large centres, when population size was entered before the accessibility function, $\sum_{j=1}^{11} P_j d_{ij}^{-3}$, and being relatively low for intermediate centres when the accessibility function, $\sum_{j=1}^{11} P_j d_{ij}^{-3}$, was entered before population size.

As can be seen from the first four lines of Table 2, the significance of each variable varied between the size classes although all of the variables were significant at, at least, the .01 level of confidence. It is interesting to note that the population size variable, P_i, was very significant for all three size classes, yet its significance was not great enough for the variable to be included in the regression equation when all centres were considered. This probably results from the fact that the sign of the coefficient changes between groups and so helps to 'cancel out' its explanatory power, i.e. the relationship between population size and growth rates is likely to be non-linear. From the β coefficients on the P_i variable, it can be seen that for centres of less than a 1,000 population, the population size of the centre in that group is relatively more important in explaining growth than it is for the other two groups, even given the smaller value of the P_i value. For intermediate and large size centres the β coefficient for the P_i variable is of the order of a thousand times smaller. This indicates that growth rates will decline relatively very sharply up to a population size of 1,000: they will then drop slowly up to a population size of 10,000; and then will rise slowly thereafter. This relationship is exaggerated in Diagram 5.

Diagram 5



It is useful to note here that although R^2 values are not reported in great detail in this analysis (the concentration being made upon the significance values of the variables which are derived from a reliable F statistic[1]), the R^2 value for large centres was much higher than that for small or intermediate sized centres. This may be due to the inherent bias of R^2 towards smaller sized samples or it may be due to the fact that the approximation of using straight line distances to growth centres is truer for larger centres than it

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[1]For some of the drawbacks of using R^2 see Parks [1976].

is for small and intermediate-sized centres.

Because of the non-linear relationship between population size and the rate of growth, two more regressions were run which attempted to overcome this problem. The first used the $\log_N$ of the population size as an independent variable instead of simply population size. For all centres, the regression equation was then:

$$\hat{r}_i = -9.12365 + .00003509 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} - .5127 \log_N P_i +$$

$$.001497 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} \qquad (3.10)$$

Thus, the $\log_N$ of the population size now entered the regression and was very significant (sig.<.001). The relationship between the $\log_N$ of the population size and rate of growth is negative.

The second method used to overcome the problem of non-linearity between population size and rate of growth was to assume the relationship to be curvilinear and from Figure 5 an expression relating population size to rate of growth was formulated as follows:

$$r_i = 7.5 + \frac{1000}{P_i} \qquad (3.11)$$

The regression equation for all centres using this expression was then:

$$\hat{r}_i = -19.39 + .000035375 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .73488(7.5 + \frac{1000)}{P_i} +$$

$$.001307 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.12)$$

The relationship between population size and rate of growth was again very significant (sig.<.001), although positive this time. This indicates that equation (3.11) is a good expression of the relationship between population size and rate of growth and this was then used as a variable in regressions run for disaggregated population size data. The same three size classes were used as were used to derive equations (3.7), (3.8) and (3.9) and the following equations were produced:

For small centres (less than 1,000 population):

$$\hat{r}_i^S = -18.91 + .0000304 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .8817 (7.5 + \frac{1000)}{P_i} +$$

$$.0506 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.13)$$

For intermediate centres (between 1,000 and 10,000 population):

$$\hat{r}_i^{\,I} = -30.29 + .0000327 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + 2.311(7.5 + \frac{1000}{P_i})$$

$$+ \; .00147 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.14)$$

and for large centres (greater than 10,000 population):

$$\hat{r}_i^{\,L} = -98.3 + .0000373 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .0011 \sum_{j=1}^{11} P_j d_{ij}^{-3} +$$

$$11.034(7.5 + \frac{1000}{P_i}) \qquad (3.15)$$

For each category, the accessibility function, $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$ was entered into the regression first. The population size variable was entered second for small and intermediate-sized centres but third for large sized centres indicating a different arrangement of the importance of the variables in the latter group.

In comparing the above results to those in equations (3.7), (3.8) and (3.9), the new population variable given in equation (3.11) only increased the R^2 value for intermediate centres. The R^2 values decreased for small and large centres. Similarly, the significance values given in Table 2 indicate that the population size variable decreased in significance for large and small sized centres while it remained constant (<.001) for intermediate-sized centres. This indicates that the relationship between rate of growth and population size is likely to be near linear for small and large centres but it is likely to be curvilinear for intermediate sized centres. Thus, on Diagram 5, the maximum curve is likely to be between the values of 1000 and 10,000 on the abscissae.

A final analysis was undertaken by disaggregating growth rates in two ways: by population size as previously; and by whether the centre had exhibited relative decline or growth over the period 1966-71. Relative decline, r_i^D, was defined as a rate of growth lower than the average for Ontario between 1966-71, which was 7.5678%. Relative growth, r_i^G, was defined as a rate of growth above the average figure. The dichotomy of relative growth and relative decline was produced for all three population size classes making six data sets in all and a regression was run on each data set. Two final runs were made aggregating size class but keeping the dichotomy between growth and decline. The equations derived from the regressions are given below and the significance values for all variables are given in Table 2. Again the order of the variables in the equation represents the order of entry in the regression: if $\hat{r}_i^{SG}$ is the estimated rate of growth of an ordinary centre i, with a population of less than 1,000 and which has a growth rate above the mean for the region:

$$\hat{r}_i^{SG} = 17.094 + .103 \sum_{j=1}^{11} P_j d_{ij}^{-3} - .0132 P_i + .0000069 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} \qquad (3.16)$$

$$\hat{r}_i^{IG} = -4.0 + .0000316 \sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}} - .00408 \sum_{j=1}^{11} P_j d_{ij}^{-3} + .00038 P_i \qquad (3.17)$$

$$\hat{r}_i^{LG} = -6.26 + .0000313 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} - .000024 P_i - .00076 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.18)$$

If $\hat{r}_i^{SD}$ is the estimated rate of growth of an ordinary centre i, with a population of less than 1,000 and which has a growth rate lower than the mean for the region:

$$\hat{r}_i^{SD} = -12.75 + .0000249 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} - .01025 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.19)$$

$$\hat{r}_i^{ID} = -4.8 + .0000105 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .003503 \sum_{j=1}^{11} P_j d_{ij}^{-3} + .0000784 P_i \qquad (3.20)$$

$$\hat{r}_i^{LD} = -7.39 - .07046 \sum_{j=1}^{11} P_j d_{ij}^{-3} + .0000169 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .00005 P_i \qquad (3.21),$$

If $\hat{r}_i^{\overline{G}}$ is the estimated rate of growth for all ordinary centres i that have growth rates above the mean for the region:

$$\hat{r}_i^{\overline{G}} = -1.408 + .00002856 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} -$$

$$.00006625P_i - .002436 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.22)$$

$$\hat{r}_i^{\overline{D}} = -5.9 + .0000126 \sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}} + .00004018P_i +$$

$$.001855 \sum_{j=1}^{11} P_j d_{ij}^{-3} \qquad (3.23)$$

One of the most interesting points from the above results is that the accessibility variable, $\sum_{j=1}^{11} P_j d_{ij}^{-3}$, is entered first into the regression in just two cases: -for small centres that are growing faster than average, and for large centres that are growing slower than average. What this indicates is that small centres that are growing very rapidly are very close to the main growth centres - a SUBURBANISATION EFFECT; while large centres that are growing slower than average are also very close to the main growth centres - a SHADOW EFFECT. Because the sign of the accessibility coefficient for small centres growing faster than average is positive, this indicates that as distance away from growth centres increases, growth rates decline rapidly. In equation (3.21) the sign on the accessibility coefficient for large centres that are growing slower than average is negative, indicating that as distance from growth centres increases, rates of growth increase. When large centres are located very close to growth centres they suffer their largest relative declines. When very small centres are located very close to growth centres they achieve their highest rates of growth.

The sign of the P_i variable is also interesting in the above regressions. For small places that are growing faster than average (3.16), population size is negatively related to rate of growth indicating that as centres within this group get larger, their rate of growth decreases. For small centres that are declining relative to all other centres (3.19), population size has no relationship with rate of growth and the variable was not significant enough to be placed in the regression.

Again the relationship between population size and rate of growth changes between size groups. Consider the centres that are growing faster than average, then from equations (3.16), (3.17) and (3.18) it can be seen that the relationship between rate of growth and population size is negative for small centres, positive for intermediate centres and negative for large centres. This situation can be represented in Diagram 6. The overall relationship between population size and rate of growth for all centres that are growing faster than average is negative as indicated by equation (3.22).

Diagram 6

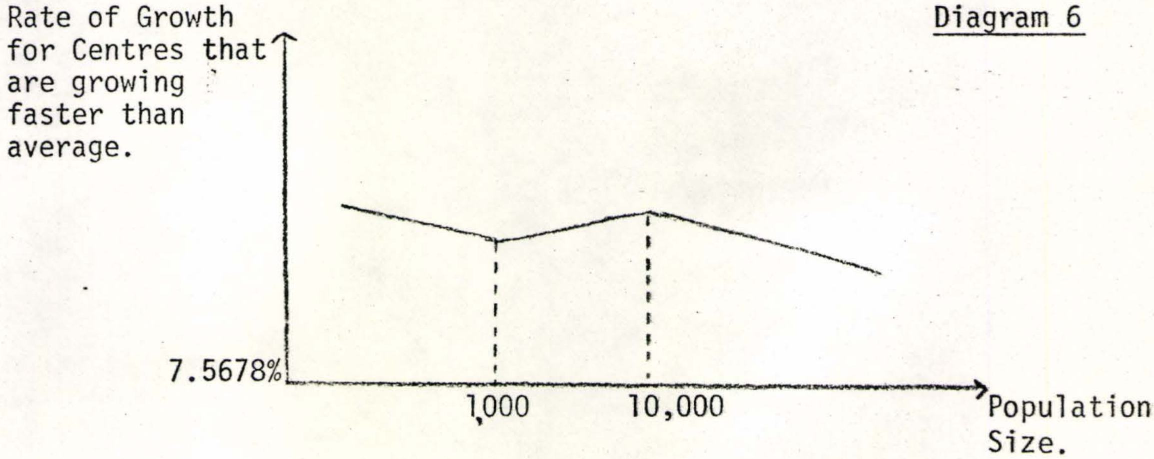

Table 2 - Significance values for the variables in the preceeding regression analyses.

VARIABLE r_i and equation		$\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$	$\sum_{j=1}^{11} P_j d_{ij}^{-3}$	P_i
$\hat{r}_i$	(3.6)	<.001*** (+ve)[1]	<.001*** (+ve)	–[2]
$\hat{r}_i^{S}$	(3.7)	.007** (+ve)	.005** (+ve)	.002** (-ve)
$\hat{r}_i^{I}$	(3.8)	<.001*** (+ve)	<.001*** (+ve)	<.001*** (-ve)
$\hat{r}_i^{L}$	(3.9)	<.001*** (+ve)	.004** (+ve)	.001*** (+ve)
$\hat{r}_i$	(3.10)	<.001*** (+ve)	<.001*** (+ve)	<.001[3]*** (-ve)
$\hat{r}_i$	(3.12)	<.001*** (+ve)	<.001*** (+ve)	<.001[4]*** (+ve)
$\hat{r}_i^{S}$	(3.13)	.007** (+ve)	.028* (+ve)	.014[4]* (+ve)
$\hat{r}_i^{I}$	(3.14)	<.001*** (+ve)	<.001*** (+ve)	<.001[4]*** (+ve)
$\hat{r}_i^{L}$	(3.15)	<.001*** (+ve)	.001*** (+ve)	.004[4]** (+ve)
$\hat{r}_i^{SG}$	(3.16)	.041* (+ve)	.052 (+ve)	.016* (-ve)
$\hat{r}_i^{IG}$	(3.17)	.023* (+ve)	.033* (-ve)	.063 (+ve)
$\hat{r}_i^{LG}$	(3.18)	.055 (+ve)	.325 (-ve)	.166 (-ve)
$\hat{r}_i^{SD}$	(3.19)	.012* (+ve)	.044* (-ve)	–
$\hat{r}_i^{ID}$	(3.20)	.026* (+ve)	.067 (+ve)	.140 (+ve)
$\hat{r}_i^{LD}$	(3.21)	.040* (+ve)	.104 (-ve)	.051 (+ve)
$\hat{r}_i^{\overline{G}}$	(3.22)	.002** (+ve)	.006** (-ve)	.003** (-ve)
$\hat{r}_i^{\overline{D}}$	(3.23)	.001*** (+ve)	.008** (+ve)	.003** (+ve)

[1]The direction of the relationship.
[2]Variable not significant enough to enter the regression.
[3] $\log_N P_i$ used
[4] $(7.5 + 1000/P_i)$ used.

***variable significant at 99.9% level of confidence.
** variable significant at 99% level of confidence.
* variable significant at 95% level of confidence.

The line is virtually straight, however, as can be seen by differentiating equation (3.16), (3.17) and (3.18) with respect to P_i.

It has been mentioned that for large-sized centres that are growing more rapidly than average, population size and rate of growth are negatively related, yet by equation (3.21) for large-sized centres that have growth rates lower than average, the relationship between population size and rate of growth is positive. Thus a larger centre is likely to have a growth rate near the mean rate of growth for the region and it indicates that for centres over 10,000 population, the larger a centre is the more stable will be its rate of growth and this rate of growth will not fluctuate far from the mean rate of growth. Smaller centres will be more prone to wilder fluctuations away from the mean rate of growth. This is also indicated by comparing the signs of the population variable in equations (3.22) and (3.23).

Two final points can be made regarding the results of the regression analysis. One is that the variables have much higher significance values for equations (3.22) and (3.23), where centres are aggregated by population size and disaggregated by growth rates, than they do for equations (3.16) through (3.21) where centres are disaggregated by both population size and growth rates. This is perhaps due to the greater degrees of freedom present when centres are aggregated by size. The second point is that the accessibility variable, $\sum_{j=1}^{11} P_j d_{ij}^{-\frac{1}{2}}$, is significant in nearly all cases indicating polarised growth around the eleven designated growth centres.

3.4 COMMENTS UPON THE RESULTS

As mentioned earlier, equation (3.6) showed, by the fact that both variables of accessibility to growth centres were very significant (see Table 2), that growth was in fact polarised around the eleven designated growth centres. More information was derived about the polarisation of growth by mapping the residuals[1] from the regression of equation (3.6). This map is given overpage as Figure 7. On the map, positive residuals thus indicate those centres that were growing at a faster rate than that predicted from the model, while negative residuals indicate centres that were growing at a slower rate than that predicted from the model. Inspection of this map shows several points:

(i) Centres in Eastern Ontario were generally growing less than expected. This indicates that Ottawa and Montreal may not have been transmitting growth to their hinterlands as would have been expected and hence it is doubtful that they are true growth centres. If Ottawa and Montreal were omitted

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[1] The residuals are given by the formula $r_i - \hat{r}_i$, where r_i is the actual rate of growth of centre i and $\hat{r}_i$ is the estimated rate of growth from equation (3.6).

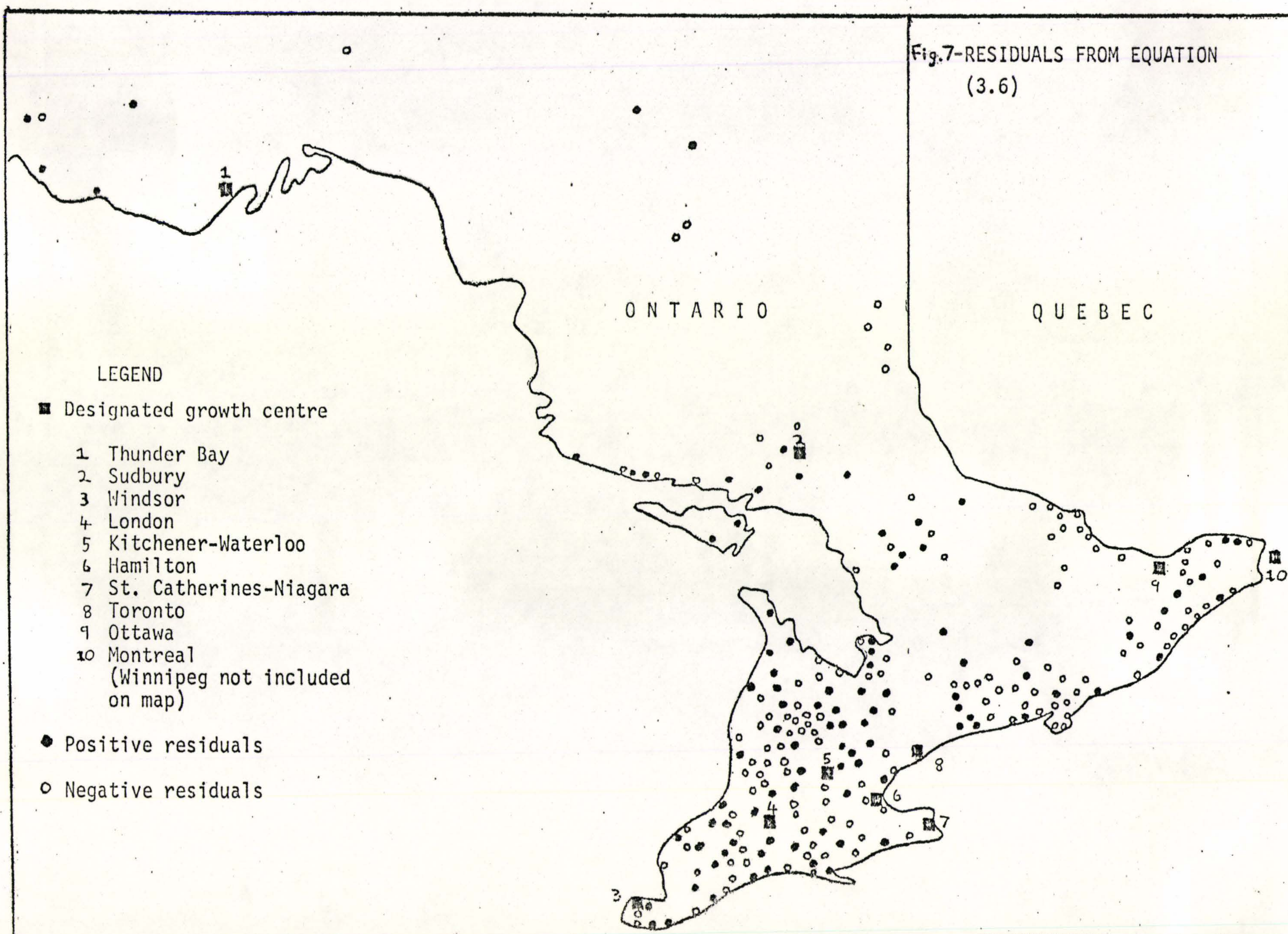
Fig.7-RESIDUALS FROM EQUATION (3.6)
ONTARIO
QUEBEC
LEGEND
Designated growth centre
1 Thunder Bay
2 Sudbury
3 Windsor
4 London
5 Kitchener-Waterloo
6 Hamilton
7 St. Catherines-Niagara
8 Toronto
9 Ottawa
10 Montreal
(Winnipeg not included on map)
Positive residuals
Negative residuals

from the calculation of accessibility, then the model could be expected to work far better because centres in Eastern Ontario would not be expected to have very high growth rates, while centres in Southern Ontario would be expected to have higher growth rates. It is interesting to note that Higgins[1] also found that there were no true growth centres in Eastern Ontario.

(ii) Toronto appeared to be transmitting more growth than expected - indicated by the large number of positive residuals encircling the Toronto area.

(iii) There is an area of negative residuals to the North-West of Kitchener-Waterloo. This could be explained by this area having relatively poor connections to the designated growth centres as no major highway passes through the area. Thus another variable could perhaps be added to the regression equation indicating nearness to a major highway. This is also indicated as being an important variable in explaining growth rates by the fact that most centres close to Highway 400, running North from Toronto, and most centres close to Highway 401, running between Toronto and Windsor, were growing at faster rates than expected. An alternative method to include such a variable in the model is, of course, to use actual distances to growth centres instead of straight line distances, or to use some time variable instead of distance variable to growth centres.

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[1] Details of the study unkown. Mentioned in a symposium on growth poles at the Canadian Economics Association Conference at New Brunswick, 1977.

One more comment can be made upon the residual map, in that it has helped to identify designated growth centres that were not true growth centres, that is, Ottawa and Montreal, and it has shown that the other nine growth centres were actually acting as growth centres between 1966 and 1971. Thus the model outlined in equation (3.6) can be used as a method for identifying growth centres around which growth is polarised. This is particularly useful because it allows any number of growth centres to be identified in a region and is not restricted to simply identifying one growth centre as many other models have been.

The analysis outlined in section 3.3 has shown that accessibility and population size are important variables in explaining growth. This is clearly shown by the significance values in Table 2. Generally, as accessibility increases, population growth rate increases. The relationship between population size and growth rates was not so clear, however, and population size was not included as a significant variable in the first regression when all centres were considered (equation (3.6)). It was included though when the data was disaggregated by population size and it was found that the direction of the relationship changed between population size classes. Growth rates and population were negatively related for centres of less than 1,000 population, positively related for centres with a population between 1,000 and 10,000, and negatively related for centres over 10,000 population. This indicates that the relationship between population growth rate and population size was non-linear for all centres in Ontario between 1966 and 1971. This result indicates that there may not be the simple relationship such as the larger a centre, the higher its growth rate as has sometimes been shown.[1] In fact, if anything, it would seem that smaller centres have higher growth rates than larger centres for any given accessibility measure to growth centres.

A final comment can be made upon the results given in Section 3.3 and it is that generally growth has been shown to be transmitted gradually outwards from growth centres with no sharp decline in growth rates, as indicated by the generally superior performance of the "gradual" accessibility measure (3.2) relative to the "steep" cubic measure. The only exceptions to this were small places that were growing rapidly and large places that were growing very slowly or declining. This would appear to indicate, as mentioned, a suburbanisation effect and a shadow effect, respectively. For small centres that were growing rapidly, growth rates declined sharply with distance from growth centres, while growth rates increased sharply with distance for large centres that were growing slowly or declining. This gives an indication of how spread and backwash effects may be operating on different sized centres. The following diagram is a representation of the

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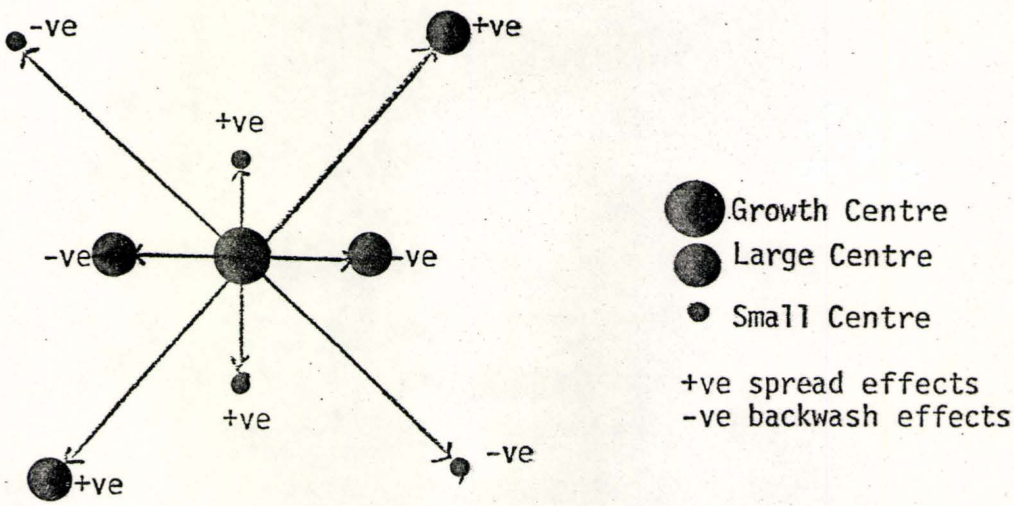
[1]for examples see Borchert [1963] and Salisbury and Rushton [1963].

above result:

Diagram 7



Spread effects are transmitted from a growth centre to small centres in its immediate environs and to large centres further away. Backwash effects are transmitted to large centres in close proximity to the growth centre and to small centres at some distance from it.

A further note on spread and backwash effects, attempting to place more precise limits on their spatial extent, is given in Chapter 4.

CHAPTER 4

A NOTE OF THE SPATIAL EXTENT OF GROWTH CENTRE IMPACTS

"the spatial incidence of economic growth is a function of distance from the central city ....(and)...troughs of backwardness lie in the most inaccessible areas."

-B.J.L. Berry [1969, p. 288

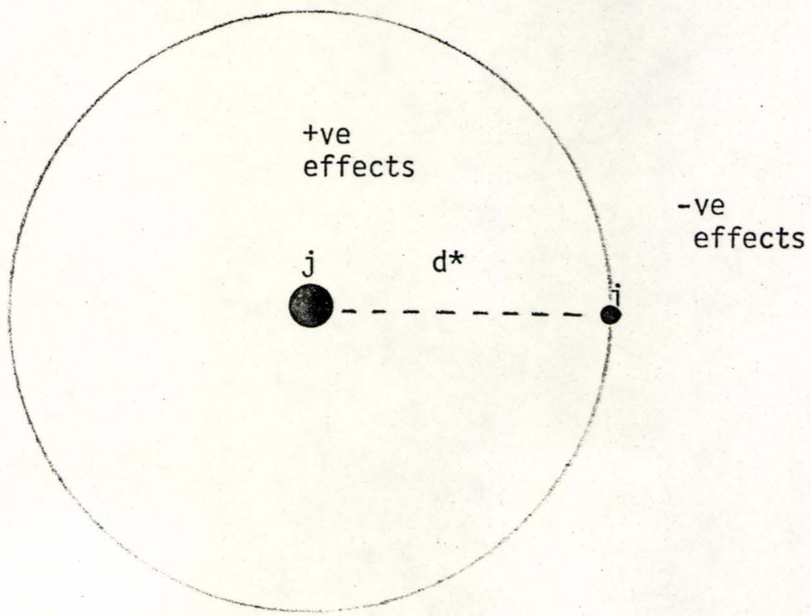
CHAPTER 4

A NOTE ON THE SPATIAL EXTENT OF GROWTH CENTRE IMPACTS

4.1 A MODEL

Consider a region with N growth centres and assume that spread and backwash effects are transmitted from these growth centres in the form of a core-periphery model such as that discussed by Friedmann (1963). The following diagram is a representation of such a model.

Diagram 8



where i = an ordinary centre

j = a growth centre

and d* = the radius of spread effects

Backwash effects thus begin at distance $(d^* + \Delta)$, where Δ is some small increment.

The purpose of this chapter is to attempt to formulate an expression for d^*.

It has already been established[1] that growth rates are significantly related to distance in the following bivariate linear regression equation:

$$r_i = \alpha + \beta \sum_{j=1}^{N} P_j (d_{ij})^{-\gamma} \qquad (4.1)$$

where r_i is the growth rate of ordinary centre i,

P_j is the population of growth centre j

and α, β and γ are constants. (The relationship was found to be significant when $\gamma = \frac{1}{2}$).

Let the mean rate of growth for all M centres of classification i be r^* so that;

$$r^* = \frac{1}{M} \sum_{i=1}^{M} r_i \qquad (4.2)$$

Then, spread effects occur when $r_i > r^*$ and backwash effects occur when $r_i < r^*$.

Suppose that place i is a place for which the rate of growth predicted by equation (4.1) is exactly r^*, that is, place i is growing at the average rate. The locus of all such places around a single growth centre is a circle with radius d^*, as shown in diagram 8.

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[1] see chapter 3.

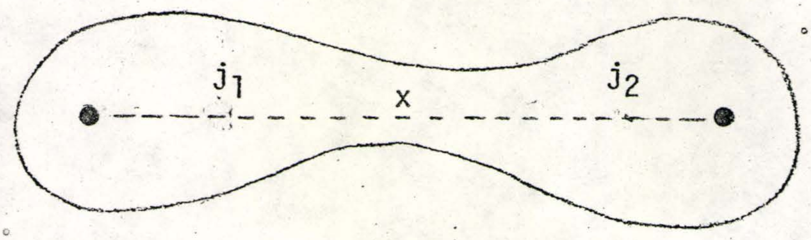
In a multi-growth centre situation, let d_i^* be the mean distance from i to the set of growth centres j. Thus di^* is given by:

$$d_i^* = \frac{1}{N}\sum_{j=1}^{N} d_{ij} \qquad (4.3)$$

and d_i^* is a constant where $d_1^* = d_2^* + \ldots . d^*$ for all places i that are predicted to grow at the equilibrium rate.

In a two growth centre situation, the locus of points predicted to grow at the equilibrium rate, r*, would become distorted as follows:

Diagram 9



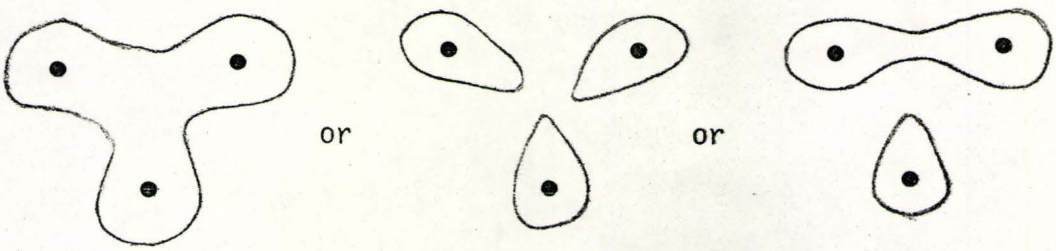
or, if $x > 2d_i^*$ for some places i on the line between j_1 and j_2,

Diagram 10

All places within these lines would be expected to receive spread effects from j, while places lying outside the line would receive backwash effects.

In a three growth centre situation, the line representing equilibrium growth rates may have any of a number of different shapes such as;

Diagram 11



and so on.

let L^* represent the locus of equilibrium growth rate points, that is, L^* is one of the lines drawn above in diagrams 8, 9, 10 or 11. Given any locus, L^*, of equilibrium growth rate points such as those shown above, the global mean equilibrium growth rate distance, d#, can be defined as the line integral of d_i^* along L^*. In particular, suppose that L^* has been divided into K subarcs of length,

$$\Delta s_1, \Delta s_2, \ldots\ldots, \Delta s_k{}^{1}$$

Let i be an arbitrary point in the i th subarc and then:

$$\sum_{i=1}^{k} d_i^* \Delta s_i = \sum_{i=1}^{k} \left(\frac{1}{N} \sum_{j=1}^{N} d_{ij}\right) \Delta s_i \qquad (4.4)$$

in the limit as K approaches ∞ (if such a limit exists) and as the largest Δs_i approaches zero, then the sum in equation (4.4) is the line integral of d_i^* along the locus L*. This is the global mean equilibrium growth rate distance, d#, and is given by:

$$d^{\#} = \int_{L^*} d_i^* \, ds \equiv \lim_{\substack{k \to \infty \\ \Delta s \to 0}} \sum_{i=1}^{k} d_i^* \Delta s_i \qquad (4.5)$$

In words, the global mean equilibrium growth rate distance is the mean over all equilibrium growth rate points of all the mean distances to growth centres. It is a complicated matter to evaluate this particular line integral to obtain the global mean equilibrium growth rate distance, $d^{\#}$. However, a reasonable approximation to $d^{\#}$ is obtained by using the proxy, d^*, where d^* is defined to be a distance such that if an ordinary centre were separated from all growth centres by that distance then its growth rate would be r*. In other words, d* is taken to be the distance which solves the following equation:

$$r^* = \alpha + \beta \sum_{j=1}^{N} P_j \, (d^*)^{-\gamma} \qquad (4.6)$$

This is equation (4.1) with the N different distances, d_{ij}, replaced by the single distance d*. d* can then be called the approximate equilibrium growth-rate distance, or the approximate mean distance for short.

[1]This exposition follows George B. Thomas Jnr. "Calculus and Analytic Geometry." [1969]

Transforming (4.6) gives:

$$\sum_{j=1}^{N} P_j (d^*)^{-\gamma} = \frac{r^* - \alpha}{\beta} \tag{4.7}$$

Taking $(d^*)^{-\gamma}$ out of the summation,

$$(d^*)^{-\gamma} \sum_{j=1}^{N} P_j = \frac{r^* - \alpha}{\beta} \tag{4.8}$$

Dividing by N and transforming, an expression for d^* can be stated as:

$$d^* = \left(\frac{\beta . N . \overline{P}_j}{r^* - \alpha} \right)^{\frac{1}{\gamma}} \tag{4.9}$$

where $\overline{P}_j$ is the mean value of P_j.

The denominator of the equation, $r^* - \alpha$, must always be positive as the β coefficient, relating growth to 1/distance is always positive. α must then be a number less than r^* for equation (4.6) to hold true.

From equation (4.9), d^* is then the approximate mean distance from a centre i to a growth centre j at which the rate of growth at centre i is r^*; that is, the point at which the system is in equilibrium. Thus, it is approximately[1] true that:

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[1]The assertions in the inequalities are correct when there is only one growth centre. A glance at diagrams 9, 10 and 11 reveals the obvious fact the assertions are only approximations when there are multiple growth centres.

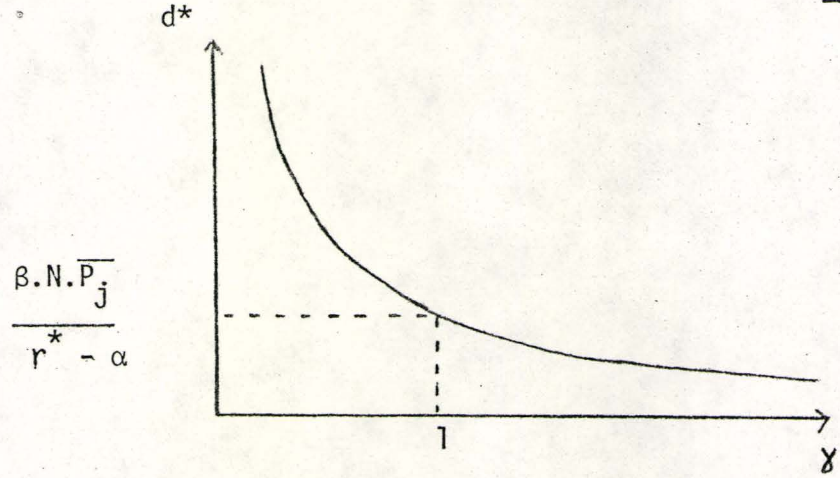
$$r_i < r^* \text{ for all i's when } d_{ij} > d^*$$

and

$$r_i > r^* \text{ for all i's when } d_{ij} < d^*$$

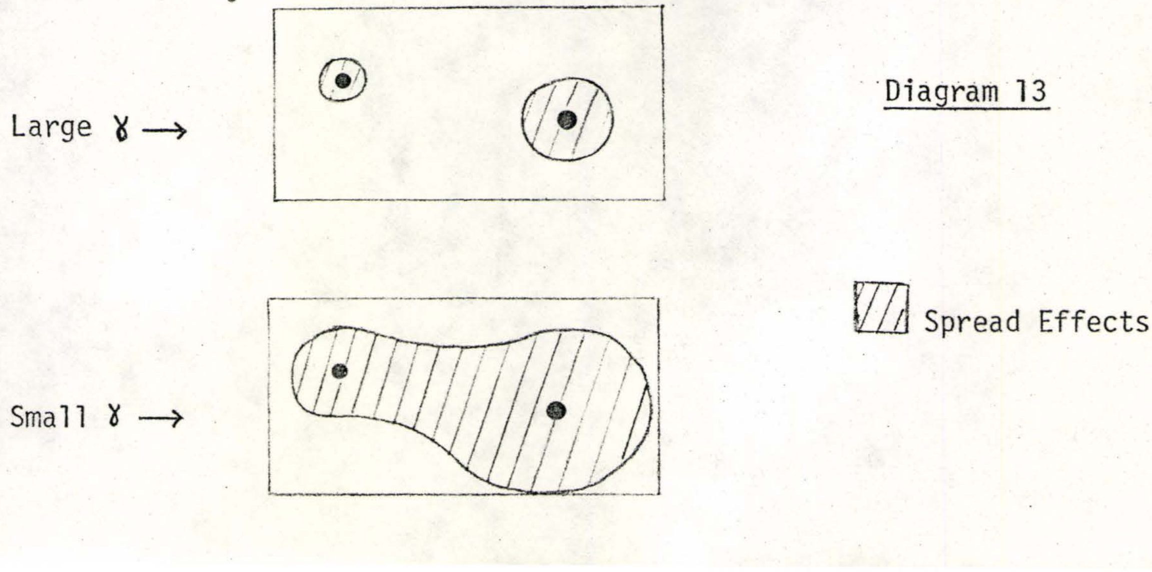
An interesting point to note from equation (4.9) is the relationship between d^* and γ which can be graphed simply as follows:

Diagram 12



γ is then a spatial polarisation parameter and as it increases, the area over which places receive spread effects decreases. This is shown diagramatically as:

Diagram 13



4.2 EMPIRICAL RESULTS

The model given in equation (4.9) was tested with population growth data obtained for 243 centres in Ontario. The average rate of growth, r^*, defined as the change in population of a centre between 1966 and 1971 expressed as a percentage of the 1966 population, for all settlements that were considered as non-growth centres, was 7.5678%. Growth centers were simply defined as being all places in Ontario with a population of in 1966 greater than 100,000; Montreal and Winnipeg were also included. In all, 11 growth centres were defined and the mean population of these 11 centres was 678,000 in 1966. γ was taken as ½ in the regression and from this earlier regression the values for α and β were found to be -12.9605 and .00003516 respectively.

Substituting the above values into equation (4.9) gave a value for d^* of 163.2 miles. This implies that the average spatial impact of spread effects from growth centres in Ontario between 1966-71 was 163.2 miles. If the mean distance of an ordinary centre to the 11 designated growth centres was less than 163 miles the ordinary centre would probably be receiving spread effects from the growth centres and would thus have a growth rate of over 7.5678 %, i.e. $r_i > r^*$. If, however, the mean distance of an ordinary centre to the 11 growth centres was greater than 163 miles the ordinary centre would probably be suffering from backwash effects and its rate of growth would be less than the average, i.e. $r_i < r^*$.

Further testing of the model was undertaken by disaggregating the population growth data from Ontario into 3 classes based on the population size of the ordinary centres under investigation. The same value for r^* was used in each case and the d^* results from each test will thus indicate how close to the designated growth centres ordinary centres of each class need to be in order to receive spread effects. Different values for the constants α and β were used for each size category and these values were obtained from previously-run regressions mentioned in Chapter 3. The results for each size class are given in Table 3.

TABLE 3

Size Class (population)	Number of Observations	d^*
< 1,000	83	171 miles
1,000 - 10,000	131	160 miles
10,000 - 100,000	29	153 miles

The results in Table 3 indicate that smaller centres are less dependent upon distance to the designated growth centres than are the larger centres, in order to achieve higher than average growth. Proximity to a growth centre becomes increasingly important as the size class of the ordinary centre becomes larger. It is useful to note that this information regarding distance to a growth centre and size class of a centre is not indicated by the β values derived from regressing equation (4.1). A reason for this is that the interaction between the α and the β values has to be taken into account in explaining the growth rates of centres i.

A test of these results was made by using the whole of the regression equation given previously as equation (3.4) and rewritten here as equation (4.10)

$$r_i = \alpha + \beta_1 \sum_{j=1}^{N} P_j(d_{ij})^{-\frac{1}{2}} + \beta_2 \sum_{j=1}^{N} P_j(d_{ij})^{-3} + \beta_3 P_i \qquad (4.10)$$

Thus the growth rate at centre i is now related to two accessibility functions and the population at centre i. The d_{ij}'s in the equation were again substituted by d^*, and r_i was substituted by r^* to give:

$$r^* = \alpha + \beta_1 \sum_{j=1}^{N} P_j(d^*)^{-\frac{1}{2}} + \beta_2 \sum_{j=1}^{N} P_j(d^*)^{-3} + \beta_3 P_i \qquad (4.11)$$

The reason why this equation was not used as the original model for finding d^* is that to obtain results one must approximate twice to substitute d^* in equation (4.10) for d_{ij}. Also the value of P_i has to be approximated to $\overline{P_i}$, where $\overline{P_i}$ represents the mean value of P_i.

Equation (4.11) was solved iteratively for d^* and the closest approximations for $r^* = 7.5678$ (i.e. the average rate of growth) occurred when d^* had the values shown in Table 4.

Table 4

Size Class (population)	d^*
< 1,000	161 miles
1,000 - 10,000	158 miles
10,000 - 100,000	152 miles

The order of these values reinforces the order given in Table 3. The small differences in magnitude are probably due to the extra approximations present in the latter method.

From equation (4.4) a relationship between the mean rate of growth, r^*, and the mean distance away from all growth centres, d^*, can be found by finding the differential of the equation. Thus,

$$\frac{dr^*}{dd^*} = -\gamma.\beta.d^{*(-\gamma-1)} \sum_{j=1}^{N} P_j \qquad (4.12)$$

As $\overline{P}_j = \frac{1}{N} \sum_{j=1}^{N} P_j$, $\sum_{j=1}^{N} P_j$ can be substituted in equation (4.12) by $N.\overline{P}_j$ to give;

$$\frac{dr^*}{dd^*} = -\gamma.\beta.d^{*(-\gamma-1)}.N.\overline{P}_j \qquad (4.13)$$

When $\gamma = \frac{1}{2}$, for example,

$$\frac{dr^*}{dd^*} = \frac{-\beta.N.\overline{P}_j}{2\sqrt{(d^*)^3}} \qquad (4.14)$$

Thus, when β = .00003516

$$N = 11$$

$$P_j = 678000$$

and $$d^* = 163.2$$

$$\frac{dr^*}{dd^*} = -.0629 \text{ \%/mile} \qquad \text{or} \qquad \frac{dd^*}{dr^*} = -15.9 \text{ miles/\%}$$

In mean distance terms, this result indicates that as you move one mile away from the designated growth centres the rate of growth of a centre will decrease by .0629%. Or to obtain a decrease of 1% a mean distance of 15.9 miles has to be covered. This indicates the dependence of ordinary centres upon the designated growth centres in this study for their growth.

By taking the second derivative of equation (4.13), again with $\gamma = \frac{1}{2}$, more information is obtained about how the function is decreasing away from the growth centres. Thus,

$$\frac{d(r^*)^2}{d(d^*)^2} = \frac{3}{4}.\ \beta.N.\overline{P}_j.(d^*)^{-\frac{5}{2}}$$

$$= \frac{3.\beta.N.\overline{P}_j}{4\sqrt{(d^*)^5}} \qquad (4.15)$$

By substituting in the above values for β,N,P_j, and d^*;

$$\frac{d(r^*)^2}{d(d^*)^2} = .000575$$

This indicates that the function is decreasing at a decreasing rate. There are no points of inflexion. Thus the effect of distance upon the rate of growth of a centre is one where the rate of growth decreases negative-exponentially as distance increases.

By using this method, similar to that used by Casetti, King and Odland [1971], polarised growth around a set of growth centres has been shown to exist, and proximity to growth centres is a major factor in explaining growth rates. For comparison, Casetti et al. used time series data and indicated that the ratio of employment at time t to employment in the base year 1950 (z) was polarised around Los Angeles. The first derivative with respect to time was,

$$\frac{\partial z}{\partial t} = .12 - .00004s \quad \text{where } s = \text{distance.}$$

This was positive for all plausible values of s. The second derivative with respect to distance and time, was negative (-.00004) which indicated that the ratio of employment in the base year grew more rapidly the smaller the distance from Los Angeles. This is a similar result to that found in the present study, only the present study has the advantage of assuming a multi-growth centre region and not just a single growth centre. Also the analysis by Casetti et al. was undermined when another variable, total non-agricultural employment, was found not to be polarised around Los Angeles and, in fact, was shown to increase with distance from Los Angeles.

For the function given in equation (4.11), $\log_N r^*$ was plotted against values of d^*, for large, intermediate and small-sized centres. The results are shown in figures 8 and 9. Figure 8 shows the function graphed over values of d^* from 1 to 175, and figure 9 shows the function graphed over values of d^* from 1 to 45. The graphs indicate that when small centres are very close to growth centres, their rates of growth are much higher than the equivalent figure for intermediate and large-sized centres. This can be termed a "suburbanisation effect". As the mean distances to all growth centres increases, the rates of increase for small, intermediate and large-sized centres decrease at a decreasing rate and tend to converge which indicates that as places become very isolated the size of a place has little effect on growth rates-all centres will decline in absolute or relative terms. A policy implication from these results is that for any constant distance away from large centres of population, small centres tend to have higher rates of growth than larger centres. Thus, in trying to stimulate growth in ordinary centres in a region which is experiencing spread effects, it may be more worthwhile to promote several small ordinary centres instead of one large ordinary centre - depending, of course, upon the

Figure 8 - Graph of the Log_n of the Rate of Growth against the Mean Distance to Growth centres for small, intermediate and large-sized places. Distances up to 175 miles.

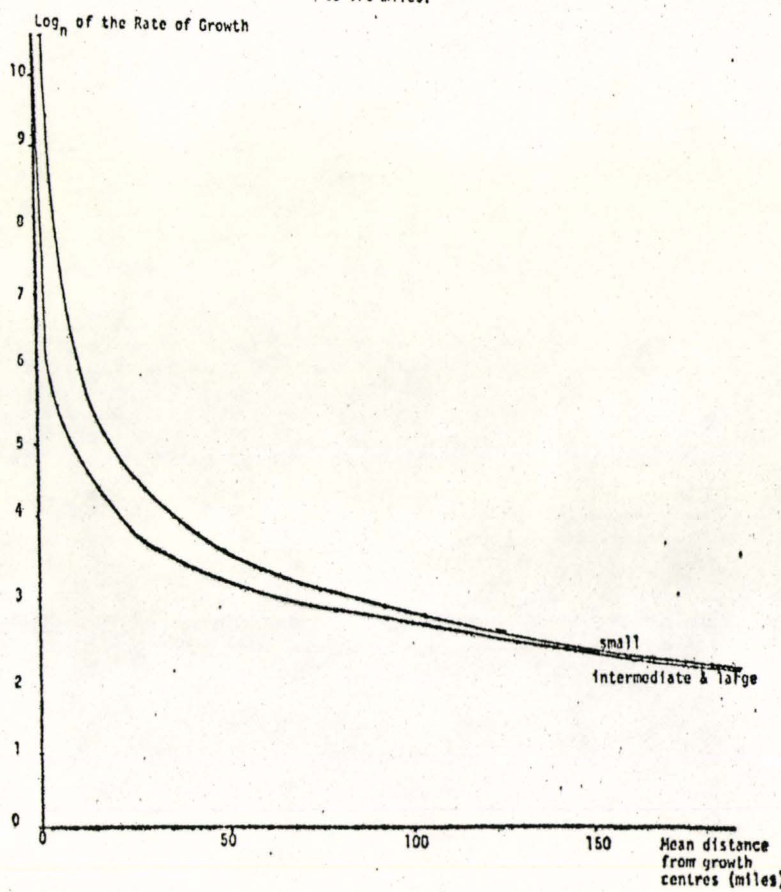
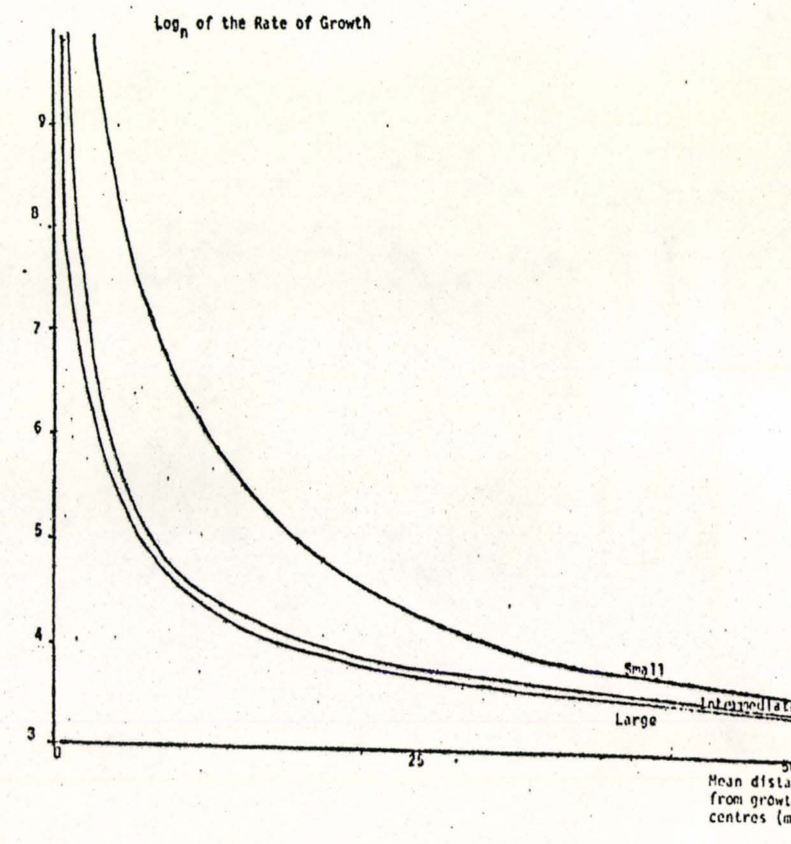


Figure 9 - Graph of the Log_n of the Rate of Growth against the Mean Distance to Growth centres for small, intermediate and large-sized places. Distances up to 50 miles.



economies of scale that could be derived from a larger centre.

It may be the case, however, that the results merely reflect the fact that small centres are true satellites or suburbs of growth centres, dependent in their production and growth on the demands from growth centres. Larger centres, in contrast, may be independent centres whose output depends less on the welfare of nearby large centres and more on variables (such as the quality of public services) excluded from this study.

4.3 CONCLUSIONS

It has been shown in this analysis that the spatial extent of spread and backwash effects from growth centres can be measured. It would be useful to compare values for the spatial extent of growth centres in various areas such as the Maritimes and the Prairies in order to see where the greatest impacts, and perhaps benefits, of locating growth centres would occur. In a National sense then, this could be of use for example, in determining whether to promote growth in Winnipeg or Halifax.

It has also been shown in this chapter that distance to a growth centre becomes increasingly important as the size of an ordinary centre becomes larger. One reason for this result could be that ordinary centres of smaller size are more likely to obtain spread effects from large, or even intermediate-sized centres, than are the large or intermediate-sized centres themselves. Thus, distance to large and intermediate-sized centres is likely to play an important part in explaining the distribution of spread effects among small, ordinary centres. Larger centres, however, are much more likely to be dependent upon growth centres for receiving spread effects. Thus, these results indicate that growth is probably being transmitted down the hierarchy of a central place system and distance to a centre of n-1 order may be a good explanatory variable of growth in a centre of order n. However, it is not the only explanatory variable because growth can be transmitted directly to a small centre from a growth centre, as indicated by figures 8 and 9, and growth is probably being transmitted hierarchically and spatially. This would explain why, for a given distance from a growth centre, smaller centres achieve higher rates of growth than larger centres. The smaller centres receive impulses from the growth centre and from the intermediate centre, while the intermediate centre receives growth only from the growth centre.

Finally, it is useful to perorate the earlier comments regarding policy implications of these results. Growth centre impacts should play an important part in the decision of which centres ought to be designated as growth centres. One would assume that the centre offering the greatest potential impact on its environs would be the most successful centre in which to invest. For instance, in Ontario, as mentioned in the previous chapter, Toronto would be a better investment centre than Montreal, which is fairly obvious, and Hamilton would be a better investment centre than Ottawa, which is not so obvious.

Similarly, those centres receiving relatively greater impacts from growth centres should not be overlooked for investment opportunities. In Ontario it has been found that such centres were the small places of less than 1,000 population in which growth rates were greater than in either intermediate-sized places of between 1,000 and 10,000 population or large centres of over 10,000 population. Much of the former work done on small centres has proposed that they are declining and consequently unworthy of investment. This is not the case in Ontario, or was not the case between 1966-71, and although the growth of small centres could be explained by the fact that this was a period of boom in Ontario, it is still interesting that the growth rate of small centres outstripped that of intermediate and large-sized centres, *ceteris paribus*.

Thus, by concentrating upon the spatial impacts of growth centres, much information can be obtained that is especially useful for policy analysis. It seems only sensible that if the primary purpose of a growth centre is to transmit growth into its environs, then one of the main lines of investigation into growth centres should be to see how far, and in what form, this growth is transmitted.

CHAPTER 5

CONCLUDING COMMENTS

"it is better to know some
of the questions than all
of the answers."
-James Thurber

CHAPTER 5

CONCLUDING COMMENTS

There is a great deal of intuitive appeal in the notion of a growth centre in which economic and social development is initiated and transmitted to an area around it, and as Kuehn and Bender [1969] state:

> "Cost effectiveness of a given budget theoretically will be greater using this [growth centre] approach than one which spreads expenditures thinly over a wide area without regard to secondary benefits".
> -p. 435

This indicates that the most important normative questions of regional economic development, those concerned with the regional allocation of investments in both time and space, can be given some clearer direction if this intuitive idea of growth centres is adopted. Planned centres, for example, can be instrumental to at least three main planning goals:

(1) the stimulation of depressed areas.

(2) relieving congestion in large increasingly inefficient metropolitan areas.

(3) securing balance in the development process among regions to avoid political rifts and the emergence, or maintenance of economic dualism.

However, before growth centres should be used to any large extent in an attempt to solve a multitude of problems, greater details of their spatial impacts should be understood. It could be, for example, that growth centres transmit greater backwash effects than spread effects and consequently they would be a poor planning tool, or it could be that growth centres do actually raise the level of development in a whole area. Either way, much more should be known about the spatial impacts a growth centre has upon its environs.

The analysis presented in this paper has attempted to discover new information regarding the spatial impacts of growth centres, in a multi-growth centre environment. The latter point was considered to be a more reasonable representation of reality than would a single growth centre environment and as Hodge [1966] notes:

> "If, as already has been noted, urban centers are keys to a region's development and public policy ought to be cognizant of urban systems and their trends, then the problem is one of distinguishing the prospects for growth and decline of all urban places in the region. A solution to this problem cannot proceed very far before one has to acknowledge the considerable complexity of urban centres individually and in connection with other centres."
>
> -p. 2

The main results of the analysis presented here may be summarized as follows:

(1) Polarised growth has been shown to exist around nine of the eleven designated growth centres in Ontario. Two centres that were thought to be growth centres were found not to be so.

(2) Growth rates of an ordinary centre appear to be significantly related to the population size of the centre and to its proximity to growth centres.

(3) It is not necessarily so that smaller centres are growing more slowly than are large centres and in fact the opposite could be the case. The relationship could also be non-linear and it has been shown that for smaller centres (<1,000 population), growth rates and population size are negatively related; for intermediate centres (between 1,000 and 10,000 population) the relationship is positive; and for large centres (between 10,000 and 100,000 population) the relationship is again negative.

(4) Growth rates generally decline gradually with distance from growth centres. The only exceptions to this in all of the results were the cases of large centres growing at slower than average rates and small centres growing at faster than average rates. Growth rates for the former increased sharply with distance from growth centres, indicating a shadow effect, and growth rates for the latter decreased rapidly as proximity to growth centres increased, indicating a suburbanisation effect.

(5) The growth rates of large centres were found to be more stable than those of small and intermediate-sized centres. This is probably attributable to the larger base of centres over 10,000 population.

(6) The relations among growth rates, proximity to large centres and size of ordinary centres varies according to the size and proximity classes of the ordinary centres. There is interdependence between size-classes and proximity classes. Spread effects were found to be transmitted to small centres in close proximity to growth centres and to large centres at some distance away. Backwash effects were found to be transmitted to large centres in close proximity to growth centres and to small centres further away.

(7) Fairly precise information has been given upon the spatial extent of spread effects from growth centres in Ontario. The approximate mean spatial impact of spread effects from growth centres was found to be in the order of 163 miles. This distance exceeded 163 miles for smaller centres and fell short of 163 miles for larger centres indicating, perhaps, that smaller centres are less dependent upon distance to growth centres than are large centres, in order to achieve higher than average growth. This could indicate a hierarchic diffusion of growth whereby smaller centres can receive growth

impulses from large or intermediate-sized towns and consequently need to be less near to growth centres than do the large or intermediate-sized towns themselves.

(8) Growth is likely to be transmitted both by a hierarchical and a neighbourhood effect.

Some of the above results were to be expected but needed proving: some others were not and may have an heuristic value. If further research was to be undertaken in this area, for example, several aspects of improving the model can be mentioned. A composite index for growth could be better than the single index of population growth rate, for instance. Population growth rate, by itself, may be affected by demographic trends and Hodge [1966] found, for example, that an urban centre could be expected to experience a faster rate of population growth when its population is relatively young and when its adult education level is not high. Thus, some composite index of growth, perhaps taking into account such indicators as economic growth, population growth and industrial growth, could be constructed. Or what of the inclusion of social factors also? Should the growth of housing quality, education levels, patient:doctor ratios etc. be considered for growth? One would imagine so as they are often quoted as indices of spread and backwash effects.

Further variables could also be added to the independent side of the equation and the residuals shown in Figure 7 would appear to indicate that nearness to major highways is important for a centre to have high rates of growth. Another independent variable could be one including time. It would be expected that growth rates in time period, t-1, would influence growth rates in time, t. Introducing time into the model, by for example, expanding the parameters in terms of time, would also be useful in investigating whether the diffusion of growth is being transmitted in waves from growth centres - a subject of still no great certainty. The inclusion of time would also make the model a better predictor of growth rates at future time periods.

The model presented in this paper, like most others, has only described and attempted to explain, growth that has taken place. However, from such a description and explanation it is hoped that predictions could be made for future growth centre strategies. For instance, by indicating how far growth is transmitted, can this tell us anything about the spacing of growth centres? A new growth centre could be simulated in Ontario and the model rerun, with different accessibility functions of course, in order to find the most suitable site for such a growth centre. If the objective is to locate the centre so as to produce the most benefit for ordinary centres, then normally the best site will be in an area which most effectively increases the average accessibility of all centres. But it has been shown here that this is not always the best location strategy. For example, if the policy goal is to stimulate growth of larger ordinary centres then the conclusions about shadow effects suggest that it may be unproductive to locate a growth centre near such ordinary centres.

As mentioned in Chapter 4, the model can be run in different areas to investigate where investments would be most effective. A growth centre having a larger radius of spread effects would be considered a better investment than one with a much smaller radius. Similarly, a region in which growth is very weakly transmitted from growth centres would be considered as a poorer investment than a region in which growth was very strongly transmitted from growth centres.

It should be noted that although this analysis has been carried out on a regional scale and most of the implications of the model have been made at such a scale, there are no conceptual difficulties in using such a model at smaller or larger scales.

It is useful to finally conclude why investigating the spatial impacts of growth centres was seen as an important subject to study within the general area of growth centres. Three main reasons can be given:

(i) Many theoreticians incorporate the notion of spatial impact into their definitions of the term growth centre (see Chapter 1 for examples).

(ii) The assumption that growth centres do benefit much wider areas appears implicit in public policies designed to stimulate development by concentrating upon a few favoured places. Indeed, as Moseley [1974] says:

> "the political acceptability of such discriminating policies may in part rest upon the notion of spatial impact."
>
> -p. 114

(iii) The general level of ignorance on the subject. As Hoover [1969] said:

> "we do not yet know much, particularly in quantitative terms, of the way in which a favourable economic effect is propagated from an urban growth centre to the surrounding territory, or the range and speed of the various impacts."
>
> -p. 352

Hoover's words, even though said at the beginning of an era of quantitative growth centre analysis, could still be echoed today.

Thus, while we observe that some centres grow and because of their growth attract more firms, investment and people, and while we have some idea that this growth may be transmitted to other areas, so far we have little evidence regarding how far, or in what direction, it is transmitted. This paper has presented a method by which several aspects of growth diffusion from growth centres can be measured and it has perhaps indicated some new directions for research in this area.

APPENDIX I - Wilson's justification of the Gravity Model rewritten in terms of growth diffusion.

Define G_{ij} to be the flow of growth from i to j and let:

$$G_{ij} = A_i \, O_i \, B_j \, D_j \, f(c_{ij}) \qquad (1)$$

where A_i and B_j are balancing factors calculated to let

$$\sum_j G_{ij} = O_i \qquad (2)$$

and

$$\sum_i G_{ij} = D_j \qquad (3)$$

so that,

$$A_i = \frac{1}{\sum_i B_j \, D_j \, f(c_{ij})} \qquad (4)$$

$$B_j = \frac{1}{\sum_i A_i \, O_i \, f(c_{ij})} \qquad (5)$$

and $f(c_{ij})$ can be a distance-decay expression such as $d_{ij}^{-\beta}$.
Then rewrite,

$$O_i - \sum_j G_{ij} = 0 \qquad (6)$$

$$D_j - \sum_i G_{ij} = 0 \qquad (7)$$

and also define,

$$C - \sum_{ij}\sum T_{ij} \; c_{ij} = 0 \qquad (8)$$

to indicate that there is some total expenditure of travel effort made.

Then, the number of different ways growth can be assigned to growth flows is:

$$w(G_{ij}) = \frac{G!}{\pi_{ij} \; G_{ij}!} \qquad (9)$$

and the total number of states possible is $W = \Sigma w(G_{ij})$. Now if Lagrangian multipliers are introduced to maximise equation (9) subject to equations (6) and (8) the solution for G_{ij} in terms of the other variables is:

$$G_{ij} = A_i \; B_j \; O_i \; D_j \; e^{-\beta c_{ij}} \qquad (10)$$

which is a gravity-type model that arises when growth flows assume their most-probable state. In equation (9) log w is the entropy of the function and it is this that the gravity model maximises. An alternative statement involving $P_{ij} = G_{ij}/G$ and maximizing $H = -\sum_i \sum_j P_{ij} \log P_{ij}$ gives the same result.

APPENDIX II - Simulation Program to compute accessibility measures to 11 growth centres for a 54x35 grid matrix.

```
      PROGRAM TST (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
      DIMENSION NX(11),NY(11),NP(11),MX(54,35),MY(54,35),F(54,35,11)
      DIMENSION G(54,35),FNX(11),FNY(11),FMX(54,35),FMY(54,35)
      READ(5,10)(NX(K),NY(K),K=1,11)
10    FORMAT(2I2)
      READ(5,20)(NP(K),K=1,11)
20    FORMAT(I7)
      DO 30 J=1,35
      DO 40 I=1,54
      MX(I,J)=I
40    CONTINUE
30    CONTINUE
      DO 50 I=1,54
      DO 60 J=1,35
      MY(I,J)=J
60    CONTINUE
50    CONTINUE
      DO 70 K=1,11
      DO 80 I=1,54
      DO 90 J=1,35
      FNX(K)=NX(K)
      FMX(I,J)=MX(I,J)
      FNY(K)=NY(K)
      FNY(I,J)=MY(I,J)
      F(I,J,K)=SQRT((FNX(K)-FMX(I,J))**2+(FNY(K)-FMY(I,J))**2)*17.6
      IF(F(I,J,K).EQ.0.) F(I,J,K)=0.0000001
90    CONTINUE
80    CONTINUE
70    CONTINUE
      DO 100 I=1,54
      DO 110 J=1,35
      DO 120 K=1,11
      F(I,J,K)=NP(K)/(F(I,J,K))**3
120   CONTINUE
110   CONTINUE
100   CONTINUE
      DO 130 I=1,54
      DO 140 J=1,35
      G(I,J)=0
      DO 150 K=1,11
      G(I,J)=G(I,J)+F(I,J,K)
150   CONTINUE
140   CONTINUE
130   CONTINUE
      WRITE(6,180)((G(I,J),I=1,54),J=1,35)
180   FORMAT(1X,7F12.3)
      STOP
      END
```

APPENDIX III - Rates of growth 1966-71: Population Size 1966; and Accessibility measures for 258 centres in Ontario.

# of Settlement[1]	Rate of Growth 1966-71	Population Size 1966	$\sum_{j=1}^{N} P_j d_{ij}^{-3}$	$\sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$
1	9.15619	557	31.1477	566387.
2	32.9686	9412	51.6385	745501.
3	13.1285	2864	17.8929	651371.
4	.408163	1225	23.0247	666258.
5	8	650	8.40855	531138.
6	11.3769	4641	37.8095	470194.
7	14.6699	409	12.0091	542112.
8	5.67363	5693	11.9625	580208.
9	13.8486	1242	45.5189	727523.
10	6.88623	1002	2.90021	563442.
11	5.64319	4501	22.899	576208.
12	5.76208	2152	1.8435	550884.
13	15.2398	24016	19.6202	673470.
14	3.17003	1388	1.77264	546051.
15	6.86016	758	2.08073	561268.
16	8.40517	464	7.0497	557981.
17	3.38983	531	2.61326	541941.
18	6.75966	932	74.7696	697157.
19	6.31262	998	119.196	809258.
20	7.14656	32785.	2.89742	581267.
21	16.3265	686	19.9109	564016.
22	-4.61709	3617	.54807	425836.
23	-2.66667	750	2.56799	573196.
24	1.87735	799	8.60016	582589.
25	21.3429	1251	10.9196	644592.
26	20.2773	577	1.05645	510652.
27	-1.21951	820	4.00772	499754.
28	13.6416	36264.	587.78	973592.
29	126.7	3045	3.54569	574034.
30	34.48	2529	82.06	777804.
31	-1.50943	530	5.6094	565195.
32	7.63023	59854.	87.3332	733315.
33	12.5059	2111	1734.69	749222.
34	6.86913	2766	4.29752	598823.
35	2.59005	19266	4.72757	575806.
36	.59761	502	.392755	415334.
37	10.7317	820	8.02969	590999.
38	3.125	864	1.51564	523201.
39	31.971	65941.	1475.18	904794.
40	11.6743	651	1.80567	479570.
41	35.2155	673	105.613	807785.
42	16.8073	2725	50.6395	705354.
43	2.23512	3445	4.07902	597695.
44	3.24118	1049	22.3504	689334.
45	4.17099	4819	12.3919	588683.
46	8.96496	1227	24.7467	644198.
47	5.14064	1031	64.7635	713666.
48	.736648	1086	1.57505	527200.
49	-10.8844	147	.422359	422924.
50	8.9224	32424	5.48962	497117.

[1] See appendix IV.

# of Settlement	Rate of Growth 1966-71	Population Size 1966	$\sum_{j=1}^{N} P_j d_{ij}^{-3}$	$\sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$
51	1.01266	395	4.79383	575697.
52	.415184	1686	4.76964	572336.
53	-.476948	1258	14.6791	622409.
54	7.76699	515	10.9211	618437.
55	-.633198	2211	.525363	436014.
56	2.66075	902	1.21086	520616.
57	-2.09997	11524	9.50423	639677.
58	9.51724	1450	5.80222	613623.
59	5.41667	720	8.56797	620298.
60	15.3937	8471	7.4865	608278.
61	7.98663	2692	52.3476	481110.
62	18.1311	717	97.0255	794123.
63	16.6619	3505	1177.73	496503.
64	2.94979	45766.	15.3515	642930.
65	8.70021	5724	6.16515	494939.
66	11.3895	878	18.2437	668161.
67	1.75848	5573	1.31974	518452.
68	11.1619	3503	29.9704	663821.
69	37.8378	185	2.38438	570567.
70	1.47059	1836	2.46236	573819.
71	11.0783	677	25.1358	677726.
72	-.126476	2372	5.58712	500057.
73	3.07487	6732	8.94336E-02	285062.
74	14.574	892	13.5952	644593.
75	11.0122	15501	1673.39	853084.
76	3.22103	5402	45.8866	696448.
77	1.57676	2410	8.93758	613182.
78	3.53774	848	17.501	549914.
79	-5.6157	1478	4.24272	557301.
80	6.98351	1031	11.9952	640228.
81	17.7554	597	46.2988	661103.
82	-3.85475	1790	.358919	418950.
83	.992063	504	3.63734	500734.
84	8.29268	205	3.89015	495312.
85	8.58631	5567	2.59077	457935.
86	3.96776	3226	14.0609	579531.
87	15.0997	1404	5.84393	607201.
88	3.38542	384	13.154	631804.
89	9.48396	2151	6.52213	528773.
90	4.44141	9524	9.73186E-02	285833.
91	2.13933	1823	5.06078	607394.
92	16.1417	33491.	136.98	762733.
93	-.477373	5237	2.5347	561115.
94	44.1261	11832	126.701	833137.
95	-13.1219	3658	8.18765E-02	314921.
96	17.0464	1185	442.162	615011.
97	1.53502	6710	4.88189	549953.
98	11.1111	693	.689725	442219.
99	-12.0101	791	17.903	562729.
100	19.2612	758	38.6343	725539.

# of Settlement	Rate of Growth 1966- 1	Population Size 1966	$\sum_{j=1}^{N} P_j d_{ij}^{-3}$	$\sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$
101	119.005	3257	3.20087	564927.
102	16.9531	51377.	95.1378	778590.
103	3.70722	298121.	*1.70141E+38	1.7014
104	2.1167	1748	17.4308	649570.
105	1.54559	1941	46.5831	468567.
106	7.56881	872	5.63394	612983.
107	8.16993E-02	1224	3.37738	587644.
108	3.85439	934	9.49859	567013.
109	12.3867	331	2.75456	540887.
110	.712589	421	5.12464	516638.
111	0	165	.267508	399013.
112	192.759	3342	1.85689	540249.
113	14.6982	762	.350267	410704.
114	7.27432	1141	10.8372	609289.
115	17.1116	824	34.1559	679102.
116	1.7199	12617	.097152	352971.
117	-2.53165	316	1.54664	527723.
118	1.10101	2089	.282959	283615.
119	10.5866	2182	24.6901	611156.
120	-3.03674	11295	.224243	283187.
121	-1.81818	825	2.16929	543821.
122	14.7361	2823	2.92689	536810.
123	14.9788	3545	21.2923	470873.
124	19.8906	93255.	*1.70141E+38	1.70141
125	.133809	2242	6.54242	620172.
126	3.00501	599	28.055	677177.
127	-2.54545	3025	17.1956	459807.
128	5.42597	12090	10.7478	645107.
129	11.7225	418	1.64697	511029.
130	3.33628	4526	27.5453	640699.
131	8.60514	1441	1.13397	455140.
132	-5.33291	3169	142.208	474134.
133	13.4895	1238	36.4715	694818.
134	16.5183	1011	120.429	607823.
135	-4.4708	1096	5.12353	565412.
136	-2.31047	1385	2.42263	572137.
137	6.25	192	1.46612	510178.
138	11.0512	1113	12.3271	639964.
139	4.49714	1223	1.11345	440556.
140	-8.33599	3143	.981811	491520.
141	4.63011	3866	4.50397	575010.
142	-.107411	931	10.1644	589540.
143	8.52009	10129	5.87256	596534.
144	2.12089	943	7.07759	593418.
145	-1.94384	926	14.0973	662031.
146	6.32798	1122	22.3141	629299.
147	7.33868	2371	14.018	606635.
148	6.03715	1938	11.3504	616815.
149	6.22595	2859	13.2058	638109.
150	.760374	4603	2.3241	570332.

# of Settlement	Rate of Growth 1966-71	Population Size 1966	$\sum_{j=1}^{N} P_j d_{ij}^{-3}$	$\sum_{j=1}^{N} P_j d_{ij}^{-\frac{1}{2}}$
151	2.65957	564	8.79085	606256.
152	4.96454	282	4.08916	572301.
153	.977199	614	2.2441	567499.
154	-.879766	341	49.9511	572078.
155	15.3207	1684	9.51951	638158.
156	23.3798	2438	41.4585	652525.
157	4.35444	5259	.472751	431089.
158	18.0556	56891.	*1.70141E+38	1.70141E+
159	108.111	23635	1.03244	485394.
160	6.73759	1692	23.9083	641184.
161	8.23422	1093	4.2177	599091.
162	16.4605	52793.	343.077	923007.
163	8.15939	527	5.28008	514023.
164	-9.33489	857	16.3708	668863.
165	44.4882	5588	60.1361	763038.
166	17.2959	78082.	75.3201	774220.
167	3.98991	290741.	*1.70141E+38	1.70141E+
168	13.6103	698	3.62922	553101.
169	13.7339	1631	13.5278	620105.
170	3.38064	6271	123.696	728867.
171	3.64121	1126	31.1477	566387.
172	-.99983	5901	2.08748	535567.
173	1.7341	16262	1.96065	535993.
174	2.76687	5349	4.99968	586464.
175	3.76749	5574	1.77859	532570.
176	3.44269	56177.	8.14209	630977.
177	2.92695	3929	4.29935	506854.
178	27.4234	1991	38.4998	726223.
179	-3.02367	5027	2.21669	565732.
180	8.73206	836	25.7129	675050.
181	-4.47813	2903	4.08147	508703.
182	6.70732	656	11.9567	589344.
183	5.80745	3220	16.3149	635568.
184	20.0331	1208	6.45002	601356.
185	12.2972	2651	32.7112	713183.
186	11.0246	771	11.0485	608108.
187	15.9274	1488	9.0689	539643.
188	8.5901	1071	1.14084	500128.
189	-.212519	5176	6.67384	586180.
190	4.09051	1149	.174962	283720.
191	5.41177	425	3.58525	548292.
192	-4.80855	2246	57.7507	645105.
193	3.87134	3513	20.3538	640206.
194	-6.78899	1090	10.414	539321.
195	16.4502	231	2.09915	539694.
196	12.9978	97101.	*1.70141E+38	1.70141E+
197	13.803	1746	79.2872	493943.
198	16.0377	530	20.8998	658390.
199	-2.10526	4750	36.8575	631680.
200	11.1474	22983	62.9735	598000.

Settlement	Rate of Growth 1966-71	Population Size 1966	$\sum_{j=1}^{..} P_j d_{ij}^{-3}$	$\sum_{j=1}^{..} P_j d_{ij}^{-1/2}$
201	5.66799	54552.	3.79615	500760.
202	7.69231	74594.	.19905	384844.
203	-4.77465	2241	8.80917	575971.
204	14.5833	336	7.44957	604448.
205	32.2009	1354	17.4438	663870.
206	8.70178	9929	22.2152	653572.
207	-2.94654	9876	6.81222	580157.
208	4.03023	1191	.128318	367782.
209	12.0341	939	1.67702	525959.
210	7.40741	486	18.0318	612895.
211	9.31151	1772	13.7931	649192.
212	10.7829	1354	2.82361	580721.
213	20.7753	1651	79.823	644182.
214	15.6979	7243	2293.45	891137.
215	6.24241	23068	57.3288	640685.
216	13.9302	5786	20.73	553268.
217	3.60809	6430	1.70008	472091.
218	125	16	10.9564	645409.
219	6.65229	84888.	*1.70141E+38	1.70141E-
220	1.2605	714	1.50962	513535.
221	19.5167	538	3.61774	556337.
222	4.93702	4922	748.544	512764.
223	5.02137	936	5.99449	572190.
224	-3.65511	1067	6.68121	524767.
225	4.35414	689	21.1892	581785.
226	11.3152	1688	.303523	404537.
227	6.17929	1149	5.80013	590340.
228	-12.1019	157	.200484	384703.
229	1.25651	6526	48.945	603782.
230	-2.597	29303	.187759	383136.
231	46.134	388	4.22877	561607.
232	7.25296	664584.	*1.70141E+38	1.70141E-
233	106.914	781	35.9923	717049.
234	12.6923	520	1.15275	505064.
235	-.515169	1747	2.96698	582794.
236	17.3979	2621	45.3194	736744.
237	-7.38391	24269	147.928	654581.
238	1.74489	1662	59.3794	726238.
239	11.5799	1114	5.6662	597011.
240	13.0435	345	13.8882	599292.
241	2.26027	4380	4.41143	561705.
242	23.5669	314	76.6024	581620.
243	39.1462	1382	9.41173	624554.
244	10.9044	1935	632.919	852667.
245	22.7107	29889	*1.70141E+38	1.70141E-
246	7.77521	1299	7.63527	531489.
247	1.03627	579	13.9141	454442.
248	11.1036	39960.	152.801	765197.
249	2.06612	968	2.39752	569009.
250	10.6168	989	26.2682	561665.
251	-2.43507	616	3.5754	570770.
252	9.24287	2034	2.57457	538292.
253	5.58626	192544.	*1.70141E+38	1.70141E-
254	-2.05111	2974	5.45323	572011.
255	8.93162	24027	50.0357	642406.
256	9.74478	431	15.3478	661632.
257	24.9023	1024	5.00655	514515.
258	4.07056	737	10.8656	602315.

* = Designated Growth Centres. Infinite accessibilities due to dividing by 0.

APPENDIX IV - Names of the 258 centres used.

Number	Name	Number	Name
1	Ailsa Craig	38	Burk's Falls
2	Ajax	39	Burlington
3	Alexandria	40	Cache Bay
4	Alfred	41	Caledon East
5	Alvinston	42	Caledonia
6	Amherstburg	43	Campellford
7	Arkona	44	Cannington
8	Arnprior	45	Carleton Place
9	Arthur	46	Casselman
10	Athens	47	Cayuga
11	Aylmer	48	Chalk River
12	Bancroft	49	Charlton
13	Barrie	50	Chatham
14	Barry's Bay	51	Chatsworth
15	Bath	52	Chesley
16	Bayfield	53	Chesterville
17	Beachburg	54	Clifford
18	Beachville	55	Cobalt
19	Beeton	56	Cobden
20	Belleville	57	Cobourg
21	Belmont	58	Colborne
22	Blind River	59	Coldwater
23	Bloomfield	60	Collingwood
24	Blyth	61	Coniston
25	Bobcaygeon	62	Cookstown
26	Bonfield	63	Copper Cliff
27	Bothwell	64	Cornwall
28	Brampton	65	Courtright
29	Bracebridge	66	Creemore
30	Bradford	67	Deep River
31	Braeside	68	Delhi
32	Brantford	69	Deloro
33	Bridgeport	70	Deseronto
34	Brighton	71	Drayton
35	Brockville	72	Dresden
36	Bruce Mines	73	Dryden
37	Brussels	74	Dundalk

Number	Name	Number	Name
75	Dundas	126	Lancaster
76	Dunnville	127	Levack
77	Durham	128	Lindsay
78	Dutton	129	Lion's Head
79	Eganville	130	Listowel
80	Elmvale	131	Little Current
81	Embro	132	Lively
82	Englehart	133	L'Original
83	Erieau	134	Lucan
84	Erie Beach	135	Lucknow
85	Espanola	136	Madoc
86	Exeter	137	Magnetawan
87	Fenelon Falls	138	Markdale
88	Finch	139	Massey
89	Forest	140	Mattawa
90	Fort Frances	141	Meaford
91	Frankford	142	Merrickville
92	Galt	143	Midland
93	Gananoque	144	Mildmay
94	Georgetown	145	Millbrook
95	Geraldton	146	Milverton
96	Glencoe	147	Mitchell
97	Goderich	148	Morrisburg
98	Gore Bay	149	Mount Forest
99	Grand Bend	150	Napanee
100	Grand Valley	151	Neustadt
101	Gravenhurst	152	Newboro
102	Guelph	153	Newburgh
103	Hamilton	154	Newbury
104	Harriston	155	Newcastle
105	Harrow	156	New Hamburg
106	Hastings	157	New Liskeard
107	Havelock	158	Niagara Falls
108	Hensall	159	North Bay
109	Hepworth	160	Norwich
110	Highgate	161	Norwood
111	Hilton Beach	162	Oakville
112	Huntsville	163	Oil Springs
113	Iron Bridge	164	Omemee
114	Iroquois	165	Orangeville
115	Jarvis	166	Oshawa
116	Kapukasing	167	Ottawa
117	Kearney	168	Paisley
118	Keewatin	169	Palmerston
119	Kemptville	170	Paris
120	Kenora	171	Parkhill
121	Killaloe Station	172	Parry Sound
122	Kincardine	173	Pembroke
123	Kingsville	174	Pentaguishene
124	Kitchener	175	Petawawa
125	Lakefield	176	Peterborough

Number	Name
177	Petrolia
178	Pickering
179	Picton
180	Plantagenet
181	Point Edward
182	Port Burwell
183	Port Dover
184	Port McNicoll
185	Port Perry
186	Port Rowan
187	Port Stanley
188	Powassan
189	Prescott
190	Rainy River
191	Ripley
192	Rockcliffe Park
193	Rockland
194	Rodney
195	Rosseau
196	St. Catherines
197	St. Clair Beach
198	St. Isodore de Prescott
199	St. Mary's
200	St. Thomas
201	Sarnia
202	Soo
203	Seaforth
204	Shallow Lake
205	Shelburne
206	Simcoe
207	Smith's Falls
208	Smooth Rock Falls
209	South River
210	Springfield
211	Stayner
212	Stirling
213	Stittsville
214	Stoney Creek
215	Stratford
216	Strathroy
217	Sturgeon Falls
218	Sturgeon Point
219	Sudbury
220	Sundridge
221	Tara
222	Tecumseh
223	Teeswater

Number	Name
224	Thamesville
225	Thedford
226	Thessalon
227	Thornbury
228	Thornloe
229	Tillsonburg
230	Timmins
231	Tiverton
232	Toronto
233	Tottenham
234	Trout Creek
235	Tweed
236	Uxbridge
237	Vanier
238	Vankleek Hill
239	Victoria Harbour
240	Vienna
241	Walkerton
242	Wardsville
243	Wasaga Beach
244	Waterdown
245	Waterloo
246	Watford
247	Webbwood
248	Welland
249	Wellington
250	West Lorne
251	Westport
252	Wiarton
253	Windsor
254	Wingham
255	Woodstock
256	Woodville
257	Wyoming
258	Zurich

BIBLIOGRAPHY

Allen, K. & T. Hermansen, [1968] "Economic Growth-regional problems and growth centres", in EFTA [1968].

Allen, K. & M.C. MacLennan, [1970] "Regional Problems and Policies in Italy and France". Allen and Unwin, London.

Alonso, W. [1968] "Industrial Location and Regional Policy in Economic Development". Center for Planning and Development Research, Working Paper 74, University of California, February.

Alonso, W. & E. Medrich, [1972] "Spontaneous Growth Centres in Twentieth Century American Urbanisation", in N.M. Hansen [1972].

Appalachia Regional Commission [1968] "The State and Regional Development Plans in Appalachia, 1968".

Aydalot, P. [1965] "Etudes sur les processus de polarisation et sur les réactions des industries anciennes à la lumière de l'expérience à Lacq". Cahiers de l'I.S.E.A., L, March.

Berry, B.J.L. [1967] "Spatial Organization and Levels of Welfare. Degree of Metropolitan Labor Market Participation as a variable in Economic Development". Paper presented to the Economic Development Administration Research Conference, Washington, D.C. October 9-13, 1967.

Berry, B.J.L. [1969] "Relationships between Regional Economic Development and the Urban System: the case of Chile". Tijdschrift voor Economisch en Sociale Geografie, 60, pp. 283-307.

Berry, B.J.L. [1972] "Hierarchical Diffusion: The basis of Development filtering and spread in a system of Growth Centres", in N.M. Hansen, [1972].

Berry, B.J.L. [1973] article in "Geographic Perspectives and Urban Problems" ed. F. Horton, National Academy of Sciences, Washington, D.C.

Berry, B.J.L. & E. Neils, [1969] "Location, Size and Shape of Cities as Influenced by Environmental Factors: The Urban Environment Writ Large", in "The Quality of the Urban Environment" ed. H.S. Perloff [1969].

Beyers, W.B. [no date] "Growth Centers and Interindustry Linkages". Unpublished paper, Department of Geography, University of Washington, Seattle.

Borchert, J-R. [1963] "The Urbanisation of the Upper-Midwest: 1930-1960". Upper Midwest Economic Study, Urban Report #2, pp. 13-19.

Boudeville, J-R. [1957] "Contribution à létude des pôles de Croissance Brésiliennes: une industrie motice, la sidéruge du Minas Gerais." Cahiers de l'I.S.E.A. F, 10.

Boudeville, J-R. [1961] "Un Modèle des Mauvements Commerciaux interrégionaux en France". Cahiers de L'I.S.E.A. L, 9

Boudeville, J-R. [1966] "Problems of Regional Economic Planning". Edinburgh University Press, Edinburgh.

Boudeville, J-R. [1968] "Les Notions d'espace et d'intégration", in "L'Espace et les Pôles de Croissance", ed. J-R. Boudeville [1968].

Boventor E. von [1973] "City Size Systems: theoretical issues, empirical regularities, and planning guides". Urban Studies. 10(2), pp 145-162.

Bowers, R.V. [1937] "The Direction of Intra-Societal Diffusion". American Sociological Review, 2, pp. 826-36.

Brewis, T.N. [1968] "Regional Economic Policies in Canada".

Carol, H. [1966] "Geographic Identification of Regional Growth Centres and Development Regions in S. Ontario". A report to the Regional Development Branch, Department of Economics and Development, Province of Ontario, Toronto.

Casetti, E. [1972]"Generating Models by the Expansion Method; Applications to Geographical Research". Geographical Analysis, 4. pp. 81-91.

Casetti, E. [1973] "Testing for Spatial-Temporal Trends: An Application to Urban Population Density Trends using the Expansion Method". Canadian Geographer, Summer, pp. 127-137.

Casetti, E., L.J. King & J. Odland, [1971] "The Formalisation and Testing of Concepts of Growth Poles in a Spatial Context". Environment and Planning Vol. 3, pp. 377-382.

Casetti, E., L.J. King & F. Williams, [1972] "Concerning the Spread of Economic Development", in "International Geography" 1972 eds. W.P. Adams & F. Helleiner. Vol. 2. pp. 897-899, University of Toronto Press.

Chisholm, M. [1964] "Rural Settlement and Land Use".

Cohen, Y.S. [1972] "Diffusion of an Innovation in an Urban System: the spread of planned regional shopping centres in the United States, 1949-1968". University of Chicago, Department of Geography, Research Paper #140, Chicago.

Crain, R.L. [1966] "Fluoridation: The Diffusion of an Innovation Among Cities" Social Forces, 44, pp. 467-76.

Darwent, D.F. [1969] "Growth Poles and Growth Centres in Regional Planning: A Review". Environment and Planning Vol. 1, #1 pp 5-31. Reprinted in Friedmann & Alonso [1975].

Davin, L.E. [1961] "Les conditions de croissance des economies régionales dans les pays développés". Théorie et Politique de l'Expansion Régionale, Institut de Science Economique, Universitié de Liége.

Davin, L.E., L. Degeer & J. Paelinck [1959] "Dynamique Economie de la Région Liégeoise". Press Universitaire de France, Paris.

"Design for Development: The Toronto-Centered Region" Toronto [1970].

EFTA [1968] "Regional Policy in EFTA: An Examination of the Growth Centre Idea". Oliver & Boyd, Edinburgh.

Fotheringham, A.S. [1975] "Time Space Divergence and Spatial Reorganisation in Cleveland". Unpublished Batchelor's thesis. University of Aberdeen, 1975.

Fox, C. [1966] "The Role of Growth Centres in Regional Economic Development".

Friedmann, J. [1963] "Regional Economic Policy for Developing Areas". Papers of the Regional Science Association. 11 pp 41-61.

Friedmann, J. [1966] "Regional Development Policy-A case study of Venezuala". M.I.T. Press, Cambridge, Mass.

Friedmann, J. & W. Alonso, [1975] "Regional Policy. Readings in Theory and Applications". The M.I.T. Press, Cambridge, Mass.

Gaile, J. [1973] "Growth Center Theory: an Analysis of its Formal Spatial-Temporal Aspects". Unpublished paper presented at the Southern California Academy of Sciences Annual Meeting, Long Beach, California, May 1973.

Goodall, B. [1972] "The Economies of Urban Areas". Pergamon, Oxford.

Government of Canada Publication. Census of Canada 1971.

Hägerstrand, T. [1952] "The Propagation of Innovation Waves". Lund: Gleerup. Lund Studies in Geography, 1952.

Hägerstrand, T. [1953] "Innovations for loppet ur korologisk Synpunkt". Lund: Gleerup. Translated in 1967 in "Innovation Diffusion as a Spatial Process". University of Chicago Press, Chicago.

Hanham, R.Q. & L.A. Brown [1976] "Diffusion Waves within the context of Regional Economic Development". Journal of Regional Science. Vol. 16. #1, 1976, pp. 65-71.

Hansen, N.M. [1967] "Development Pole Theory in a Regional Context". Kyklos xx pp. 709-725.

Hansen, N.M. [1970] "Rural Poverty and the Urban Crisis: A Strategy for Regional Development. Indiana University Press, Bloomington.

Hansen, N.M. [1971] "Intermediate-Size Centres as Growth Centres". Praeger, New York.

Hansen, N.M. [1972a] "Criteria for a Growth Centre Plicy", in Kuklinski, A. [1972].

Hansen, N.M. (ed.) [1972b] "Growth Centres in Regional Economic Development". The free press of Glencoe, New York.

Hansen, N.M. [1975] "An Evaluation of Growth Centre Theory and Practice". Environment and Planning 1975, Vol. 7, pp. 821-832.

Heathfield, D.F. (ed.) [1976] "Topics in Applied Macroeconomics".

Hermansen, T. [1972] "Development Poles and Development Centres", in A. Kuklinski [1972].

Higgins, B. [1972]"Regional Interaction, the Frontier and Economic Growth", in A. Kuklinski [1972].

Hirsch, W.Z. [1968] "The Supply of Urban Public Services", in H.S. Perloff & L. Wingo Jnr. (eds.) "Issues in Urban Economics". The John Hopkins Press, Baltimore, Md.

Hirschman, A.O. [1958] "The Strategy of Economic Development". Yale University Press, New Haven.

Hodge, G. [1966] "The Identification of Growth Poles in Eastern Ontario". A report to the Ontario Department of Economics and Development, Ontario.

Hoover, E.M. [1968] "The Location of Economic Activity".

Hoover, E.M. [1969] "Some Old and New Issues in Regional Development", in "Backward Areas in Advanced Countries". ed. E.A.G. Robinson, MacMillan, London.

Isard, W. & E.W. Schooler, [1959] "Industrial Complex Analysis: Agglomeration, Economies and Regional Development". Journal of Regional Science, Spring.

Jozsa, J.M. [1975] "A Method for the Analysis of Economic Polarization: Two Case Studies; Halifax-Dartmouth, Nova Scotia and Quebec City, Quebec". Master's Research Report, Department of Geography, McMaster University, 1975.

Keeble, D.E. [1967] "Models of Economic Development", in "Socio-Economic Models in Geography". eds. R.J. Chorley & P. Haggett, Methuen, London.

King, L.J. [1974] "Conceptual Limitations and Data Problems in the formulating of Growth Pole Strategies. The Case of Ontario, Canada". Geoforum Vol. 17, pp. 61-67.

King, L.J., E. Casetti & D. Jeffrey, [1969] "Economic Impulses in a Regional System of Cities: A study of Spatial Interaction". Regional Studies, 3 pp. 213-218.

Kuehn, J.A. & C.P. Bender [1969] "An Empirical Identification of Growth Centers". Land Economics, 45 pp 435-43.

Kuklinski, A. [1972] "Growth Poles and Growth Centres in Regional Planning".

Lasuen, J-R. [1973] "Urbanisation and Development - the Temporal Interaction between geographical and sectoral clusters". Urban Studies, 10(2), 163.

Lloyd, P. & P. Dicken [1975] "Location in Space".

Martin, F. [1976] "La dynamique du dévelopement urbain au Quebec". Annexe au Rapport du Groupe de travail sur l'urbanisation. Quebec, 1976.

McCombie, J.S.L. [1974] "Some Aspects of Growth in the Space Economy". Unpublished Master's Research Paper, Department of Geography, McMaster University, 1974.

McKee, D., R. Dean & W. Leahy [1970] eds. "Regional Economics". The Free Press, New York.

McVoy, E.C. [1946] "Patterns of Diffusion in the United States". American Sociological Review, 5 (1940) pp. 219-27.

Mønsted, M. [1974] "Francois Perroux's Theory of 'Growth Pole and Development Pole': A critique". Antipode 6, 2. pp. 106-113.

Moriarty, B.M. [1976] "The Distributed Lag between Metropolitan-Area Employment and Population Growth". Journal of Regional Science. Vol. 16, No. 2. 1976, pp. 195-212.

Morrill, R.L. [1968] "Waves of Spatial Diffusion". Journal of Regional Science. Vol. 8. pp. 1-18.

Morrill, R.L. [1973] "On the Size and Spacing of Growth Centers." Growth and Change 4(2) pp. 21-24.

Moseley, M.J. [1973a] "The Impact of Growth Centres in rural regions I. An Analysis of spatial 'patterns' in Brittany". Regional Studies, 7. pp. 77-94.

Moseley, M.J. [1973b] "The Impact of Growth Centres in rural regions II: An Analysis of spatial 'flows' in East Anglia". Regional Studies, 7. pp 77-94.

Moseley, M.J. [1974] "Growth Centres in Spatial Planning". Pergamon Press.

Myrdal, G. [1957] "Economic Theory in Underdeveloped Regions".

Newling, B.E. [1969] "The Spatial Variation of Urban Population Densities". Geographical Review, 59, pp. 242-252.

Nichols, V. [1969] "Growth Poles: An Evaluation of their Effect". Environment and Planning. Vol. 1 pp. 193-208. Reprinted in Friedmann & Alonso [1975].

Odland, J., E. Casetti, & L.J. King [1973] "Testing Hypotheses of Polarised Growth within a Central Place Hierarchy". Economic Geography. 49, 1 pp. 74-79.

Paelinck, J.C. [1965] "La Théorie du Développement Régionale Polarisé". Cahiers de Institut de Science Applique. Serio L. No. 15.

Parks, R.D. [1976] "Econometric Introduction" - article in "Topics in Applied Macroeconomics" ed. D.F. Heathfield [1976].

Parr, J.B. [1966] "Outmigration and the Depressed Area Problem". Land Economics, 42 pp. 149-59.

Parr, J.B. [1973] "Growth Poles, Regional Development and Central Place Theory". Papers of the Regional Science Association. 31, p. 175.

Pedersen, P.O. [1970] "Innovation Diffusion within and between National Urban Systems". Geographical Analysis, 2, 1970. pp. 203-254.

Perroux, F. [1950] "Economic Space, Theory and Applications". Quarterly Journal of Economics. 64. pp 89-104.

Perroux, F. [1955] "Note sur la notion de 'pole de croissance". in McKee, Dean and Leahy [1970].

Pred, A.R. [1966] "The Spatial Dynamics of U.S. Urban-Industrial Growth, 1800-1914: Interpretive and Theoretical Essays". M.I.T. Press, Cambridge, Mass.

Regulski, J. [1972] "Development Pole Theory and its Applications in Poland". In Kuklinski [1972].

Report to the Congress on the Proposal for an Economic Adjustment Program [1974]. Department of Commerce and the Office of Management and Budget, Washinton, D.C.

Richardson, H.W. [1971] "Regional Development Policy in Spain". Urban Studies, 8, pp.39-53.

Richardson, H.W. [1976] "Growth Pole Spillovers: the dynamics of Backwash and Spread", Regional Studies, Vol. 10, pp. 1-9.

Rikkinen, K. [1968] "Change in village and rural population with distance from Duluth". Economic Geography, 44 pp 312-25.

Robinson, E.A.G. [1969] "Introduction" in E.A.G. Robinson (ed.) "Backward Areas in Advanced Countries". New York. St. Martin's Press.

Salisbury, N.E. & G. Rushton [1963] "Growth and Decline of Iowa villages: A pilot Study". Department of Geography, No. 4. State University of Iowa, 1963.

Scitovsky, T. "Two Concepts of External Economies". Journal of Political Economy. April 1954. Vol. 62. p. 143 ff.

Semple, R.K., H.L. Gauthier & C.E. Youngman. [1972] "Growth Poles in Sao Paulo, Brazil". AAAG 62, pp. 591-9.

Thomas, G.B. Jnr. [1969] "Calculus and Analytical Geometry". Addison Wesley, Reading, Mass.

Thompson, W.R. [1965] "A Preface to Urban Economies" Baltimore, Md., The Johns Hopkins Press.

Todd, D. [1974] "An appraisal of the Development Pole Concept in Regional Analysis". Environment and Planning. 6(3) pp 291-306.

Tolosa, H. & J.A. Reiner [1970]. "The Economic Programming of a System of Planned Poles". Economic Geography, 46. pp. 449-57.

Wilson, A.G. [1967] "Towards Comprehensive Planning Models". Paper presented at the London conference of the Regional Science Association, August, 1967.

Yeates, M.H. & P.E. Lloyd [1969] "Impact of Industrial Incentives: Southern Georgian Bay Region, Ontario". Geography Paper #44, Policy and Planning Branch, Department of Energy, Mines and Resources, Ottawa, Canada.