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# Functional Polycentrism and Urban Network Development in the Greater South East, United Kingdom: Evidence from Commuting Patterns, 1981–2001

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De Goei B., Burger M. J., Van Oort F. G. and Kitson M. Functional polycentrism and urban network development in the Greater South East, United Kingdom: evidence from commuting patterns, 1981–2001, *Regional Studies*. In contemporary literature on changing urban systems, it is often argued that the traditional central place conceptualization is outdated and should be replaced by a network view that emphasizes the increasing criss-crossing pattern of interdependencies between spatial units. This paper tests how urban networks develop by looking at commuting patterns in the Greater South East, United Kingdom, for the period 1981–2001. Although the empirical results indicate that the Greater South East cannot be currently characterized as a polycentric urban region or an integrated urban network, there is some evidence for urban network development at the local, intra-urban, level, and a decentralization of the system at the regional, inter-urban, level.

United Kingdom Greater South East Urban networks Commuting Gravity model

De Goei B., Burger M. J., Van Oort F. G. and Kitson M. 英国大东南部地区的功能多中心主义和城市网络发展：来自1981–2001年间通勤模式的相关证据，区域研究。目前讨论城市系统变迁的多数研究认为，传统的中心地概念已经过时，而强调空间单元之间纵横交错、相互依存关系的网络观点应将其取代。通过关注英国大东南地区1981–2001年期间的通勤模式，本文考察了城市网络是如何发展的。尽管实证结果表明，英国大东南地区目前还不能作为一个多中心的城市地区或整合的城市网络，但这种城市网络在地方和城市内的层面已有所发展，而在区域和城市间层面上也出现非中心的（城镇）体系。

英国 大东南部 城市网络 通勤交通 引力模型

De Goei B., Burger M. J., Van Oort F. G. et Kitson M. Le polycentrisme fonctionnel et le développement des réseaux urbains dans l'agglomération du sud-est du R-U: des preuves provenant de la structure des migrations quotidiennes entre 1981 et 2001, *Regional Studies*. Dans la documentation récente sur l'évolution des systèmes urbains, on affirme souvent que la notion classique de la place centrale est démodée et que l'on devrait la remplacer par une notion de réseaux qui souligne la croissance des interdépendances entrecroisées des zones géographiques. Cet article cherche à tester l'évolution des réseaux urbains tout en examinant la structure des migrations quotidiennes urbaines dans l'agglomération du sud-est du R-U entre 1981 et 2001. Bien que les résultats empiriques laissent voir que l'agglomération du sud-est du R-U ne se caractérise actuellement ni comme une région urbaine polycentrique, ni comme un réseau urbain intégré, il y a des preuves en faveur du développement des réseaux urbains sur le plan local intraurbain et d'une décentralisation du système au niveau régional interurbain.

Royaume-Uni Agglomération du sud-est Réseaux urbains Migrations quotidiennes Modèle de gravité

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DE GOEI B., BURGER M. J., VAN OORT F. G. und KITSON M. Funktionaler Polyzentrismus und Entwicklung urbaner Netzwerke im Großraum des Südostens von Großbritannien: Belege aus Pendlerströmen, 1981–2001, *Regional Studies*. In der modernen Literatur über Veränderungen in den urbanen Systemen wird oftmals die These aufgestellt, dass die traditionelle Konzeptualisierung eines zentralen Ortes veraltet ist und durch eine Netzwerkperspektive ersetzt werden sollte, mit der die zunehmend kreuz und quer verlaufenden Wechselwirkungen zwischen räumlichen Einheiten betont wird. In diesem Beitrag überprüfen wir die Entwicklung urbaner Netzwerke am Beispiel der Pendlerströme im Großraum des Südostens von Großbritannien zwischen 1981 und 2001. Aus den empirischen Ergebnissen geht hervor, dass sich der Südosten Großbritanniens derzeit nicht als polyzentrische urbane Region oder integriertes urbanes Netzwerk charakterisieren lässt. Dennoch gibt es einige Anzeichen für die Entwicklung eines urbanen Netzwerks auf lokaler intra-urbaner Ebene sowie für eine Dezentralisierung des Systems auf regionaler intra-urbaner Ebene.

Großbritannien Großraum Südost Urbane Netzwerke Pendlerverkehr Schwerkraftmodell

DE GOEI B., BURGER M. J., VAN OORT F. G. y KITSON M. Policentrismo funcional y desarrollo de redes urbanas en el sureste de Inglaterra: evidencias de modelos de desplazamientos, 1981–2001, *Regional Studies*. En la literatura contemporánea sobre cambios en los sistemas urbanos se suele argumentar que la conceptualización tradicional de un lugar céntrico está desfasada y debería reemplazarse por una visión de redes que haga hincapié en el creciente modelo entrecruzado de interdependencias entre las unidades espaciales. En este artículo comprobamos cómo se desarrollan las redes urbanas al observar los modelos de desplazamientos en la región sureste del Reino Unido durante el periodo 1981–2001. Aunque los resultados empíricos indican que la región sureste del Reino Unido no se puede caracterizar actualmente como una región urbana policéntrica o una red urbana integrada, hay evidencias de un desarrollo de redes urbanas a nivel local e intraurbano y una descentralización del sistema a nivel regional e interurbano.

Reino Unido Zona sureste Redes urbanas Desplazamientos al trabajo Modelo de gravedad

JEL classifications: O21, R11, R23, R58

## INTRODUCTION

Regional planners in the Netherlands, Belgium, Germany, and the United Kingdom have increasingly viewed the development of urban networks as a means to stimulate local and regional economic growth and competitiveness (MEIJERS, 2005; HALL and PAIN, 2006). This view has also been embraced by the European Union ministers responsible for spatial and regional planning (COMMITTEE ON SPATIAL DEVELOPMENT (CSD), 1999).[1] In particular, urban networks are promoted to take advantage of positive externalities associated with large agglomerations, such as an enlarged labour market and major facilities such as air- and seaports, while avoiding the negative externalities of urban sprawl and congestion (BAILEY and TUROK, 2001; PARR, 2004). In addition, the city and its surrounding region is considered as the new loci of international territorial competition (ROMEIN, 2004). This has increased the desire of local policy-makers to promote their city regions as one entity, in order to position them more strongly on the international stage (MEIJERS, 2005). In the UK, the Greater South East – the large conurbation around the city of London and extending from Southampton in the south-west to Peterborough in the north (Fig. 1) – is perceived as a mega-city region which is increasingly evolving into an urban network (HALL *et al.*, 2006; ALLEN and COCHRANE, 2007; PAIN, 2008).

The debate on urban networks is fuelled by a large literature on the changing spatial organization of cities at the intra-urban and inter-urban scales (BATTEN, 1995; KLOOSTERMAN and MUSTERD, 2001). In this literature, it is often argued that recent advances in transport and communication technology, the increasing connectivity of economies worldwide (globalization), and the individualization of production have had a significant impact on the spatial configuration of urban regions. At the local or metropolitan intra-urban scale, cities are developing from a monocentric urban city towards a more polycentric urban configuration. The traditional city has a strict city–hinterland separation, with a city centre generating demand for labour and surrounding suburban areas providing the labour supply (BURGESS, 1925). However, it can be conjectured that suburban areas increasingly emerge into local centres that develop their own economic activities and demand for labour. Consequently, these 'new' local centres start competing with the original urban core (GARREAU, 1991). Concurrently, the geographical scope of social and economic processes (such as commuting, inter-firm relations, and business-to-consumer relations) is continuously increasing (VAN DER LAAN, 1998; FRANDBERG and VILHELMSON, 2003; URRY, 2004). The latter results in an increasingly complex formation of functional linkages between historically separated urban regions at the regional inter-urban scale. Hence, it is often argued that the traditional central place conceptualization of urban systems, characterized by local urban hierarchies, is outdated and should be replaced by a regional urban network view that emphasizes a complex pattern of interdependencies between spatial units at the intra-urban (local) and inter-urban (regional) scales (KLOOSTERMAN and MUSTERD, 2001).

The academic literature and the policy discourse on urban networks are rich in their analytical descriptions

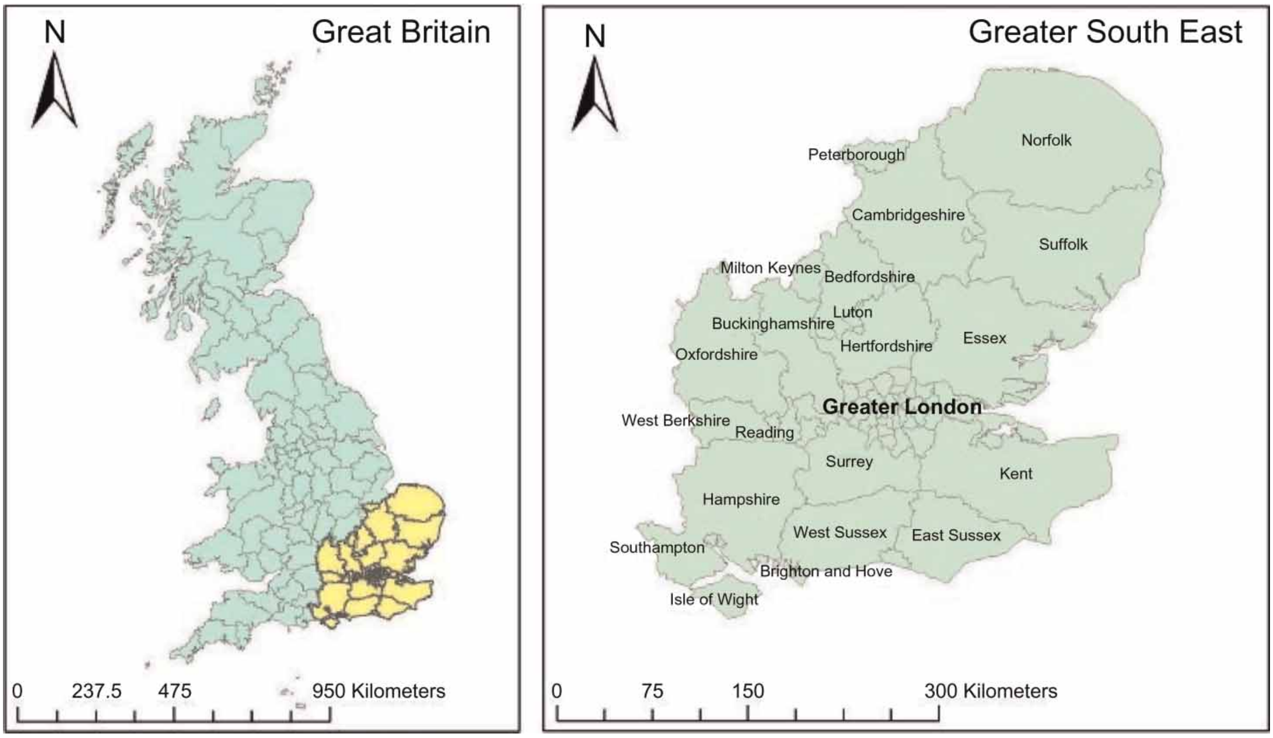


*Fig. 1. The Greater South East in the United Kingdom*

of polycentric regions and urban networks. However, only a few empirical studies have quantitatively assessed how well the urban network model fits the reality of contemporary urban systems (DAVOUDI, 2003). Moreover, these studies suffer from two major difficulties. First, most of the available empirical evidence is based on node characteristics. Consequently, researchers use methods such as location quotients, rank–size relations, sufficiency indices, and employment-to-work ratios rather than methods based on flow characteristics (LIMTANAKOOL *et al.*, 2007). This is partly due to a lack of data regarding the network between cities. However, the focus on node characteristics is unsatisfactory in that it can only yield a proxy of spatial interaction; it cannot account for the actual structure of urban systems (IRWIN and HUGHES, 1992; SOHN, 2004). The existence of multiple centres in close proximity to each other does not necessarily mean that there are strong functional linkages between these centres (LAMBOOY, 1998; ALBRECHTS, 2001). Indeed, most of the theoretical foundations for the central place and urban network model are based on *flows* linked to the physical movement of goods, people, and services (HALL, 2001; LIMTANAKOOL *et al.*, 2007). Hence, polycentrism is addressed in the present paper by looking at functional networks between cities, rather than by looking at the mere existence of multiple centres within one area (MEIJERS, 2008). As such, the term '(functional) polycentrism' is synonymous with 'urban network integration' in this paper.[2]

Second, the few studies on the configuration of urban systems using flow characteristics (for example, VAN DER LAAN, 1998; HALL and GREEN, 2005; and VAN OORT *et al.*, 2010) have predominantly assessed the central place model versus the network model at one point in time. Notable exceptions are recent studies by NIELSEN and HOVGESEN (2008) and LIMTANAKOOL *et al.* (2009). As a consequence, the ways in which the present situation is changing remain ambiguous. As BERTAUD (2004) correctly observes, cities are not born polycentric, but they may evolve in that direction. Instead, a dynamic model based on flow characteristics is a more accurate approach to examining the existence and functioning of urban networks, while allowing for an investigation into the evolution of the structure of the urban system over time.[3]

The main contribution of this paper is to overcome some of the limitations discussed above by providing an empirical assessment of changing urban systems, using flow data on commuting and analysing urban network development over time. Building on the POLYNET research outlined by HALL and PAIN (2006) and CATTAN (2007), the focus in the present work is on the urban network development in the Greater South East of the United Kingdom in the period 1981–2001. The representation of the Greater South East as an urban network is based on the assumption that there is considerable regional cohesion in personal, occupational, and corporate relationships of people, organizations, and firms that transcends the boundaries of traditional metropolitan areas. Commuting patterns are useful data when investigating the development of urban networks, as journey-to-work travelling constitutes the majority of all daily trips, both at the inter- and intra-urban scales (White, 1988; Clark and Kuijpers-Linde, 1994).

The remainder of this paper is organized as follows. The next section provides an overview of the theory on the evolution of the urban system in relation to economic and social changes. In the third section, the case study, the data set and research methods are discussed and an empirical model is employed to test the validity of the urban network concept. The fourth section contains an overview of the main empirical results, followed by a discussion and conclusion in the fifth section.

## THE DYNAMICS OF URBAN SYSTEMS

Urban systems are in constant flux. This section gives a brief overview of the literature on changing urban systems at the intra-urban and inter-urban levels. Specifically, it considers the literature on *how* urban systems change and what developments are *driving* these changes. In particular, attention is given to changing urban systems with respect to commuting in the Greater South East.

### *From a monocentric city to a polycentric region*

In urban systems theory, introduced by Berry (1964) and Pred (1977), urban systems are generally referred to as functionally interdependent sets of cities. However, the structure of these urban systems can range from those that are fully monocentric to those that are fully polycentric. Also, the dominant structure can differ at various spatial scales (Batten, 1995). Yet, the traditional starting point for a treatment of the theory on urban systems is Burgess's concept of the monocentric city (Burgess, 1925), which was later extended by Alonso (1964) and Muth (1961). The concept of the monocentric city involves a central unit, the central business district, surrounded by a circular residential area whereby land is allocated according to its most profitable use. The general idea of the monocentric city is that most economic activities are based in the urban core, whereas suburbs only fulfil a residential function. Hence, the relationship between the urban core and its suburbs in the monocentric model is hierarchical–nodal or *centralized* in the sense that most commuting flows are directed from the suburban areas towards the central cities. A graphical representation of this idea is given in Fig. 2 (A1).

However, the conceptualization of urban systems as monocentric city regions is becoming increasingly problematic (Clark and Kuijpers-Linde, 1994; Kloosterman and Musterd, 2001; Meijers, 2007). For a variety of reasons (that is, cheaper land, a low level of amenities in the city centre, and decreasing transportation costs), firms and households may increasingly choose to locate themselves in secondary employment centres, despite the potential advantages of being located in the central city. As a result, suburban areas are themselves emerging into local centres that develop their own economic activities and gradually become incorporated into an expanded but coherent metropolitan area (Anas *et al.*, 1998). The result is the development of cities with multiple centres, or polycentric cities, at the intra-urban scale (Fig. 2, A2) (Kloosterman and Musterd, 2001). In such a polycentric city, commuting is no longer centralized, but reciprocal in the sense that commuting is now directed not only from the suburbs to the urban core, but also from the urban core to the suburbs. In transport geography, this phenomenon is better known as exchange commuting, while Champion (1989) describes this development as counter-urbanization.

Furthermore, the suburbs become increasingly self-contained in the sense that many suburban residents are employed in the suburban area in which they live. These sub-centres may grow in importance over time as people start relocating to these sub-centres in order to follow their employer, for the benefit of cheaper land, or a better quality of life (Van der Laan, 1998). As such, territorial competition emerges between the original core and the new sub-centres, changing the characteristic of the city to that of a *network-city* (Fig. 2, A3). In this situation, the central city has lost its primacy: flows of goods, services, and people become *decentralized* as the number of workers commuting between suburbs, and bypassing the old urban core, increases. Hence, in this state the functioning of the metropolitan area is dependent not only on the central business district, but also on the functioning of its surrounding suburbs. In fact, one location may be regarded as 'central' in terms of one particular function, while other places might be central in terms of different functions. Finally, there is a third type of polycentric city region, which consists of multiple, *self-contained* centres (Fig. 2, A4); in this case, many suburban residents are employed in the suburbs and many urban residents are employed in the urban core (Schwanen *et al.*, 2004). In this fashion, transportation costs are minimized. However, according to Bertaud (2004), such a polycentric urban structure, in which there is only network formation between the suburbs, is a utopian planning concept that is rarely observed in reality.

The focus of the contemporary debate on changing urban systems has increasingly shifted from the intra-urban scale to the inter-urban scale (Kloosterman and Musterd, 2001).[4] Due to advances in transportation and communication technologies, it is argued that significant functional linkages are formed at increasingly higher levels of scale than those of the 'traditional' city (Van Oort *et al.*, 2010). As a result, the catchment areas of different cities start to overlap. Metropolitan areas lose significance as an independently functioning 'daily urban system' and could, instead, be perceived as forming part of an urban network. Much

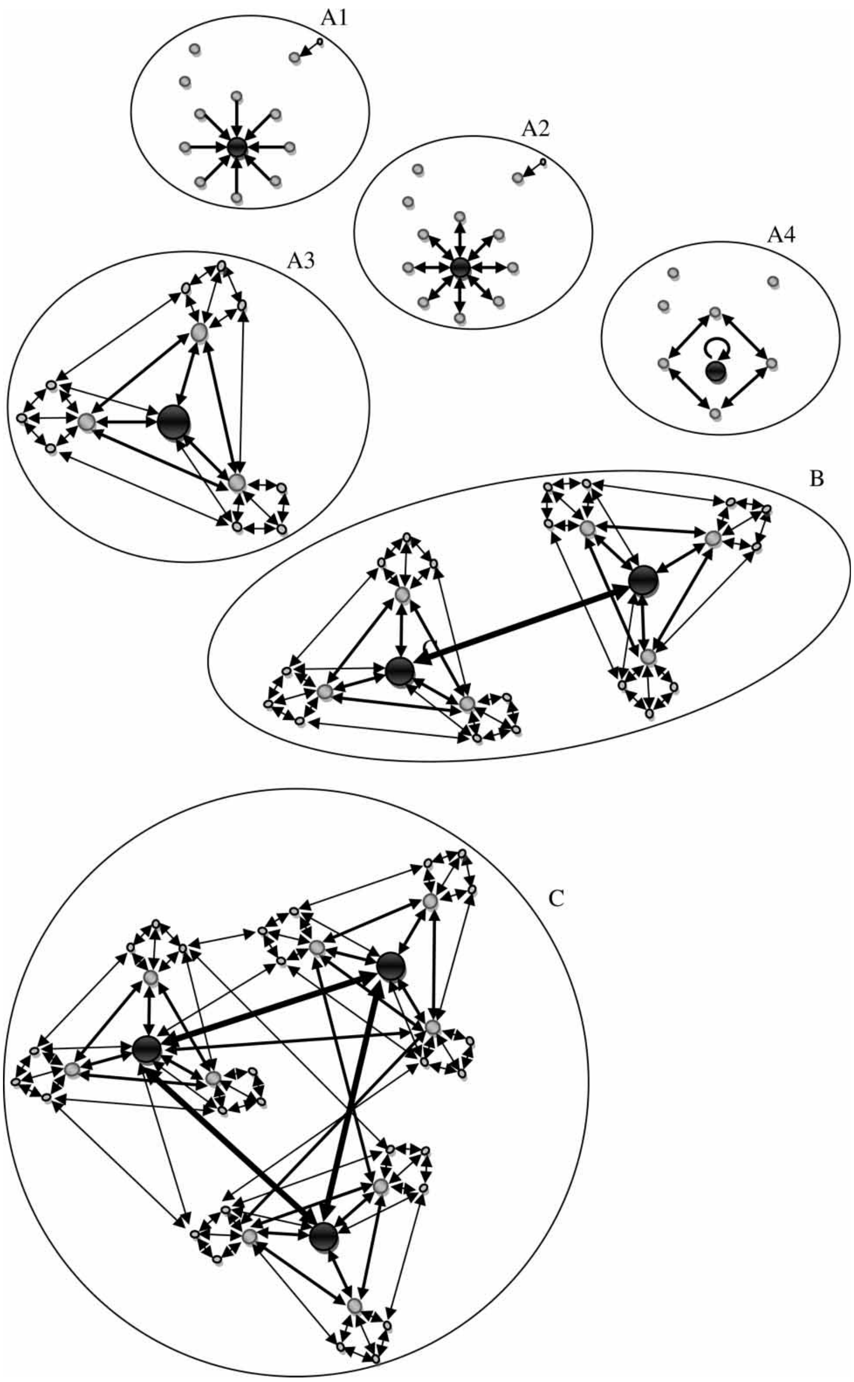


*Fig. 2. Urban network development on the intra-urban and inter-urban scales*
*Note:* (A) Network formation at the intra-urban level (a Polycentric City); (B) a Corridor City at the inter-urban level; and (C) network formation at the inter-urban level (a Polycentric Urban Region)
*Sources:* Adapted from VAN DER KNAAP (2002) and SCHWANEN et al. (2004)

of the current literature is focused on this – the notion of the polycentric urban region. The polycentric urban region can be represented as an *urban network* of historically and spatially separate metropolitan areas comprising a region (Fig. 2, B and C) (BOURNE and SIMMONS, 1978; PARR, 2004). These metropolitan areas can be network-cities themselves, but this is not necessarily the case (that is, the urban system can be dominated by a polycentric structure at the inter-urban level and a monocentric structure at the intra-urban level, or vice versa). Likewise, urban network formation at the *inter*-urban scale is not necessarily the next evolutionary step after the network-city (PARR, 2004).

The degree of urban network formation differs between various polycentric urban regions. First, the distinction between *nodal urban networks* and *fully integrated urban networks* is important. Nodal urban networks (Fig. 2, B) (for example, BATTEN, 1995) are characterized by urban network formation between the old urban cores of different metropolitan areas. In contrast, fully integrated urban networks also have functional linkages between: (1) the suburbs and urban cores of different metropolitan areas; and (2) suburbs of different metropolitan areas (Fig. 2, C). Second, at the inter-urban level the urban spatial structure can be characterized either as centralized, exchange, or decentralized, depending on the existence or non-existence of a regional hierarchy of the different metropolitan relations. The fourth section of the present paper considers formal tests for this.

*The driving forces behind changing urban systems*

Before discussing the specific conditions that characterize a polycentric urban region ( in the third section), a brief overview of the drivers behind changing urban systems is considered. The reasons given in the literature for changing urban systems can be broadly grouped under three different headers: the increased spatial mobility and flexibility of firms; the increased spatial mobility and flexibility of households; and local and regional policies.

*Increased flexibility and mobility of firms.* The effect of increasing flexibility and mobility of firms on the urban system is known as the restructuring hypothesis. The central theme of the restructuring hypothesis is that trends in urban system dynamics are driven by changes in the spatial distribution of employment opportunities (RENKOW and HOOVER, 2000). These changes in the spatial distribution of employment opportunities are both *caused* and *made possible* by key advancements in information and communication technology and are enhanced by the economic change of most Western economies from being dominated by manufacturing to being dominated by services (AOYAMA and CASTELLS, 2002). There is a considerable academic debate on the precise spatial and economic effects of information and communication technology. Some authors predict that developed economies will make a complete shift to a services and information economy, unbounded by physical distance, leading to a complete spatial disintegration of the economy (GILLESPIE and WILLIAMS, 1988; CAIRNCROSS, 1997). Other authors claim that information and communication technology can be well integrated in production economies and physical goods are still bounded by physical distance despite vast improvements in transport technologies and reductions in transport costs (CASTELLS, 2000). Moreover, many service firms are *also* physically constrained by the necessity of face-to-face contact, usually locationally bounded to the 'old' central business district (COUCLELIS, 2000). As such, the old urban cores maintain strong contacts with the suburban areas, creating an ever more complex integrated urban network (GEYER, 2002).

*Increased flexibility and mobility of households.* The effect of increasing flexibility and mobility of people on the urban system is also known as the deconcentration hypothesis. The deconcentration hypothesis holds that urban system dynamics are the result of widespread changes in residential preferences (RENKOW and HOOVER, 2000). Where the increasing flexibility of firms has changed the nature of the *demand* for labour, the same advances in transport and communication technologies changed the nature of the *supply* of labour (CLARK and KUIJPERS-LINDE, 1994; VAN DER LAAN 1998). To some extent, these residential preferences are influenced by enhanced mobility and the increasingly flexible workplace (HALL, 2001). Even more important are the changes in residential preferences caused by demographic developments within most developed economies, which have an impact on the urban structure through their effect on the choices of lifestyle and the attitudes of households (CHAMPION, 2002). The full realm of the demographic changes mentioned are comprehensively summarized by HALL and WHITE (1995) and include the locational preferences of two-earner households, the increasing number of women working, a higher life expectancy, a markedly lower fertility, and an increasing number of single-person households. The common factor in these demographic developments is that they have changed the residential preferences of large groups of people, changing residential patterns, and causing dislocation to the traditional monocentric urban system (VAN HAM, 2002).

*Local and regional policy.* Local and regional policies can have the explicit intention of economic deconcentration and urban network formation, but are most commonly an unintended by-product. A well-known example of an *intentional* policy towards economic deconcentration was the 'growth pole concept' introduced by PERROUX (1955). The aim of this policy was to create economic development in peripheral areas by moving (semi-)governmental departments to, or by encouraging the establishment of industrial growth centres in, the periphery. Ultimately, this should have led to the development of the hinterlands of these growth centres, in turn spreading the benefits of economic development over a larger area. Similarly, by embracing the urban network concept, policy-makers and urban planners have attempted actively to develop suburban areas, with the objective of spreading economic prosperity. ROMEIN (2004) argues that a regional urban network perspective of planning, where cities and communities actively work together, will strengthen the territorial competitiveness of these systems. However, CAPELLO (2000) argues that planners should not automatically assume that cooperation within regional urban networks stimulates growth in each participating city.

Paradoxically, it is suggested that those policies with urban network formation as an unintended by-product are the most efficient. In particular, restrictions on urban development have had a profound impact on the development of the urban structure (CULLINGWORTH and NADIN, 1997). Governments of many countries have introduced strict land-planning policies, mainly aimed against urban sprawl. The Town and Country Planning Act 1947 in the UK is perhaps one of the best examples of such land-planning policies (BEST, 1981). Better known as the Abercrombie Plan, the core of this particular planning act was the formation of a 'Green Belt' around London and several smaller cities in the countryside, whereby new construction was only possible within the set city boundary, or at other designated key settlements (CHAMPION, 2002). It is apparent that the economic pressures on cities such as London to grow did not stop after these laws were implemented. Consequently, much of the population and employment growth has been restricted to settlements beyond the Green Belt (LONGLEY *et al.*, 1992). These settlements have maintained a very strong link with the original core, and combined with the developments previously discussed, this has resulted in the development of polycentric urban regions.

## URBAN NETWORK FORMATION IN THE GREATER SOUTH EAST IN THE UNITED KINGDOM

### *The Greater South East as policy initiative*

Researchers and policy-makers increasingly identify the Greater South East in the UK as an integrated urban network. HALL (2006) states that the Greater South East region of England is a prime example of a 'global mega-city region' in the same fashion as Jean Gottman's Megalopolis on the north-eastern seaboard of the United States (GOTTMAN, 1961). The agglomeration (Fig. 1), which comprises the three Governmental Office regions of London, the South East, and the East of England,[5] has approximately 21 million inhabitants and generates an annual gross domestic product of US$900 billion. The concept of the Greater South East has been used by the relevant English Regional Development Agencies (RDAs) to encourage cooperation in several areas (for example, the 2012 Summer Olympic Games) (SOUTH EAST ENGLAND DEVELOPMENT AGENCY (SEEDA), 2005). The development of the Greater South East reflects London's need for more space; the Green Belt policy ensured that the population and employment growth leapfrogged over the belt, and a well-developed transport network and technological advances facilitated commuting and the mobility of firms (GORDON, 2004; HALL and GREEN, 2005).

An important question is what are the dynamics of the urban configuration of the Greater South East? Given the size of London, one would perhaps automatically assume that the Greater South East is a prime example of a monocentric region. However, HALL (2006) argues that London, unlike other city regions, should be characterized as being functionally polycentric and not morphologically polycentric. Indeed, a region may geographically consist of more than one centre. However, this in itself is not evidence that there are social and economic interactions between firms and people residing in these centres (LAMBOOY, 1998; ALBRECHTS, 2001; MEIJERS, 2008). HALL and GREEN (2005) and HALL and PAIN (2006) both state that in South East England there are only limited functional relations that are not related to London. This suggests a relatively high degree of complementarity amongst centres, especially compared with other polycentric regions in Europe (for example, the Rhein-Ruhr region in Germany and Randstad Holland in the Netherlands). Results from recent research on data from the European Union Communication Innovation Survey provide support for this conjecture. SIMMIE *et al.* (2002) found that the innovative capacity of the Greater South East is well above the European Union average, but that this is largely due to high concentrations of innovative activity outside London (for example, Cambridge, and Oxford). Yet, the crucial assets on which the companies in these concentrations rely (that is, finance and skilled labour) tend to originate from organizations and institutions located at the regional, rather than at the local, scale. Likewise, PAIN (2008) reports a high degree of interaction between different offices of advanced producer services firms in the Greater South East. These intra-firm network relationships vary from formal meetings to joint working and inter-office support.

Many UK policy-makers seem quicker than most researchers to embrace the idea of the Greater South East as a polycentric urban region. The East of England Development Agency states that 'it is clearer than ever that the East of England doesn't stand alone. Instead it is part of a highly integrated Greater South East' (FINCH and MARSHALL, 2007, p. 4). Likewise, the South East Development Agency identifies twenty-one towns and cities creating a network of centres of economic activity (SEEDA, 2006). A whole array of different local and regional initiatives has been employed to promote the Greater South East as an integrated polycentric region (ALLEN and COCHRANE, 2007; OFFICE OF THE DEPUTY PRIME MINISTER (ODPM), 2003). These growth sub-regions, for instance the London–Stansted–Cambridge–Peterborough corridor, cut across the official regional boundaries promoting the integration of the Greater South East Region (for a summary of the different Greater South East growth centres and corridors proposed by different agencies, see Table 1). The Regional Development Agencies also published a joint study titled *The UK's Engine for Growth and Prosperity: A Case for Targeted Investment in the Greater South East* (SEEDA, 2005). In addition, the boards of the three different Regional Development Agencies have decided to intensify their communication with each other and have started an annual Greater South East Regional Development Agency boards meeting (LONDON DEVELOPMENT AGENCY (LDA), 2007).

*Table* 1. *Growth centres and gateways in the Greater South East in the United Kingdom*

| | |
|---|---|
| Greater Norwich | South Hampshire |
| Greater Peterborough | Sussex Coast |
| Greater Cambridge | East Kent/Ashford |
| Haven Gateway | Western Corridor |
| Aylesbury/Milton Keynes/South Midlands | Central Oxfordshire |
| London Arc (or London Fringe) | Gatwick Area |
| Kent/Thames Gateway/South Essex | Greater London |

*Visualizing commuting linkages in the Greater South East Region*

Increasingly, research on urban systems has shifted from considering the physical appearance of a city region (morphological polycentricity) to analysing the functional flow characteristics between nodes in an urban system. Thus, in the contemporary economy the dominance of cities is primarily determined by what flows through cities instead of what is fixed within them (LIMTANAKOOL *et al.*, 2007). Focusing on linkages rather than nodes also facilitates the policy debate on the spatial integration of regions. For this analysis of the development of spatial linkages in the Greater South East, commuting interaction data between districts for the past twenty years (1981, 1991, and 2001) are used. These data were obtained from the Special Workplace Statistics (Set C) in the British census.[6] The '*CIDS 1991/2001 Common Geography*' was used to avoid potential problems with the changes of district boundaries during the past twenty years (BOYLE and FENG, 2002). Using the common geography, the Greater South East can be divided into urban areas; the urban area here is a slightly adapted version of the conventional Nomenclature des Unités Territoriales Statistiques (NUTS)-III definition (see Appendix A). Using these boundaries, there are a total of 146 districts in the Greater South East that account for twenty-seven urban areas, each with one core district (for more details, see Table B1 in Appendix B).

Fig. 3 depicts the net commuting flows in 1981 and 2001 (flows above fifty commuters). Despite the obvious absolute increase in commuting numbers over the investigated twenty-year period, the relative net flows indicate that people still commute within their own urban region. Moreover, the commuting intensity between urban areas is primarily directed towards the London region, indicating a hub-and-spoke system. In fact, there appears to be little commuting activity between urban regions located in the South East and East of England regions. Apart from changing local commuting intensities (for example, increasing around Norwich and Crawley, and decreasing around Oxford and Portsmouth), no major changes in the period 1981–2001 can be visually observed from the data. Hence, at first sight, the data give little evidence for the existence of an urban network and its development over time. However, an obvious criticism of such a visual analysis is that it does not allow for differences in the absolute sizes of districts (in terms of population) and the physical distances between them. GREEN (2007) and HALL and PAIN (2006) did not address this issue in the POLYNET research framework. For example, the London area is relatively small and densely populated. Probably, the large number of commuters within the London area is largely due to the large population of London compared with other areas in the Greater South East, and the relatively small road distances and travel times compared with distances between other urban regions. Put more formally, the likelihood of a commuting flow directed to a large city with many jobs is larger than one directed to a smaller district with fewer jobs. Likewise, the likelihood of a commuting flow between two districts in close proximity to each other is larger than one between districts located far from each other (VAN OORT *et al.*, 2010). FINGLETON (2003) argues that all locations and regions in the modern economy interact to some extent. Therefore, it is impossible to make robust inferences about (the development of) the urban system in the Greater South East through simple visualization. Therefore, it is important to use a model that controls for mass and physical proximity.

## METHODS

*A gravity model of commuting*

In this section, a formal model is used to test the structure in spatial interaction patterns of commuting relations in the Greater South East. The objective is to investigate whether the Greater South East consists of network-cities at the intra-urban scale and whether the adjoining districts form a fully integrated, larger-scale urban network. The fully integrated, larger-scale urban network can be viewed as the most extreme form of functional polycentricity at the inter-urban level. In general, it could be concluded that such a form exists when there is no effect of spatial context on commuting network intensities, other than that determined by the mass of sending and receiving localities and the physical distance between them. If the Greater South East functions as a spatially integrated cluster (from an economic point of view), the inter-urban network structure of commuting relations should be solely determined by these variables. Although this strict definition of an integrated network of commuters being randomly distributed over space is very demanding, it can be tested whether the interactions evolve over time towards this situation.

A gravity model (HAYNES and FOTHERINGHAM, 1984) is employed to test for these conditions. In this model, Sir Isaac Newton's law of universal gravitation[7] is used to explain the interaction between spatial units, in the present case commuting flows between districts. The contemporary use of gravity models in geography and regional science originates from the

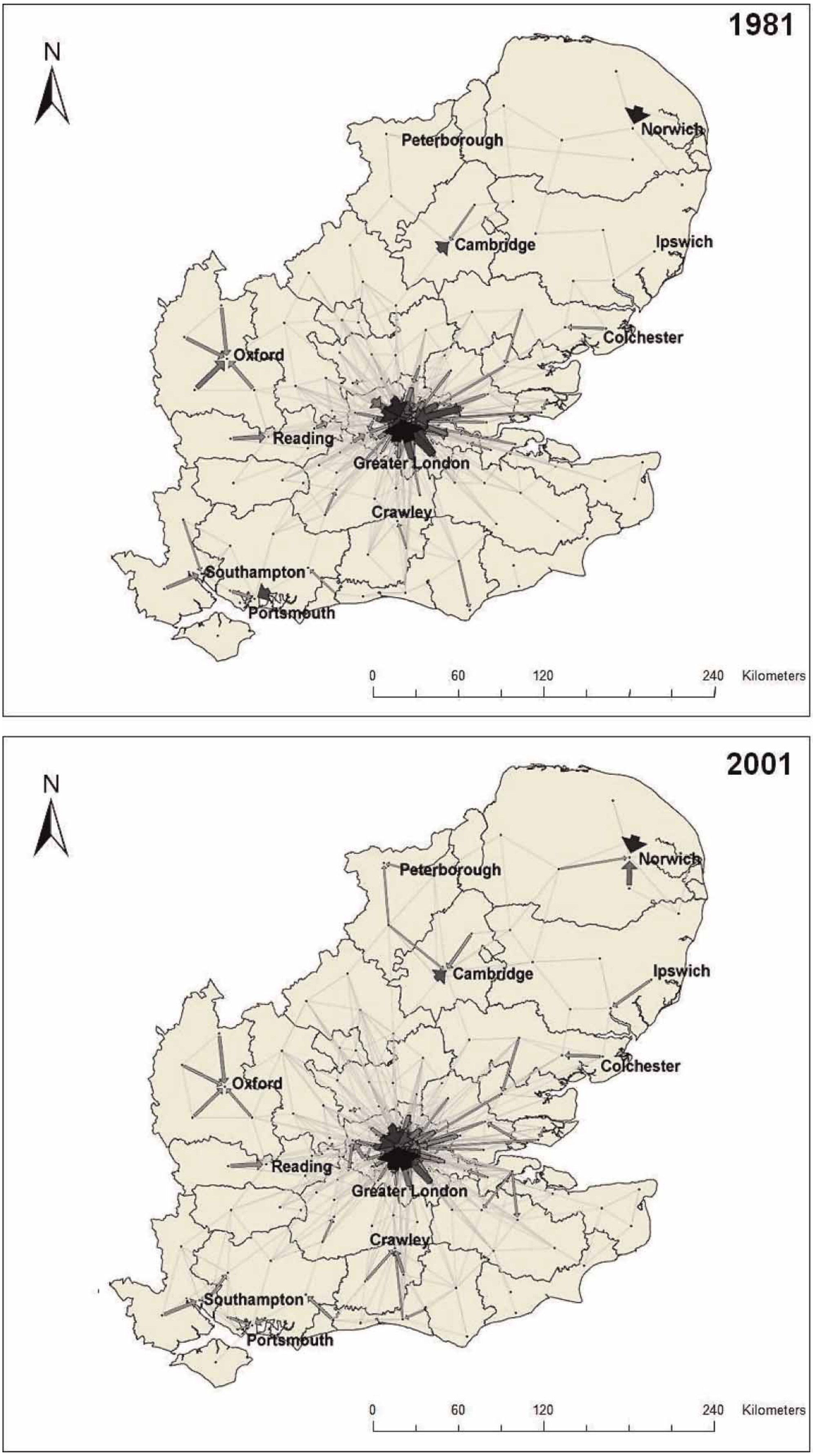


*Fig. 3. Commuting interaction within the Greater South East, 1981 and 2001*

*Note:* Flows presented are net-flows with a threshold set above 50. The width of the arrow is proportional to the total of the net flows above the threshold within the Greater South East work of Stewart (1948) and Ullman (1954).[8] Such models hold that the gravitational force between two spatial units is directly proportional to the product of the mass of the spatial units and inversely proportional to the physical distance between them. More formally, the gravity model can be expressed by:

$$I_{ij} = K\frac{M_i^{\beta_1} M_j^{\beta_2}}{d_{ij}^{\beta_3}} \qquad (1)$$

where $I_{ij}$ is the interaction intensity, or the number of commuters between areas $i$ and $j$; $K$ is a proportionality constant; $M_i$ is the mass of the district of origin; $M_j$ is the mass of the district of destination; $d_{ij}$ is the physical distance between the two areas; $\beta_1$ is the potential to generate commuting flows; $\beta_2$ is the potential to attract commuting flows; and $\beta_3$ is an impedance factor reflecting the rate of increase of the friction of physical distance. In the present estimations, the physical distance between districts is measured as the actual road distance between districts $i$ and $j$. The road distance is based on the road network in the Greater South East in 2005 and is obtained by linking an origin–destination cost matrix to the road network, where the cost was set to distance.[9] However, the overall average road distance between neighbouring districts is likely to be overestimated, as it measures the distance between the two centres of gravity. A dummy reflecting contiguity is included in order to correct for this measurement error in calculating the relevant road distances.

*Modified Poisson specification of the gravity model*

Spatial interaction data should be handled as count data, as they 'count' the number of times something has happened; in the present case this refers to flow frequencies (the number of commuters) between, and within, districts. Although equation (1) is often estimated using ordinary least-squares (OLS), the application of the linear regression model here can lead to inefficient, inconsistent, and biased results (Long, 1997), as the underlying assumptions of normal distribution and homoscedasticity are often not satisfied. For this reason, the use of alternative regression techniques is more appropriate (Burger *et al.*, 2009). Probably the most common regression model applied to count data is the Poisson regression, which is estimated by means of maximum-likelihood estimation techniques.

Using a Poisson model specification (Flowerdew and Aitkin, 1982; Long, 1997), the multiplicative form (equation 1) can be converted into the following testable equation (2), in which the probability of observing the value of $I_{ij}$ is expressed as:

$$\Pr[I_{ij}] = \frac{\exp(-\mu_{ij})\mu_{ij}^{I_{ij}}}{I_{ij}!} \quad (I_{ij} = 0, 1 \ldots) \qquad (2.1)$$

where the conditional mean $\mu_{ij}$ is linked to an exponential function of a set of regression variables:

$$\mu_{ij} = \exp(K + \beta_1 \ln M_i + \beta_2 \ln M_j + \beta_3 \ln d_{ij}) \qquad (2.2)$$

Equation (2.2) is an unconstrained gravity model, as the model does not take into account the constraint that the estimated number of commuters entering and leaving the district should be equal to the observed number of commuters. In order to satisfy this condition, and because of primarily interest is the estimation of the effects of the different interdependencies on the volume of commuting between and within districts, equation (1) is estimated including origin and destination fixed-effects. Such a *doubly constrained gravity model* ensures that the total number of observed commuters equates to the total number of expected commuters and yields consistent parameter estimates for the variables of interest (Bröcker, 1989a; Fotheringham and O'Kelley, 1989). In equation (2.2), this implies the inclusion of district-specific origin and destination dummy variables. More formally, the fixed-effects specification of the most basic gravity model (including physical distance) would be as follows:

$$\mu_{ij} = \exp(K + \beta_3 \ln d_{ij} + \eta_i + \gamma_j) \qquad (2.3)$$

where $\eta_i$ is an effect specific to the district of origin (a residential district-specific effect); and $\gamma_j$ is an effect specific to the district of destination (a work district-specific effect). These fixed-effects terms replace the mass variables in equation (2.2) and also control for other district-specific characteristics.

It is important to recognize that the aforementioned Poisson model assumes equi-dispersion:

$$\left(E(I_{ij}|x) \propto V(I_{ij}|x)\right)$$

for which the conditional variance of the dependent variable should be equal to its conditional mean. If not, the data set displays over-dispersion. In addition, the dependent variable is modelled as having a Poisson distribution. However, often an excessive number of zero counts is observed, which means that the incidence of zero counts is greater than is expected for the Poisson or negative binomial distribution. In order to correct for this, a negative binomial (in case of over-dispersion), zero-inflated Poisson regression (in case of excess zeros), or zero-inflated negative binomial regression (in case of over-dispersion and excess zeros) is employed. These modified Poisson regression models can be viewed as extensions of the Poisson model. Not correcting for over-dispersion and/or the excess zero count normally results in incorrect and biased estimates, exemplified by spuriously large $z$-values and spuriously small $p$-values, due to downward-biased standard errors (Cameron and Trivedi, 1986; Gourieroux *et al.*, 1984).[10]

For more detailed discussion of extensions of the Poisson regression model, see GREENE (1994), LONG (1997), and BURGER *et al.* (2009).

*Modelling urban network conditions and change over time*

The model presented above is a gravity model in its most basic form. It can be extended to include other variables. In the model, dummy variables that express the spatial–functional context of the commuting interactions between different types of districts are included to examine the spatial structure of the commuting network in the Greater South East. These spatial–functional contexts are formally called regimes and build up the degree of spatial integration in the region. As outlined above, twenty-seven central city districts can be distinguished, each with its own suburban districts. A distinction is made between thirteen different regimes (types of relations) at the intra-urban and inter-urban scales. These regimes are shown in Fig. 4 and convey the spatial context of flows between districts.

At the *intra-urban* scale, an urban area can be characterized as a monocentric city when – controlling for the sizes of districts and the distance between them – the *within central city* interdependencies and the *periphery–core* interdependencies between suburban districts and their 'own' central city are strongest (Fig. 2, A1). In contrast, the separate districts in the Greater South East can be characterized as network-cities when, *ceteris paribus*, the *within central city* dependencies are not stronger than all other intra-urban interdependencies (Fig. 2, A2 and A3). Moreover, no observable

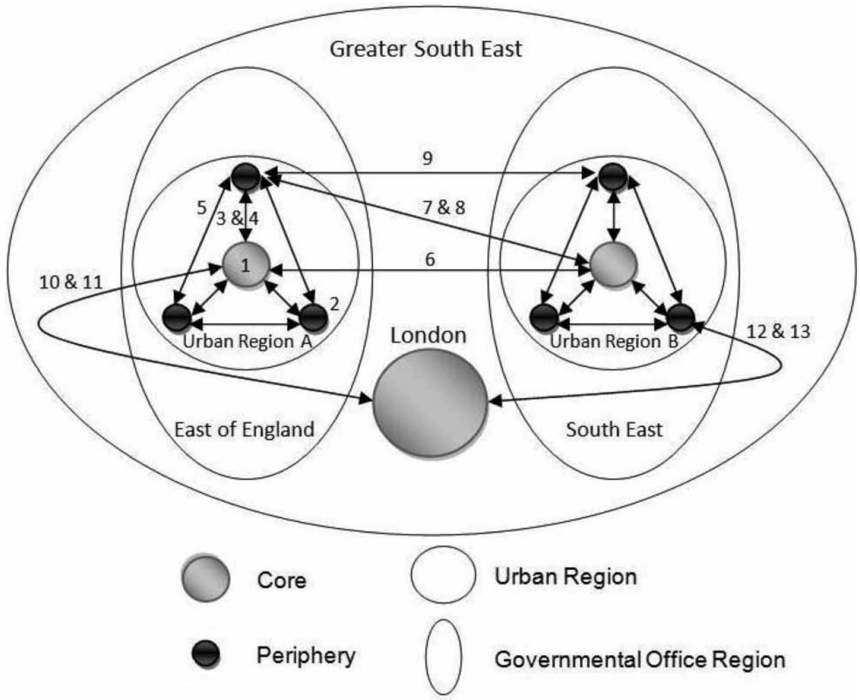


*Fig. 4. Conceptualization of urban interdependencies*

*Notes:* (A) Intra-urban commuting flows within districts in the South East and East of England: (1) within central cities dependencies based on relationships that remain entirely within a central city district; and (2) within suburbs dependencies based on relationships that remain entirely within a suburban district.

(B) Intra-urban commuting flows within urban areas in the South East and East of England: (3) intra-urban core–periphery interdependencies between the central cities and one of its 'own' suburban districts; (4) intra-urban periphery–core interdependencies between the suburban districts and their 'own' central city; and (5) intra-urban criss-cross interdependencies between the suburban districts within a given urban region.

(C) Inter-urban commuting flows between urban regions in the South East and East of England: (6) inter-urban inter-core interdependencies between the central cities of different urban regions; (7) inter-urban core–periphery interdependencies between the central cities and one of their non-'own' suburban municipalities; (8) inter-urban periphery–core interdependencies suburban districts and one of their non-'own' central cities; and (9) inter-urban criss-cross interdependencies between suburban districts that are not situated in the same urban region.

(D) Inter-urban commuting flows between urban regions and London: (10) inter-urban interdependencies between central cities in the South East and East of England and London; (11) inter-urban interdependencies between London and the central cities in the South East and East of England; (12) inter-urban interdependencies between suburban districts in the South East and East of England and London; and (13) inter-urban interdependencies between London and suburban districts in the South East and East of England hierarchy in the different types of intra-urban interdependencies should be present.

At the *inter-urban scale*, the Greater South East can be characterized as an urban network when – again controlling for mass and distance – the interdependencies between districts within urban areas in the Greater South East are not stronger than interdependencies between urban areas. In order to be classified as a fully integrated urban network, no observable hierarchy in the different types of inter-urban interdependencies should be present. In addition, one can distinguish between different types of regional interdependencies based on the presumption of a regional hierarchy. The Greater London region is here depicted as the centre in an inter-urban hub-and-spoke model. Hence, one can distinguish between four types of regional interdependencies (interdependencies 10–13, as displayed in Fig. 4).

In summary, if the Greater South East can be characterized as a fully integrated decentralized urban network consisting of network-cities at the intra-urban level, the network structure of commuting flows should be solely determined by the masses of the districts and the physical distances between them. Controlling for mass and size, commuting trips should be randomly distributed. Hence, there should be no significant relationship of the degree of interaction with any of the thirteen types of interactions identified. There should be no evidence for a regional hierarchy at the inter-urban scale. However, this can be considered the ultimate form of a polycentric urban region or urban network. As BERTAUD (2004) correctly observes, no region is fully monocentric or fully polycentric. In the analysis below, the urban structure that most appropriately describes the Greater South East best is discussed.

Besides testing the structure of the network, this analysis also examines the evolution of the urban system over time. By including time dummies and slope dummies in the gravity equation, changes of the relative strengths of the different spatial regimes (urban interdependencies) over time can be assessed (CAMERON, 2005). In other words, the change in the relative strengths of the different spatial regimes over time is captured by an interaction between the time variable and spatial regime variables (the different urban interdependencies).

## EMPIRICAL RESULTS

### *Changing urban systems at the intra-urban scale*

The results for model 1 (Table 2) test for the spatial structure in the South East and East of England at the intra-urban scale using a negative binomial regression. As expected, distance has a marked inverse correlation with commuting intensity. The coefficients can be interpreted as elasticities: when physical distance increases by 1.0%, commuting is predicted to decrease by 1.36%. Likewise, the volume of commuting between two districts that border each other is expected to be 3.85 times as high as the volume of commuting between districts that do not border each other.[11] Taking intra-nodal dependency (the flows that remain entirely within a central city district) as the reference category (as it is conceptually the strongest type of urban interdependency), it is possible to compare the relative strength of the different types of urban interdependencies while controlling for the masses of districts and the distance between them.

Looking at the average spatial structure at the intra-urban scale in the period 1981–2001, it appears that the spatial structure of urban regions within the Greater South East (intra-urban scale) is best described as *a mixture of the monocentric city model and the polycentric city model*. Some of the results strongly point to the monocentric model: the *within central cities* dependencies in the Greater South East are significantly stronger than interdependencies between districts situated in the same urban region. Furthermore, holding everything else constant, the predicted commuting intensity within central cities is about five times as high as the predicted flow between suburban districts and central cities (periphery–core relations) and between central cities and suburban districts (core–periphery relations) within the same urban region. In addition, holding everything else constant, the predicted commuting intensity between central cities is about nine times as high as the predicted flow between suburban districts (criss-cross commuting). Finally, testing for the equality of coefficients by means of a Wald test reveals that the periphery–core interdependencies are significantly stronger than the criss-cross interdependencies (Chi-squared test ($\chi^2$) = 12.05, degrees of freedom (d.f.) = 1, $p < 0.01$). However, not all conditions of the monocentric model hold. First, the periphery–core interdependencies are not significantly stronger than the core–periphery interdependencies ($\chi^2 = 0.03$, d.f. = 1, $p = 0.85$). Second, and most importantly, the within suburban areas dependencies are not significantly weaker than the within central cities dependencies. From this it can be inferred that many districts classified as 'suburban' are largely self-contained, indicating that many suburban residents are employed in the suburban area in which they live. Thus, many of those districts classified as suburban (those surrounding larger, central cities and forming their hinterland) are not primarily suburban in character, but are economically self-contained. These are strong arguments to suggest, at least to some extent, that the urban areas in the Greater South East are polycentric spatial entities.

Looking at the estimated linear trend over time (1981–2001) in Model 2 (Table 2) suggests some development toward a more polycentric urban form at the intra-urban scale. The coefficients should be interpreted as the shift in the relative strength of the different urban interdependencies vis-à-vis within central cities dependencies, over a period of ten years. In 1981, holding everything else constant, the within central cities dependencies are about 6.4 times as strong as the core–periphery urban interdependencies. This number

*Table 2. Negative binomial regression on commuting between districts in the Greater South East, United Kingdom, at the intra-urban scale, 1981–2001*

| | General structure, 1981–2001 (1) | Change over time, 1981–2001 (2) |
|---|---|---|
| Intercept | −2.509 (0.988)* | −2.398 (1.18)* |
| Road distance (ln) | −1.362 (0.049)** | −1.363 (0.049)** |
| Contiguity | 1.343 (0.040)** | 1.348 (0.040)** |
| *Urban interdependencies* | | |
| Within central city | • | • |
| Within suburban areas | −0.206 (0.182) | −0.289 (0.354)** |
| Suburbs → central city | −1.630 (0.286)** | −1.754 (0.229)** |
| Central City → suburbs | −1.557 (0.330)** | −1.854 (0.337)** |
| Suburbs → suburbs (criss-cross) | −2.224 (0.237)** | −2.505 (0.376)** |
| *Time trend* | | |
| Within central city * $T$ | | • |
| Within suburban areas * $T$ | | −0.005 (0.098) |
| Suburbs → central city * $T$ | | 0.130 (0.095) |
| Central city → suburbs * $T$ | | 0.216 (0.094)* |
| Suburbs → suburbs * $T$ | | 0.199 (0.089)* |
| Origin fixed-effects | Yes | Yes |
| Destination fixed-effects | Yes | Yes |
| Time fixed-effects | Yes | Yes |
| Over-dispersion ($\alpha$) | 0.298 (0.009)** | 0.294 (0.010)** |
| Log pseudo-likelihood | −11 204 | −11 191 |
| Akaike information criterion (AIC) | 11.13 | 11.12 |
| Number of observations | 2052 | 2052 |

*Notes:* •, Reference category; robust errors are given in parentheses.
$^{**}p < 0.01$.

decreased to 4.1 times in 2001. Likewise, the within central cities dependencies in 1981 are about 12.2 times as strong as the core–periphery urban interdependencies, while in 2001 this dropped to about 8.2 times. However, even if this trend continued, it would take at least another eighty years before one could speak of a network-city proper at the intra-urban scale. Additional evidence for decentralization of the urban system at the intra-urban scale is shown by the significant increase in the core–periphery and criss-cross urban interdependencies over time relative to the within suburb dependencies and periphery–core interdependencies. Additionally, the periphery–core interdependencies also increase in strength relative to the within central cities dependency over time (although not significantly so).

### *Changing urban systems at the inter-urban scale*

The results for Model 3 (Table 3) show the average spatial structure of the Greater South East in the period 1981–2001 at the inter-urban scale using a zero-inflated Poisson regression. Recall that the Greater South East can be characterized as an urban network if the interdependencies between districts *within* (intra-) urban areas in the Greater South East are not stronger than interdependencies *between* (inter-) urban areas. Overall, it can be concluded that the dependencies within urban regions in the South East and East of England are stronger than the dependencies between urban regions. Holding mass and physical distance constant, the predicted flow between districts within the same urban region in the South East and East of England is, on average, 100% larger than the inter-district flows that exceed the level of the urban regions. Examining the different types of inter-urban interdependencies between urban regions in the South East and the East of England, the presence of a hierarchy can be observed in the sense that the different types of interdependencies significantly differ in their relative strength. In general, the between central cities interdependencies are stronger than the inter-urban central city–suburb, inter-urban suburb–central city, and between suburbs interdependencies. From this, it can also be concluded that although the degree of urban network formation is marginal, it is mainly occurring between the core districts of the separate urban areas (Fig. 2B).

Stronger evidence for urban network formation at the inter-urban scale can be found in the interdependencies between the urban regions of the South East and the East of England (origin), on the one hand, and the London area (destination), on the other hand, as they are stronger than the dependencies within urban regions in the South East and East of England (compare HALL and PAIN, 2006). Controlling for mass and distance, the interaction intensity between the South East and the East of England areas and the London area is, on average, not significantly smaller than within urban regions in the South East and the East of England. Looking at the interaction intensity

*Table 3. Zero-inflated Poisson regression on commuting between districts in the Greater South East, United Kingdom, at the inter-urban scale, 1981–2001*

| | General structure, 1981–2001 (3) | Change over time, 1981–2001 (4) |
|---|---|---|
| Intercept | 8.314 (0.103)** | 8.309 (0.104)** |
| Road distance (ln) | −1.931 (0.018)** | −1.932 (0.019)** |
| Contiguity | 0.636 (0.039)** | 0.637 (0.040)** |
| **Urban interdependencies** | | |
| Within urban region (intra-urban) | • | • |
| *Between urban regions in South East and East of England (inter-urban)* | | |
| Between central cities | −0.461 (0.099)** | −0.582 (0.152)** |
| Suburbs → central city | −0.766 (0.092)** | −0.739 (0.165)** |
| Central city → suburbs | −0.781 (0.084)** | −0.933 (0.114)** |
| Suburbs → suburbs (criss-cross) | −0.665 (0.064)** | −0.694 (0.064)** |
| *Between London – South East and East of England (inter-urban)* | | |
| Greater South East central cities → London | −0.076 (0.328) | 0.007 (0.364) |
| Greater South East suburbs → London | −0.150 (0.323) | −0.001 (0.357) |
| London → Greater South East central cities | −1.882 (0.150)** | −0.774 (0.161)** |
| London → Greater South East suburbs | −1.622 (0.141)** | −0.290 (0.143)* |
| **Time trend** | | |
| Within urban region (intra-urban) | | • |
| *Between urban regions in South East and East of England (inter-urban)* | | |
| Between central cities * *T* | | 0.102 (0.101) |
| Suburbs → central city * *T* | | −0.020 (0.092) |
| Central city → suburbs * *T* | | 0.125 (0.063)* |
| Suburbs → suburbs (criss-cross) * *T* | | 0.025 (0.037) |
| *Between London – South East and East of England (inter-urban)* | | |
| Greater South East central cities → London * *T* | | −0.057 (0.046) |
| Greater South East suburbs → London * *T* | | −0.118 (0.026)** |
| London → Greater South East central cities * *T* | | 0.290 (0.068)** |
| London → Greater South East suburbs * *T* | | 0.121 (0.041)** |
| Origin fixed-effects | Yes | Yes |
| Destination fixed-effects | Yes | Yes |
| Time fixed-effects | Yes | Yes |
| Vuong ($z$) | 13.17** | 12.77** |
| Log pseudo-likelihood | −367 106 | −365 852 |
| Akaike information criterion (AIC) | 12.13 | 12.07 |
| Number of observations | 60 681 | 60 681 |

*Notes:* •, Reference category, cluster-robust errors are given in parentheses.
Inflated part (not shown) estimated using road distance (ln), contiguity, and interdependencies.
$^{**}p < 0.01$; $^{*}p < 0.05$.

between London and the South East and the East of England, it can be concluded that the urban network formation is one-sided. Overall, there are many employees travelling from the South East and the East of England to London, but relatively few employees travelling from London to the South East and the East of England.

The results from Model 4 (Table 3) provide evidence on the development of the urban system at the inter-urban scale over time.[12] Overall, some evidence is found for the decentralization of the Greater South East at the inter-urban scale for the period 1981–2001. First, the interdependencies between South East/East of England and London lose relative strength, compared with dependencies within urban regions in the South East and the East of England, while the interdependencies between the South East/East of England and London gain relative strength.

Second, the interdependencies between regions within the South East and East of England do not gain any strength over the dependencies within urban regions, except for the inter-urban central city–suburb interdependencies. This indicates that there is evidence for the decentralization of activities in the Greater South East at the regional level, but evidence for urban network development at the inter-urban scale (between regions) over the past twenty years is lacking.

## DISCUSSION AND CONCLUSIONS

There has been a plethora of research reports and policy documents on the development of urban networks worldwide and on the Greater South East in the United Kingdom, in particular. However, there are relatively few rigorous empirical assessments of the urban network concept. The shift from a location-based economy to a network-based economy can be seen as a continuum. As a consequence, the extent to which the urban network model has now replaced the central place model remains unclear and there is an important need for objective and quantitative assessment.

In this paper, the structure and evolution of commuting flows in districts in the Greater South East between 1981 and 2001 were modelled with an extended version of a gravity model, incorporating functional regime dummies and time trends. The strengths of the different spatial interdependencies within the Greater South East were tested on both the intra-urban and inter-urban scales. The results indicate that the Greater South East does not (yet) constitute a fully integrated urban network. However, the strength of the spatial interdependencies within suburban districts indicates that suburban nodes are increasingly operating in a manner independent of the central city. This indicates the development of polycentric regions at the intra-urban scale. Furthermore, the time-trend analysis suggests that using the gravity approach without external shocks (opening-up of infrastructure, job creation and (re-)location, and the creation of new housing facilities), based upon the difference in magnitude observed over the past twenty years, it would take another eighty years before the Greater South East is fully polycentric at the intra-urban scale. At the inter-urban scale, there is less indication of development towards urban network formation. The results generally support a monocentric interpretation of the Greater South East at the inter-urban scale, which is relatively stable over time. However, the absence of a hierarchy in the interdependencies on the regional inter-urban scale suggests that a development towards polycentricity is also possible at the inter-urban scale; however, this would require pointed investments in infrastructure and locational employment and planning.

Although the model employed for this analysis is robust, a number of points should be made about the underlying data. First, commuting data are only one way to investigate the structure of urban systems. Several authors have pointed out that movements of people are not a perfect indicator for economic interactions and should be combined with other data on economic interactions to gain a realistic insight into the structure of urban systems (GLANZMANN *et al.*, 2004). Although different groups of people exhibit various degrees of willingness to travel to work, most people prefer to live relatively close to their main place of work (TURNER and NIEMEIER, 1997; ROUWENDAL 1999). A similar analysis on different data such as buyer–supplier interactions (VAN OORT *et al.*, 2010) or innovation collaboration could potentially offer more detailed conclusions on the structure of the urban system in the Greater South East. However, such interaction data for the Greater South East are difficult to obtain or are too weak to make robust statistically inferences (HALL *et al.*, 2006).

Second, most currently available commuting data are based on survey questions on daily commuting behaviour. Thus, the choice of studying commuting trips allows a focus on the 'daily urban space' of people. When considering urban network development, however, it might be more useful to assume that interactions over larger distances do not take place everyday and to consider the 'weekly urban space' or 'monthly urban space' of people. GREEN *et al.* (1999) describe how *weekly* commutes over large distances are increasingly supplanting migration. These 'super commutes' are missing from, or disturbing, the currently available data, as people who commute weekly often have two places of residence. Green *et al.* estimate that in Britain the total number of people undertaking such super commutes is just over 1% of the total number of employed residents.

Third, and related to the previous point, it is also important that future research on functional polycentrism and urban network development concentrates on the less frequent types of trips, such as leisure and business trips (see also LAMBOOY, 1998; and HALL and PAIN, 2006) in addition to other types of functional relationships between cities, such as inter-urban trade (for example, VAN OORT *et al.*, 2010).

Finally, the empirical results presented in this paper have implications for policy. The results indicate a development towards urban networks at the intra-urban scale and relatively little development at the inter-urban scale. Thus, transport planning should, therefore, pay particular attention to the intra-urban scale. This might mean that there should be more investment on improving secondary roads and other forms of transport (including public transport and cycle routes) within the existing urban fabric rather than improving high-speed roads linking urban regions. Recent studies suggest that there are few urban economic and labour force complementarities between nearby cities in Western economies (MEIJERS, 2005). Instead, cities are increasingly trying to compete in same high-technology areas, such as knowledge-intensive business services, information and communication technology, and biotechnology (KITSON *et al.*, 2004; VAN OORT *et al.*, 2010). This 'place competition' may hamper a more integrated and synergetic 'urban network' approach which stresses collaboration between places. If this does not change, the spatial planning of housing and business sites should predominantly serves local demand and improve the efficiency of daily urban systems. And as the location of employment becomes more endogenous to population location within urban regions in Western counties (BOARNET, 1994) – meaning that 'jobs follow people' more than that 'people follow jobs' – the planning of population development becomes more important in steering the planning process.

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this paper was circulated under the title ‘Polycentric urban configuration and urban network development in the Greater South East, UK, 1981–2001’.

## APPENDIX A: URBAN AREAS

In order to investigate the hypotheses further, it was necessary to define different ‘urban areas’ within the Greater South East, each with one ‘core county’ and several ‘periphery counties’. The analyses performed in this paper allow for a rather simple definition of ‘urban areas’. In almost all instances, the most recent version of Nomenclature des Unités Territoriales Statistiques (NUTS)-III areas was used to define urban areas in the Greater South East. The NUTS-III geography is useful here for two reasons: first, it can be used with the ‘*CIDS 1991/2001 Common Geography*’; and second, NUTS-III is a commonly accepted definition of an urban area. However, in a number of instances, the NUTS-III area geography causes problems in that some counties (the unit of analysis) are a NUTS-III area on their own. In these cases, another definition of an urban area, the travel-to-work areas (TTWA), was used to assign counties to an urban area (Figs A1–A3). The core of each urban area was defined as the county with the largest city in terms of population. The rationale behind the choice for the most populous city as the core of an urban area is based on the historical role of the city as a ‘Central Place’. However, for urban areas located in the Greater London Area, this rule does not apply as London as a whole could be considered a core. For these urban areas, the county (London Borough) with the highest demand for labour was chosen as the urban core. The role of the Greater London Area as a core on its own in the Greater South East urban network is investigated separately.

## APPENDIX B

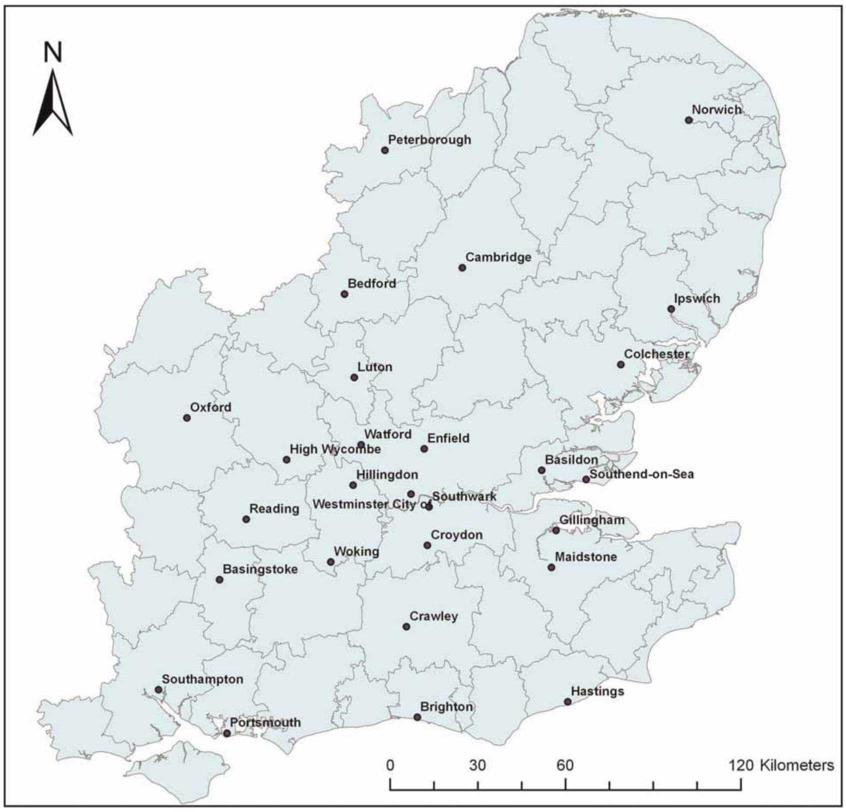
See Table B1.

## APPENDIX C: ROAD DISTANCE

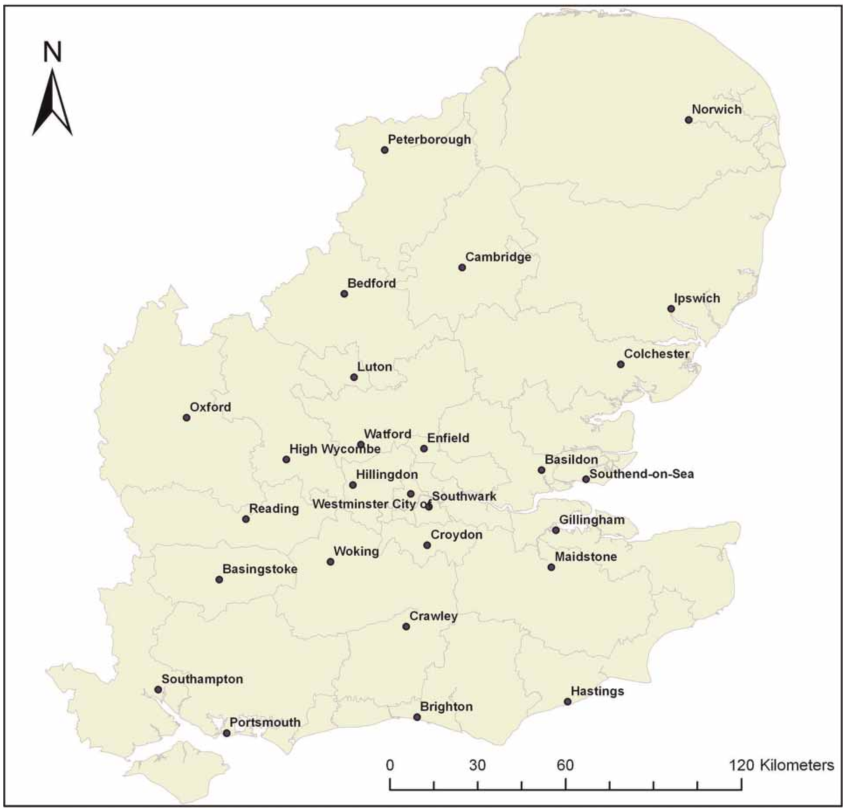
Using the actual road distance rather than the more conventional air distance is especially appropriate in the case of the Greater South East. The hub-and-spoke structure of the road network in the Greater South East makes the distance between counties often longer than expected (Fig. C1). Though a number of roads have been upgraded (which does not affect the actual distance) over the period investigated, the overall majority of all public roads were constructed at


*Figs* A1–A3. *Creation of urban areas: (A1) Greater South East NUTS-III areas; (A2) Greater South East travel-to-work areas (TTWA) areas; and (A3) the urban areas used in the present paper with their urban cores*

A2




A3




*Figs* A1–A3. *Continued*

*Table B1. Districts in the Greater South East sorted by urban area*

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Basildon** | Epping Forest | **Enfield** | Barking and | **Norwich** | Breckland | **Southend-on-** | Castle Point | **Westminster,** | Camden |
| | Harlow | | Dagenham | | Broadland | **Sea** | Chelmsford | **City of** | City of London |
| | Thurrock | | Bexley | | Great Yarmouth | | Maldon | | Hammersmith and |
| **Basingstoke and** | Hart | | Greenwich | | King's Lynn and West | | Rochford | | Fulham |
| **Deane** | Rushmoor | | Havering | | Norfolk | **Southwark** | Hackney | | Kensington and |
| **Bedford** | Mid Bedfordshire | | Redbridge | | North Norfolk | | Haringey | | Chelsea |
| | Milton Keynes | | Waltham Forest | | South Norfolk | | Islington | | Wandsworth |
| | North Hertford | **Hastings** | Rother | **Oxford** | Cherwell | | Lambeth | **Woking** | Elmbridge |
| | shire | | Shepway | | South Oxfordshire | | Lewisham | | Epsom and Ewell |
| **Brighton and** | Adur | **Hillingdon** | Barnet | | Vale of White Horse | | Newham | | Guildford |
| **Hove** | Arun | | Brent | | West Oxfordshire | | Tower Hamlets | | Mole Valley |
| | Eastbourne | | Ealing | **Peterborough** | Fenland | **Swale** | Canterbury | | Reigate and |
| **Colchester** | Lewes | | Harrow | | Huntingdonshire | | Dartford | | Banstead |
| | Wealden | | Hounslow | **Portsmouth** | Chichester | | Dover | | Runnymede |
| | Worthing | | Richmond upon | | East Hampshire | | Gravesham | | Spelthorne |
| | East | | Thames | | Fareham | | Medway Towns | | Surrey Heath |
| | Cambridgeshire | **Ipswich** | Babergh | | Gosport | | Thanet | | Tandridge |
| | South | | Forest Heath | | Havant | **Watford** | Broxbourne | | Waverley |
| | Cambridgeshire | | Mid Suffolk | | Winchester | | Dacorum | **Wycombe** | Aylesbury Vale |
| | Braintree | | St. Edmundsbury | **Reading** | Bracknell Forest | | East | | South Bucks |
| | Tendring | | Suffolk Coastal | | Slough | | Hertfordshire | | Chiltern |
| | Uttlesford | | Waveney | | Windsor and Maiden | | Hertsmere | | |
| **Crawley** | Horsham | **Luton** | South Bedfordshire | | head | | St. Albans | | |
| | Mid Sussex | **Maidstone** | Ashford | | Wokingham | | Stevenage | | |
| **Croydon** | Bromley | | Sevenoaks | **Southampton** | Eastleigh | | Welwyn Hatfield | | |
| | Kingston upon | | Tonbridge and | | Isle of Wight | | | | |
| | Thames | | Malling | | New Forest | | | | |
| | Merton | | Tunbridge Wells | | Test Valley | | | | |
| | Sutton | | | | | | | | |

*Note:* Core districts are shown in bold.

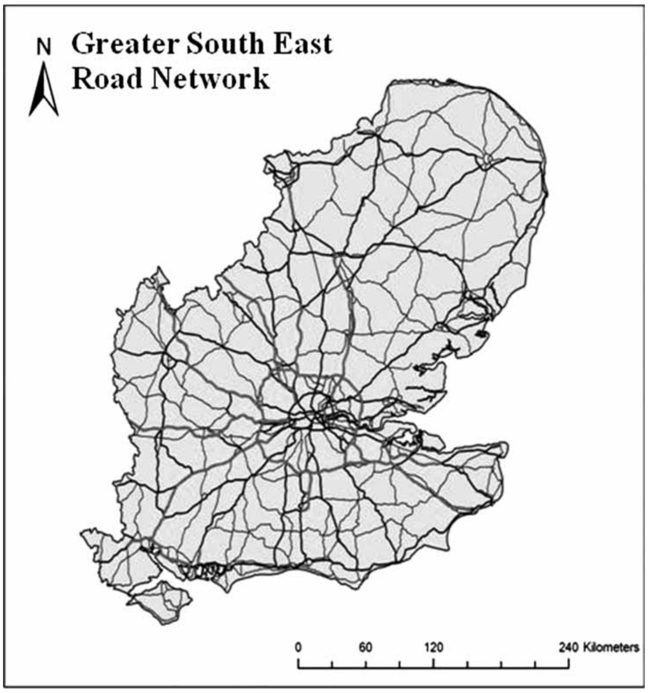



*Fig* C1. *The Greater South East Road Network 2005.* The thick gray lines indicate the major motorways, whereas the thick and thin black lines respectively indicate the major regional and local roads

the beginning of the twentieth century (THE SOCIETY FOR ALL BRITISH AND IRISH ROADS ENTHUSIASTS (SABRE), 2007). The distances calculated on the basis of the 2005 road network are, therefore, valid for all three investigated periods (1980, 1991, and 2001).

## NOTES

1. Although the European Spatial Development Perspective (ESDP) is not a product of the European Community, the European Commission has been involved in preparing it. Being published in all official European languages, the ESDP is arguably the most international planning text that exists (FALUDI and WATERHOUT, 2002, p. ix).
2. Yet, some scholars argue that it is better to reserve the term 'polycentricity' for morphological polycentricity (the existence of multiple centres in a given area), and 'urban networks' for polycentric regions that demonstrate strong functional relationships (for example, MEIJERS, 2008) to avoid confusion.
3. It should be noted that looking at the network structure is only one way to evaluate the existence of an urban network. In a broader literature, the network model refers to more characteristics, such as the existence of complementarities between cities (BATTEN, 1995; MEIJERS, 2007; VAN OORT *et al.*, 2010). Herein, it is assumed that cities in a network fulfil different but mutually beneficial roles (HAGUE and KIRK, 2003). For example, a city specialized in financial services provides these services to (firms in) a city specialized in labour-intensive industry, and vice versa. This issue is addressed in more detail by VAN OORT *et al.* (2010).
4. Following the typology of KLOOSTERMAN and MUSTERD (2001), the intra-urban scale corresponds here to commuting flows that remain within the urban region. Likewise, the inter-urban scale corresponds to commuting flows between urban regions. More specifically, intra-urban dependencies refer to those interactions in an urban region where only one urban core is involved (Figs 2 and A1–A4). Inter-urban dependencies *additionally* refer to interactions between districts in different urban regions (Fig. 2, types B and C). In Fig. 2, types B and C urban systems are blended in terms of intra-urban and inter-urban relations, in which *intra*-urban relations refer to core–periphery relations in which the 'own' core and periphery districts are involved, and in which *inter*-urban relations refer to relations between core and peripheral districts in different urban regions.
5. Yet, there is considerable academic debate on the exact dimensions and urban structure of the Greater South East. BUCK *et al.* (2002) take the functional urban area of London, measured by the London Metropolitan Area, as the dimension of the Greater South East, though they acknowledge that this might come across as a conservative definition. A more relaxed definition would take Cambridgeshire and Northamptonshire into account as well (BUCK *et al.*, 2002). Perhaps the largest drawback of the conservative definition is that it does not fit within the current policy-making framework. GORDON (2003) makes a strong case for taking the three Governmental Office Regions (GOR) of the South East, London, and the East of England as the dimensions of the Greater South East. Since this definition is more congruent with political reality, it will be the definition of the Greater South East as used in the present paper.
6. Census output is Crown copyright and is reproduced with the permission of the Controller of HMSO and

the Queen's Printer for Scotland. *Sources:* 1981 Census: Special Workplace Statistics (Set C) (re-estimated for 1991 boundaries); 1991 Census: Special Workplace Statistics (Set C); and 2001 Census: Special Workplace Statistics (Level 1).

7. The law was formulated in NEWTON's *Philosophiæ Naturalis Principia Mathematica* (1687).
8. Even earlier applications can be found in the nineteenth-century work of CAREY (1858) and RAVENSTEIN (1885) on, respectively, the analysis of human interaction patterns and migration flows.
9. Intra-district distances were calculated by means of the formula:

$$d_{ii} = \frac{2}{3}\sqrt{\frac{A_i}{\pi}}$$

where the intra-municipal distance $d_{ii}$ is two-thirds the radius of the presumed circular area $A_i$ (for the exact derivation of this and an overview of the considerations involved, see BRÖCKER, 1989b).

10. In this, a likelihood ratio test of over-dispersion (CAMERON and TRIVEDI, 1986) is employed to test whether the negative binomial distribution is preferred to a Poisson distribution, while the Vuong statistic (VUONG, 1989) provides evidence whether a zero-inflated model is favoured above its non-zero inflated counterpart.
11. The coefficients on contiguity and the interdependencies are semi-elasticities. To interpret the impact of, for example, contiguity on the interaction intensity by the estimate of equation (2.3) in terms of an elasticity, it is assumed that a district pair moves from being contagious to being non-contagious. The interaction intensity is then multiplied by a factor:

$$e^{1.349} = 3.85$$

where 1.349 is the coefficient reported in Model 1 (see Table 2).

12. In this, only a linear trend was examined. Future research should look at non-linear relationships over time more carefully.

## REFERENCES


ALBRECHTS L. (2001) How to proceed from image and discourse to action: as applied to the Flemish Diamond, *Urban Studies* **38**, 733–745.

ALLEN J. and COCHRANE A. (2007) Beyond the territorial fix: regional assemblages, politics and power, *Regional Studies* **41**, 1161–1175.

ALONSO W. (1964) *Location and Land Use*. Harvard University Press, Cambridge, MA.

ANAS A., ARNOTT A. and SMALL K. A. (1998) Urban spatial structure, *Journal of Economic Literature* **26**, 1426–1464.

AOYAMA Y. and CASTELLS M. (2002) The informational society, an empirical assessment: employment and occupational structures of G-7 countries in the 1990s, *International Labour Review* **141**, 123–159.

BAILEY N. and TUROK I. (2001) Central Scotland as a polycentric urban region: useful planning concept or chimera?, *Urban Studies* **38**, 697–715.

BATTEN D. F. (1995) Network cities: creative urban agglomerations for the 21st century, *Urban Studies* **32**, 313–327.

BERRY B. J. L. (1964) Cities as systems within systems of cities, *Papers in Regional Science* **13**, 147–163.

BERTAUD A. (2004) *The Spatial Organization of Cities: Deliberate Outcome or Unforeseen Consequence?* Working Paper Number 2004-01. Institute of Urban and Regional Development, University of California, Berkeley, CA.

BEST R. H. (1981) *Land Use and Living Space*. Methuen, London.

BOARNET M. G. (1994) The monocentric model and employment location, *Journal of Urban Economics* **36**, 79–97.

BOURNE J. S. and SIMMONS J. W. (Eds) (1978) *Systems of Cities*. Oxford University Press, Oxford.

BOYLE P. and FENG Z. (2002) A method for integrating the 1981 and 1991 British census interaction data, *Computers, Environment and Urban Systems* **26**, 241–256.

BRÖCKER J. (1989a) Partial equilibrium theory of interregional trade and the gravity model, *Papers of the Regional Science Association* **66**, 7–18.

BRÖCKER J. (1989b) How to eliminate certain effects of potential formula, *Environment and Planning A* **21**, 817–830.

BUCK N. H., GORDON I. R., HALL P., HARLOE M. and KLEINMAN M. (2002) *Working Capital: Life and Labour in Contemporary London*. Routledge, London.

BURGER M. J., VAN OORT F. G. and LINDERS G. J. M. (2009) On the specification of the gravity model of trade: zeros, excess zeros and zero-inflated estimation, *Spatial Economic Analysis* **4**, 167–190.

BURGESS E. W. (1925) *The Growth of the City*. University of Chicago Press, Chicago, IL.

CAIRNCROSS F. (1997) *The Death of Distance: How the Communications Revolution Will Change Our Lives*. Harvard Business School Press, Boston, MA.

CAMERON A. C. and TRIVEDI P. K. (1986) Econometric models based on count data: comparisons and applications of some estimators and tests, *Journal of Applied Econometrics* **1**, 29–53.

CAMERON S. (2005) *Econometrics*. McGraw-Hill, New York, NY.

CAPELLO R. (2000) The city network paradigm: measuring urban network externalities, *Urban Studies* **37**, 1925–1945.

CAREY H. C. (1858) *Principles of Social Science*. Lippincott, Philadelphia, PA.

CASTELLS M. (2000) *The Rise of the Network Society. The Information Age: Economy, Society and Culture*, Vol. 1, 2nd Edn. Blackwell, Malden, MA.

CATTAN N. (2007) Introduction in CATAN N. (Ed.) *Cities and Networks in Europe*, pp. ix−xiv. John Libbey Eurotext, Esher.

Champion A. G. (Ed.) (1989) *Counterurbanization: The Changing Pace and Nature of Population Deconcentration*. Edward Arnold, London.

Champion A. G. (2002) Population change and migration in the British urban system, in Geyer H. S. (Ed.) *International Handbook of Urban Systems*, pp. 87–120. Edward Elgar, Cheltenham.

Clark W. A. V. and Kuijpers-Linde M. (1994) Commuting in restructuring urban regions, *Urban Studies* **31**, 465–483.

Committee on Spatial Development (CSD) (1999) *European Spatial Development Perspective: Towards Balanced and Sustainable Development of the Territory of the EU*. Office for Official Publications of the European Communities, Luxembourg.

Couclelis H. (2000) From sustainable transportation to sustainable accessibility: can we avoid a new 'tragedy of the commons'?, in Janelle D. G. and Hodge D. C. (Eds) *Information, Place, and Cyberspace: Issues in Accessibility*, pp. 341–356. Springer, Berlin.

Cullingworth J. B. and Nadin V. (1997) *Town and Country Planning in the UK*, 12th Edn. Routledge, London.

Davoudi S. (2003) Polycentricity in European spatial planning: from an analytical tool to a normative agenda?, *European Planning Studies* **11**, 979–999.

Faludi A. and Waterhout B. (2002) *The Making of the European Spatial Development Perspective*. London, Routledge.

Finch D. and Marshall A. (2007) *Urban Promise: Cities and the Economic Future of the East of England*. East of England Development Agency, Histon.

Fingleton B. (2003) Externalities, economic geography and spatial econometrics: conceptual and modelling developments, *International Regional Science Review* **26**, 197–207.

Flowerdew R. and Aitkin M. (1982) A method of fitting the gravity model based on the Poisson distribution, *Journal of Regional Science* **22**, 191–202.

Fotheringham A. S. and O'Kelley M. C. (1989) *Spatial Interaction Models: Formulations and Applications*. Kluwer, Dordrecht.

Frandberg B. and Vilhelmson L. (2003) Personal mobility: a corporeal dimension of transnationalisation. The case of long-distance travel in Sweden, *Environment and Planning A* **35**, 1751–1761.

Garreau J. (1991) *Edge City: Life on the New Frontier*. Doubleday, New York, NY.

Geyer H. S. (2002) On urban system evolution, in Geyer H.S. (Ed.) *International Handbook of Urban Systems*, pp. 39–66. Edward Elgar, Cheltenham.

Gillespie A. and Williams H. (1988) Telecommunications and the reconstruction of regional comparative advantage, *Environment and Planning A* **20**, 1311–1321.

Glanzmann L., Grillon N., Kruse C. and Thierstein A. (2004) Polycentricity and metropolitan governance: a Swiss case-study. Paper presented at the 44th European Congress of the European Regional Science Association, Porto, Portugal.

Gordon I. R. (2003) Three into one: joining up the Greater South East, *Town and Country Planning* **72**, 342–343.

Gordon I. R. (2004) A disjointed dynamo: the Greater South East and inter-regional relationships, *New Economy* **11**, 40–44.

Gottman J. (1961) *The Urbanized Northeastern Seaboard of the United States*. The Twentieth Century Fund, New York, NY.

Gourieroux C., Montfort A. and Trognon A. (1984) Pseudo maximum likelihood methods: applications to Poisson models, *Econometrica* **52**, 701–720.

Green A. E., Hogarth T. and Shackleton R. E. (1999) Long distance commuting as a substitute for migration in Britain: a review of trends, issues and implications, *International Journal of Population Geography* **5**, 49–67.

Green N. (2007) Functional polycentricity: a formal definition in terms of social network analysis, *Urban Studies* **44**, 2077–2103.

Greene W. H. (1994) *Accounting for Excess Zeros and Sample Selection in Poisson and Negative Binomial Models*. Working Paper Number 94-10. Stern School of Business, New York University, New York, NY.

Hague C. and Kirk K. (2003) *Polycentricity Scoping Study*. Office of the Deputy Prime Minister (ODPM), London.

Hall P. (2001) Global city regions in the twenty-first century, in Scott A. J. (Ed.) *Global City Regions*, pp. 59–76. Oxford University Press, Oxford.

Hall P. (2006) The polycentric mega-city , in Karssenberg, H. (Interview) (available at: http://www.erasmuspc.com/index.php?id=18046&type=article) (accessed on 29 April 2008).

Hall P. and Green N. (2005) *South East England: Commuting and Definition of Functional Urban Regions*. Institute of Community Studies/The Young Foundation & Polynet Partners, London.

Hall P. and Pain K. (2006) From metropolis to polyopolis in Hall P. and Pain K. (Eds) *The Polycentric Metropolis*, pp. 3–16. Earthscan, London.

Hall P., Pain K. and Green N. (2006) The informational geography of Europolis: mapping the flow of information, in Hall P. and Pain K. (Eds) *The Polycentric Metropolis*, pp. 19–64. Earthscan, London.

Hall R. and White P. (1995) *Europe's Population: Towards the Next Century*. University College London Press, London.

Haynes K. E. and Fotheringham A. S. (1984) *Gravity and Spatial Interaction Models*. Sage, London.

Irwin I. and Hughes M. (1992) Centrality and the structure of urban interaction, *Social Forces* **71**, 17–51.

Kitson M., Martin R. and Tyler P. (2004) Regional competitiveness: an elusive but key concept?, *Regional Studies* **38**, 991–999.

Kloosterman R. C. and Musterd S. (2001) The polycentric urban region: towards a research agendas, *Urban Studies* **38**, 623–633.

Lambooy J. G. (1998) Polynucleation and urban development: the Randstad, *European Planning Studies* **6**, 457–467.

Limtanakool N., Dijst M. and Schwanen T. (2007) A theoretical framework and methodology for characterizing national urban systems on the basis of flows of people: empirical evidence for France and Germany, *Urban Studies* **44**, 2123–2145.

Limtanakool N., Schwanen T. and Dijst M. (2009) Developments in the Dutch urban system on the basis of flows, *Regional Studies* **43**, 179–196.

London Development Agency (LDA) (2007) *Report: Greater South East – Update on Joint Boards Meeting, Part 2 Item 4.2*. London Development Agency, London.

LONG J. S. (1997) *Regression Models for Categorical and Limited Dependent Variables*. Sage, Thousand Oaks, CA.
LONGLEY P., BATTY M., SHEPHERD J. and SADLER G. (1992) Do Green Belts change the shape of urban areas? A preliminary analysis of the settlement geography of South East England, *Regional Studies* **26**, 437–452.
MEIJERS E. (2005) Polycentric urban regions and the quest for synergy: is a network of cities more than the sum of its parts?, *Urban Studies* **42**, 765–781.
MEIJERS E. (2007) From a central place to a network model: theory and evidence of a paradigm change, *Tijdschrift voor Economische en Sociale Geografie* **98**, 245–259.
MEIJERS E. (2008) Measuring polycentricity and its promises, *European Planning Studies* **16**, 1313–1323.
MUTH R. F. (1961) The spatial structure of the housing market, *Papers in Regional Science* **7**, 207–220.
NEWTON I. (1687) *Philosophiæ Naturalis Principia Mathematica*, 3 bks. Jussu Societatis Regiæ ac typis Josephi Streatii, London.
NIELSEN T. A. S. and HOVGESEN H. H. (2008) Exploratory mapping of commuter flows in England and Wales, *Journal of Transport Geography* **16**, 90–99.
OFFICE OF THE DEPUTY PRIME MINISTER (ODPM) (2003) *Sustainable Communities: Building for the Future*. ODPM, London.
PAIN K. (2008) Examining 'core–periphery' relationships in a mega-city region: the case of London and South East England, *Regional Studies* **42**, 1161–1172.
PARR J. B. (2004) The polycentric urban region: a closer inspection, *Regional Studies* **38**, 231–240.
PERROUX F. (1955) Notes sur la notion de 'pôle de croissance', *Économie Appliquée* **7**, 307–320.
PRED A. (1977) *City Systems in Advanced Economies: Past Growth, Present Processes and Future Development Options*. Hutchinson, London.
RAVENSTEIN E. G. (1885) The laws of migration, *Journal of the Statistical Society* **48**, 167–235.
RENKOW M. and HOOVER D. M. (2000) Commuting, migration and rural–urban population dynamics, *Journal of Regional Science* **40**, 261–287.
ROMEIN A. (2004) Spatial planning in competitive urban regions: some practical lessons from Northwest Europe, in HAMBLETON R. and SMITH J. (Eds) *City Futures: An International Conference on Globalism and Urban Change*, pp. 1–18. University of Illinois, Chicago, IL.
ROUWENDAL J. (1999) Spatial job search and commuting distances, *Regional Science and Urban Economics* **29**, 491–517.
SCHWANEN T., DIELEMAN F. M. and DIJST M. J. (2004) The impact of metropolitan structure on commute behavior in the Netherlands: a multilevel approach, *Growth and Change* **35**, 304–334.
SIMMIE J., SENNETT J., WOOD D. and HART D. (2002) Innovation in Europe: a tale of networks, knowledge and trade in five cities, *Regional Studies* **36**, 47–64.
SOHN J. (2004) Are commuting patterns a good indicator of urban spatial structure?, *Journal of Transport Geography* **13**, 306–317.
SOUTH EAST ENGLAND DEVELOPMENT AGENCY (SEEDA) (2005) *The UK's Engine for Growth and Prosperity: A Case for Targeted Investment in the Greater South East*. South East England Development Agency, East of England Development Agency, and London Development Agency, Guildford.
SOUTH EAST ENGLAND DEVELOPMENT AGENCY (SEEDA) (2006) *A Clear Vision for the South East: The South East Plan, Executive Summary*. SEEDA, Guildford.
STEWART J. Q. (1948) Demographic gravitation: evidence and applications, *Sociometry* **11**, 31–58.
THE SOCIETY FOR ALL BRITISH AND IRISH ROADS ENTHUSIASTS (SABRE) (2007) *The Roaders' Digest* (available at: http://www.sabre-roads.org.uk/roadlists/) (accessed on 30 April 2008).
TURNER T. and NIEMEIER D. (1997) Travel to work and household responsibility: new evidence, *Transportation* **24**, 397–419.
ULLMAN E. L. (1954) Geography in spatial interaction, in REZVAN D. and ENGELBERT E. S. (Eds) *Interregional Linkages, Proceedings of the Western Committee on Regional Economic Analysis, UCLA*. University of California – Los Angeles, Berkeley, CA.
URRY J. (2004) Social networks, travel and talk, *British Journal of Sociology* **54**, 155–175.
VAN DER KNAAP G. A. (2002) *Stedelijke Bewegingsruimte: Over Veranderingen in Stad en Land*. SdU Uitgevers, The Hague.
VAN DER LAAN L. (1998) Changing urban systems: an empirical analysis at two spatial levels, *Regional Studies* **32**, 235–247.
VAN HAM M. (2002) *Job Access, Workplace Mobility, and Occupational Achievement*. Eburon, Delft.
VAN OORT F. G., BURGER M. J. and RASPE O. (Forthcoming 2010) On the economic foundation of the urban network paradigm. Spatial integration, functional integration and economic complementarities within the Dutch Randstad, *Urban Studies*.
VUONG Q. H. (1989) Likelihood ratio tests for model selection and non-nested hypotheses, *Econometrica* **57**, 307–333.
WHITE M. J. (1988) Location choice and commuting behaviour in cities with decentralized employment, *Journal of Urban Economics* **24**, 129–152.