Universidade de Aveiro
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Departamento de Ciências Sociais Políticas e do Território

**PAULO RICARDO LOPES BATISTA**

# A ESTRUTURA DE INTERAÇÃO DE UM SISTEMA E-TERRITORIAL.

## TERRITÓRIO, MERCADO DE HABITAÇÃO E ECONOMETRIA ESPACIAL

# THE INTERACTION STRUCTURE OF E-TERRITORIAL SYSTEMS

## TERRITORY, HOUSING MARKET AND SPATIAL ECONOMETRICS

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Tese apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Doutor em e-Planeamento, realizada sob a orientação científica do Doutor Eduardo Anselmo Moreira Fernandes de Castro, Professor Associado, e sob a coorientação do Doutor Arnab Bhattacharjee, Professor Catedrático Visitante, e do Doutor João José Lourenço Marques, Professor Auxiliar, no seu conjunto filiados profissionalmente no Departamento de Ciências Sociais Políticas e do Território da Universidade de Aveiro

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## o júri

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**palavras-chave**

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**resumo**

A noção de espaço (abstrato, matemático), subjacente à territorialidade, constitui a base das ferramentas analíticas convencionais, usadas em planeamento. Contudo, a dimensionalidade e geometria, subjacentes a essas ferramentas, têm vindo a ser questionadas. De facto, a revisão da literatura evidencia a necessidade de desenvolver mecanismos analíticos, capazes de relaxar os referenciais geométricos e dimensionais, adotados ao longo do processo de tomada de decisão no planeamento territorial.

O recente desenvolvimento de novos métodos de análise espacial, quer no âmbito da econometria espacial, quer noutras disciplinas de suporte ao planeamento, constitui uma oportunidade de rever as assunções geométricas e dimensionais adotadas, bem como as respetivas estratégias de análise das estruturas territoriais que lhe estão subjacentes.

Assumindo a hierarquia como uma propriedade fundamental na organização das interações dos sistemas territoriais, considera-se esta como uma condição mínima analítica, a partir do qual se propõe um novo referencial de estimação, mais liberto das condicionantes geométrica e dimensionais usuais.

Neste contexto, assumindo que as propriedades espácio – territoriais são codificadas no valor habitação bem como a relevância do tema no planeamento territorial, adota-se o mercado de habitação no sistema territorial de Aveiro – Ílhavo enquanto caso de estudo.

Cruzando as sugestões da literatura científica com os resultados de uma metodologia, de base econométrica, aplicada nestes contextos, observa-se que as estruturas de interação territorial fundem os padrões geográficos expectáveis (dos modelos clássicos) com um conjunto de relações de geometria e dimensionalidade desconhecida. De facto, tendo presente o quadro teórico que aponta para a reestruturação territorial como um elemento transformador associado às novas tecnologias de informação e comunicação, as evidências encontradas vêm reforçar a perceção teórica de que se encontram a despoletar os novos sistemas (locais) e-Territoriais.

**keywords** e-Planning, Territorial structures, Housing market, Spatial interaction, Spatio-territoriality

**abstract**

The notion of space (abstract, mathematical), inherent to territoriality, characterizes the conventional analytical tools used in planning. However, the approach to dimensionality and geometry within these tools has been questioned. The literature review suggests the need to develop analytical mechanisms, able to relax the geometric and dimensional reference framework that has been adopted in planning decision-making tools.

The development of new spatial analysis methods, within spatial econometrics as well as other disciplines which are relevant for territorial planning, provides an opportunity to review the geometric and dimensional notions and the usually applied empirical estimation strategies.

Taken hierarchy as a fundamental feature to specify the interaction structure that describes territorial systems, a minimum analytical condition is adopted that supports a new analytical framework, free of strong geometric and dimensional constraints.

The research program presented here is based on the codification of spatio-territoriality in housing values, in addition to the relevance of housing price models themselves in territorial planning, motivating the study of the housing market in the case-study of the Aveiro-Ílhavo territorial system.

The scientific knowledge about spatial interaction structures is combined with empirical insights, from a new methodology based on simpler econometric methods. It was possible to observe that territorial interaction structures are a combination of classical geographic patterns with an unknown geometry and unknown dimensionality.

The results, framed by the theoretical discussion, support the observation of territorial restructuring processes, which arise, among other factors, from the changing role of new information and communication technologies. They also reinforce the adoption of the concept of e-Territorial (local) system to frame these new territorial structural properties.

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# 1. INTRODUCTION

The perception that changes in a certain point of (the geographical) space are, somehow, related to the changes that occur in other points of that same space, has always aroused human curiosity. Theoretical and empirical efforts have been made targeting these spatial relations, where geography (Sack, 1973), economy (Roy, 2004), but also philosophy (Casey, 1997) and physics (Hesse, 1962) provided relevant insights. In planning, the approach of this phenomenon has been made by focusing two fundamental questions: What is the pattern (or patterns) of observable interactions in the geographical space? What explanation/mechanism(s) support those interactions? The search for answers to these questions has been pursued, over the years, by developing tools that support planning practices.

Simultaneously, there has been a more general ontological discussion – after all, what is space? – for which different epistemological approaches, developed under a fruitful dialogue between theory and practice and between different scientific fields have been contributing. However, fundamental questions remain unanswered. Finding answers to these questions is not only a well-known, interesting and challenging research field in physics (Greene, 2010), but also – as is argued in this work – in subjects closely related to territorial planning.

This thesis presents a discussion of space/territory, supported by the different theoretical and practical planning approaches, taking into consideration their understanding of the world and the tools that they have developed to analyse and transform it. The focus will be on one of the most integrating properties of territoriality: the observations of (spatial) interaction phenomena. Most importantly, the experience accumulated in territorial planning made clear that planning actions have effects that surpass the limits of the geographic space where the prescribed territorial transformations occurs. Moreover, empirical evidence has allowed to observe these (exogenous) effects, which constitute, themselves, challenging observational problems.

This thesis starts with a brief introduction on the roots of the concept of territory and the recent challenges to understand it, which is a first justification for the methodological direction adopted in this work.

## The roots of territoriality

The rise of modern territorial planning is usually placed in the second half of the 19th century, where the administration of land use and the control of its transformation processes constituted a societal goal. Its importance led to the automation of the political and administrative tasks in order to face: i) the need to regulate the rapid social and economic transformations that societies were witnessing; ii) the (re)organization of societies around "nation-states" (E. Hobsbawm, 1994; Tilly & Ardant, 1975), based on sovereignty mechanisms under delimited areas of the geographical space – the territory (Elden, 2010) – where the operations of land control, use and transformation are fundamental (Sack, 1986).

The planning field can be characterized by two major practices: the analysis of the position of elements on a given area and the prescription of interventions towards an active change of the observed order of these elements. These prescriptions are, among other things, related with land use rules. The most important tool that drives both planning practices is the long "tradition" of techniques developed in cartography, justifying the primacy of the Euclidean geometric framework – which will here be referred to as 'geographic space'.

The spatial geometric framework, defined by the geographic space, can be identified as the apparent dominant expression of spatial planning in the literature. However, planning surpasses these strict concepts. For example, the British tradition – probably the oldest in the western world – refers to town and country planning, suggesting that planning should not be constrained by an abstract, mathematical, auxiliary 'spatial' framework. In this work, *territorial planning* is used in a broad sense. Moreover, it is assumed that its practices – as defined previously – are concerned with the analysis and transformation of *spatio-territoriality*. The later expression is adopted to highlight the tension, which naturally shape the definitions and conceptual choices presented before: the geographical space remains a fundamental framework – and it will be fundamental in this thesis – but the history of territorial planning theory and practice extends beyond the notions of space described by its physical (geographic) dimension.

Planning often assumes itself as territorial, in recognition of the need to integrate multiple dimensions that, directly or indirectly, are acknowledged as part of the phenomenon of land use and transformation (for a debate on the concept of territory see, for example, Paasi (1998), Agnew (2001) and Elden(2010)). One of the more complex territorial phenomenon – or territorial structure/territorial structural property – is usually recognized by the expression *spatial interaction*. Therefore, it is promptly assumed that planning actions on this phenomenon cannot disregard the multi-dimensionality that shapes the spatio-territoriality which defines it – leading to the expression *territorial interaction* as an equivalent that considers the phenomena specifically implied by territoriality.

Therefore, it is consensual in the history of territorial planning that its practice involves several domains, which can be considered as dimensions to describe spatio-territoriality. These dimensions have a direct (or indirect) impact on the geographical dimensions (defined by the Euclidean space) and in this way on the observed geographic shapes of the structures/phenomena related with it.

The interchanges between the concept of space and spatio-territoriality can be linked to a recently emerging e-planning agenda, following the scientific evidences from economics, geography and sociology about a substantial transformative role of (new) information and communication technologies (ICT) on the structures of spatio-territoriality.

The increasing complexity of social interactions and the emergence of new phenomena in spatial organization, makes it useful to summarize some of the most important drivers of spatio-territorial transformation and its observables structures in the geographic space.

## New information and communication technologies

New ICT can be defined by the unique characteristics of mediated communication and automated information processing which became available from recent technological developments. Floridi (2008) present us a conceptual framework to describe the new digital mediation systems. This author argues that a digital message that seeks to mediate a process of social interaction involves three elements: i) data – usual types of codes (visual, audio, etc.), represented in a unique digital code; ii) information – constituted by one or more types of data (which can be classified as primary data, secondary data, metadata, operational data, derived data, etc.); and iii) the knowledge that is possible to obtain by the interpretation of the previous objects.

As argued by Lévy (1997), ICT present distinctive qualities: may be processed in an automatic way, with an almost absolute level of detail, very fast and in an enormous quantitative scale. The digitalisation led to a process of convergence in a communication platform that aggregates several technologies and communication media. This global platform is based on a communication architecture between machines, of ubiquitous characteristics – the Internet. Following these properties, Castells summarizes the role of new ICT as devices, which provide an integration of a set of communication features, based on the "self-expandability (ability of communication processing, concerning volume, complexity and velocity); with unlimited recombination ability (through digitalisation and constant communication); and flexibility in terms of distribution (by the combination of digitalisation and network interaction)" (as cited in Santos (2012))[1].

Ferraz de Abreu (2002) calls this transformation process as a "qualitative jump" – "the direct access of the end user to the machine, together with the control of its use, and even a certain level of programming" (p. 64). This seems to change the challenges of the "'enabling' function of IT", caused by a myriad of different constrains to the reach of

[1] Translation note (original texto): "autoexpansíveis (capacidade de processamento e comunicação, em termos de volume, complexidade e velocidade); ilimitada capacidade de recombinação (através da digitalização e da comunicação recorrente); e flexíveis em termos de distribuição (pela combinação de sistemas de digitalização e de interação em rede)"

communication, to a problem which is mainly focused on the inequality that shapes the dominant societal models.

The connected environment has been described by what Bradley (2007) defines as a "convergence model". Here, ICT assumes a role as part of several processes that, simultaneous and mutually, affect each other and are responsible for the emergence of new socio-economic and spatio-territorial configurations. The author highlights the increasingly close relation of the converging (re)configurations of traditional dimensions of social life (social interactions) with converging ICT processes.

Behind the conventional analysis of convergence focused on media (mainly coming from the communication sciences), it is important to highlight the socioeconomic dimensions of this convergence process. Furtado (2012) highlights the need to analyse the infosphere (as defined by Floridi (2010)) and its features: increasingly more time - synchronous, relocated space and correlated interactions. These characteristics have been leading to a debate about the path that social, spatial and territorial transformations associated to this process of convergence have been taking. In another direction, Castells (2005) points to the understanding of mechanisms towards the emergence of the knowledge society, related with the way in which the production, processing and transmission of information becomes a key source of productivity and power, due to new technological conditions. In other words, how the increasing sophistication of mediated communication (which enables a better communication at a distance) is translated into a new source of (economic) value and its impacts on a society organized through a capitalist economic system.

Furthermore, as Pereira (1995) argues, the sophistication of mediated communication produces an excessive presence of the spatio-territoriality as a result of the decreasing perception of the size of the planet. To illustrate this, the author mentioned that the distance from ourselves is well represented by the perception of distance from astronauts: at that scale, and with that view, our geographic distances, at the earth's surface, seems comparatively small; moreover, their point of view illustrates the ability of the human beings to analyse and conceptualize space beyond the planet earth. As we are now at a few hours distance from anywhere in the world (thanks to the developments in the transport systems), but mostly, as we are able to instantly, and sometimes simultaneously, receive a vision of events that are located somewhere in the planet, our perception and relation with spatio-territoriality is radically changed.

However, Pereira (1995) alerts to the dangers of the "spatial over-abundance". For individuals, the remote experience provided by the new ICT centralises the possibility to apprehend the distant world that surrounds them, potentiating a myriad of perceptions, hard to achieve in the past. This attraction works as a lure, in which manipulation is very hard to identify, since there is space for a certain homogenisation of perceptions, which depend on mediated information. In a complementary perspective, Furtado (2012) further points out some negative tendencies. First, there is a homogenising effect in diversity, because the "screens" creates a false sense of familiarity according to the prevalence of certain "landscapes" in detriment of others (Paris, Washington, New York, etc.). Second, the distortion in the received images may not only come from a deliberate manipulation, since the contacts with certain images in detriment of others has, in itself, a certain power and influence.

## The spatio-territoriality of a new economic system

As we have seen so far, the space-territory constitutes the key stage of the socio-economic development of human societies. After all, the observation of the territorial patterns and the social and economic transformations constitute powerful tools for the analysis of reality.

In the last decades, combined with a radical change in the global political governance system and with a process of globalisation of the capitalist economic system, an accelerated technological development, has led to a massification of communication, and other functions, at a distance. Even if the exercise is merely useful to underline the relative novelty of these transformations, we can place the beginning of these transforming processes in the 1980. But, from the decade of 2000 on, a considerable volume of works arises, seeking to empirically analyse the territorial transformations in the light of their possible connections with the development of ICT. Audirac & Fitzgerald (2003) present a reflection in this line of thought, concluding that the emerging (new) economy is globally more connected not only due to the increase of geographical mobility but also due to an expansion of communication abilities.

The authors further note that, in the new economic system, the distribution of the activities forms patterns which are fragmented, polycentric and have blurred (complex) borders, suggesting that the new mechanisms that support the (new and territorial) interactions potentiate the dispersion of repetitive operations, at the same time as they foster the centralisation of the production and accumulation of knowledge.

These empirical observations address a conceptual framework that starts from the theoretical premise that the (new) ICT are inductors of a transformation of the socio-economic system, with emphasis on the possible restructuring of the capitalist mode of production. Castells (1989) can be pointed as one of the first to develop a research program concerned with the study of the links between ICT and the economic system, and to connect this double phenomenon with possible territorial transformations. More recently, this author proposes the concept of "space of flows" to explain the root of new territorial patterns. From this perspective, the social meaning of the traditional space is diluted and widespread in a logic of permanent reconstruction (the space of "variable geometry"), which has an unknown profile, origin and ultimate purpose. According to this author, people live in physical spaces, but their relations are established on flows which might, or not, be spatially bound. Based on this mechanism, the author argues that the globalisation of flows will benefit those who own the power, at the same time as a tribalisation of local communities arises, as a result of a dissociation between the economic development, provided by the ICT, and the (lack of) efficiency of the traditional mechanisms of control (institutions of collective power, the state, etc.) – which usually act in a delimited territory.

The emerging territorial patterns will be the result of a dynamic equilibrium of these centres. This equilibrium arises from a complex set of strategic decisions made by public and private agents, resulting in concentration and dispersion phenomena. These decisions can either be the consequence of mechanisms of regulation or of exclusively corporate nature.

The territorial restructuring of the economic system changes the production (and consumption) patterns: social actors, who usually favour to be "located" in the boundaries of their social group face "that social meaning evaporates from places, and therefore, from society, and becomes diluted and diffused in the reconstructed space of flows" (Castells (1989) p. 349). But, as "societies are not made up of passive subjects resigned to structural domination (…) the meaninglessness of places, the powerlessness of political institutions are resented and resisted, individually and collectively by a variety of social actors", concluding that "the globalization of power flows and the tribalization of local communities are part of the same fundamental process (…) the growing dissociation between techno-economic development and the corresponding mechanisms of social control of such development" (Castells (1989) pp. 349-350).

It was within this line of thought that the author rehabilitates the importance of geography for the description and analysis of new territorialities, and social groups, where the concentration of people that share a status determines the model of sociability. But is it is necessary to take into account the change in the way space influences the sociability of communities. According to the author, the geographic space will lose importance as the key device for explaining and predicting territorial structures as new metrics overlap with the conventional Euclidean space to establish a topology. For the author "the space is now made up of networks and nodes that process and transmit the flow of information. This structure produces new territorial configurations through multiple, simultaneous, processes of spatial concentration and dispersion in a changing geometry of global information flows" (Castells (1989) p. 245).

## The production of (new) e-territorialities

As is argued later, the analytical framework of this work is based on the unknown dimensionality and geometry of space. It tries to combine the conventional explanation models of territorial interaction with the prevalence of the (re)structuring effects of new ICT.

It is well recognized that the technological advances in communication (in a broader sense) resulted in territorial transformations. Communications as transportation of people (and goods) are the usual basis for standard models that seek to describe territorial interactions. Describing these interaction mechanisms relies on measurable properties of the transport systems, such as Euclidian distances, or more sophisticated measures, such as travel time. These measures neither apply to the communication among individuals nor allow to measure, in an accurate way, all the dimensions that were effectively involved in the process of territorial interactions. Unlike transportation, the information and communication technologies (technologies of communication at a distance) witnessed a vertiginous acceleration in the end of the 20th century, via: i) the integration of communication with information processing (digitalisation and computation); and ii) the development and disclosure of a myriad of different technologies for the transmission of information at a distance, replacing the need for co-presence in a different set of activities. Therefore, the same way that transportation had numerous effects on the structuring of the space-territory, the effects of the (new) information and communication technologies also have far-reaching consequences.

The transformations promoted by the revolution of information and communication technologies (ICT) have been subject to many scientific approaches in recent years. Castells (1989) presents a pioneer approach to the impacts of these changes in the traditional space and territory. In the book “information city”, the author defends that the new ICT created the possibility of changing geographically confined community interactions for a social organisation that is based on networks, free from the traditional “spatial” constrains- determined by its material, physical and geographical barriers. Castels (2004) and Varnelis and Friedberg (2008) quote the example related with television, to characterise the new “Space”: events now simultaneously occur where they actually happen as in the place where they are viewed. Lévy (1997) points to the fact that the new means of communication have freed the transmission of information from the traditional “Space”.

This conception of a (new) space of flows is supported by the digitalisation of information and its transmission, which leads us to adopt the expression of ‘digital space’ – as a reference and an expansion of the previously defined traditional notion of space. Since technological infrastructures have always been embedded with forms of economic and political organization, Lévy (1997) foresees that the digital space could become a way to explore problems, to reveal complex processes and a space which allows types of collective decision-making which are closer to the communities.

It is within this context that authors such as Oldenburg (1989) and Varnelis and Friedberg (2008) describe modern places as places which can be associated with the development and multiplication of media. Authors like Morley (2002) argue that the transformations associated with the new digital space are evident in pioneer events such as the production of the suburban place. After all, the authors assign the consolidation of this (new) place in developed societies to the fact that technologies enabled the insertion of the residence – a place reserved to the social interactions inherent to "private life" – as a node integrated in the (new) space of flows. The suburban arises as a new place through its connection to the remaining nodes of the space of flows of a society, which the massification of technologies, such as the television, allowed. Therefore, there has been a substitution of the direct socialisation (which required a physical presence, geographically close and that promoted spatial concentration) by a technologically mediated socialisation, allowing the building of a place that combines the urban with the rural – the suburban. This phenomenon can be synthesised in the concept of "cyber-territory", where the internet medium (like the City as medium) provides the main tools of socialisation, in this (new) digital space.

The structure of this new territoriality is an open debate. For example, Morley (2002) highlights the work of Margaret Morse, describing "increasing functional isolation and spatial segmentation of individuals and families into private worlds which are then mediated into larger and larger entities by new forms of communication" (p.172), which results in a paradox between mass culture and social isolation. Silva (2011) synthesises the directions of territorial transformation in the digital space as: 1) the building of an extensive symbolic territory, associated to a globalist concept; 2) the implications of the territorial flexibility over the geographic and socio-political territory; and 3) the representation of individual and/or private territories.

The inability to understand the territorial interaction processes and the absence of tools that can deal with the phenomenon, in a satisfactory way, led to the integration of new scientific knowledge in the territorial planning activity. It is in this context that new subjects, among which economy and sociology, have been associated to the applied subjects in which the activity was initially based – cartography, geography, and also architecture and civil engineering.

This work can be framed within the scientific efforts that have been aiming to provide territorial planning with a framework of tools to identify and describe the general geographic patterns of territorial interactions at the local scale. Efforts will be made to contribute to the reflection on the notion of space, from its view as a geographic space towards it integration with social and economic phenomena. Moreover, this work aims to contribute specifically to the literature on spatial econometrics and its need for additional theoretical guidelines on the nature of spatial interactions: bringing spatial econometrics to the debates of regional economics, and urban studies in particular, can provide new directions for the development of new analytical tools to assess territorial planning activities.

# 1.1. AIMS AND RESEARCH QUESTIONS

The introductory overview presented the role of the concept of space for territorial planning. Moreover, the transformative potential of societal changes on that concept was highlighted: the changes in territorial properties that can be enabled by new ICT are viewed here as a renewed appeal to planners to revise how they understand spatio-territoriality in general, and the concept of space behind the tools that supports their territorial planning practice, in particular.

It does not cease to be symptomatic that the word 'complexity' has been frequently used in the contemporary scientific planning literature. Nowadays, the planning activity assumes that the connection between practice and scientific knowledge is necessary and should be increased, in order to produce a better understanding of the complexity of human societies' spatio-territorial organization. Within this context, there is:

i. the need to advance the integration and application of methods and techniques, which may not be specifically developed as decision support tools, but constitute reasonably consolidated explanatory models of territoriality.
ii. the connection between planning and the production of knowledge efforts, placing the planner at the centre of the theoretical and practical integration of different scientific subjects – where the need to integrate approaches from different disciplines is especially relevant.
iii. the recognition of the dimensions which characterise contemporary territorial patterns and their mechanisms of formation.

The context of territorial transformations has been accompanied by an intense debate on planning theory and methods. The need to redefine concepts, established in the light of these transformations, as well as the need to develop analytical approaches that allow their operationalization, are the main motto for the development of this work. We highlight the contributions for:

i. re-understanding the meaning of urban (local / municipal scale) spatio-territoriality in times of a new wave of social, economic and spatial transformations;
ii. articulating the previous efforts to (re-)understand territoriality with the development of new analytical frameworks, both theoretical and empirical, that allow the integration of these efforts in the context of the planning activity;
iii. developing new analytical strategies to produce knowledge about the effects of territorial planning decisions.

To achieve these general goals, this work seeks to answer the following research questions:

**1. HOW TO DEFINE AND DESCRIBE A TERRITORIAL SYSTEM?**

The process of fast economic and social transformation triggered by the agricultural, scientific and industrial revolutions raised the consciousness of a set of interconnected problems. For example, the pollution caused by industrial units, in certain locations, affects the air quality of populations in other locations[2], therefore interconnecting different territorial unities. Another example comes from the movement of individuals between the (different) locations they inhabit and work, which leads to distinct pattern of land use, and thus distinct territorial units that are interconnected through the social and economic relations of their users. Finally, another important example are the increasing spatial imbalances in the territorial development levels, which have been associated with the imperfections on the interlinkage structure of territorial systems.

The perception of the nature of these territorial challenges and the need to find solutions, led to the development of a technical and scientific device within the public administration – the territorial planning corpus – responsible for: i) understanding the existing interconnection/ interaction structures; ii) developing scientific knowledge applied to the identification and resolution of such problems; and iii) implementing mechanisms that help collective decision-making to guarantee the resolution and mitigation of identified problems.

Territorial planning has been developed in two ways to assure these functions: i) through a set of abstract notions which guides the planning practices – such as the notion of space; and ii) through actions based on the technical and scientific models derived from that understand of reality. The identification of territorial interaction mechanisms in the planning field must, therefore, be based on the review of both of the components described above – understanding and transforming spatio-territoriality.

In this regard, it is important to highlight that the option for a historical perspective, in the view of a defining synthesis of the mechanisms of interaction, implies focusing different layers that have been added to the planning notions and practice over time. Moreover, planning is based on contributions from geography, economy or sociology for example, that needs to be reviewed to produce a full picture of the – geometry and dimensionality – concepts behind spatio-territoriality.

[2] The territorial differentiation emerges, as it will be shown, from the concept of the territory itself, focused in the previous matter of research, considering common examples as the definition of territorial units from landscape patterns of distribution of the individuals or of the political and administrative unities, among others.

## 2. WHAT FEATURES CAN BE USED TO DESCRIBE TERRITORIAL INTERACTIONS?

The increasing evidences of a fast process of spatial restructuring, with a growing visibility in the scientific production in different fields, leads to new territorial patterns (social, economic and geographic) and thus makes it necessary to reformulate the (or propose new) mechanisms that explain them. As has been stated, this makes it necessary to develop frameworks which are more interdisciplinary, allowing to integrate explanatory dimensions of the phenomena that usually are the focus of a single scientific subject.

The multidimensionality of the concept of territory is not new in the territorial planning practice, placing this applied area of knowledge in a pivotal position to promote the above-mentioned disciplinary integration. As we will seek to argue, in planning, the concept of territory has been enhanced, both as a consequence of the dynamics of territorial transformation and by an increasing integration of the knowledge of different scientific subjects.

If, on the one hand, the evolution of the concepts that support territorial planning is anchored in its practice at each moment – such as the move from the concept of spatial planning to territorial planning, which is today more widespread and is adopted here. On the other hand, these transformations have obvious consequences for the technical and scientific devices (both theoretical and conceptual) to which this practice resorts.

The concept of space also has an important role in this thesis. It is used, as a generalist reference, to refer an observed reality, which we can associate to the object of geography (the geographic space). It is also understood as an analytical instrument of quantitative nature, the mathematical device that allows to represent and quantify a given phenomenon.

Therefore, from the space that describes the material reality (mathematical, physical, sensory), to the territorial transformations evident in the geographical (spatial) dimension of reality, the dialectical concept of space-territory will be used here, following their interchangeable roles in the contemporary planning lexicon.

## 3. HOW TO IDENTIFY THE SPATIAL INTERACTION STRUCTURE OF A TERRITORIAL SYSTEM?

It is recognised that interactions in a broad sense are based on some kind of mediated communication mechanisms among objects. At a social level, interactions are defined as the processes of information interchanges between individuals and between the individuals and their biophysical environment. The mediation devices on social interactions can be defined in several ways, but a convenient classification is based on the differentiation between face-to-face (or direct) communication and communication at a distance. In the first case, the mediation is based on archaic instruments (linguistic, symbolic, etc.) that involve multiple dimensions, and the geographic space serves as the support that allows to identify and relate each of those communicational events – not as a location device that enables an encounter can occurs but even more as a support of infrastructures that connects both individuals – the transportation infrastructure; in the second case, the communication depends on sophisticated 'means' of transmission that, with their objective specifications (possibilities), condition the quality (and dimensions) associated to that communication – for example, the telegraph, the physical telephony (two-way communication) and the mass means of communication (one-way communication), such as radio and TV.

The technological development allowed to digitalise a significant part of information in the end of the 20$^{th}$ century. Furthermore, the development of tools of digital information processing (namely, the use of computational tools), has transformed the process of digital encoding into a quite fast and autonomous/non-supervised one, bringing major changes – particularly in communication at a distance.

The connection between transportation, communication and interaction has been thoroughly established, with a relevant role for (new) ICT. The reconfiguration of the mechanisms of interaction is assumed here as the catalyst of territorial transformation (in a broad sense). Then, building new knowledge of the mechanisms of territorial interaction is naturally extremely relevant for a better territorial planning practice.

# 1.2. OUTLINE AND METHODOLOGY

The main pieces of this is work are a contribution for the debate on the definition of geometric and dimensionality references as supports of knowledge on territorial planning activities. As argued by Marques (2012) significant gaps subsist to understand territoriality that extends, naturally, to planning actions that guide territorial transformations. The importance of this debate is enhanced by the increasing role played by new information and communication technologies (ICT) as one of the major, latent, drivers of territorial restructuration. However, it is important to notice that the effects of ICT are under development, without a clear direction and respective empirical evidences.

The object of inquiry in this thesis is assumed as a continuation of debates presented by Marques (2012). Moreover, even the empirical framework, although following a newer referential, follows some insights previously developed by Arnab Bhattacharjee et al. (2013), A. Bhattacharjee, Castro, & Marques (2012) and Marques (2012). The continuity of a similar research program is assumed here as an important effort in times where the increasing complexity, highlighted by Morin (1991, 2008), points to a "scienza nuova" that comprises at the same time an increasingly multidisciplinary view of an object of inquiry and the consequent necessity to persist on a research program.

Combining the three research questions described in the introduction, this work follows a "hypothetic-deductive" approach, such as was outlined by Holt-Jensen (2009). Thus, the multiple knowledge sources derived from various disciplines and practices in planning are selected, reviewed and organized, to create a framework to identify the structure of interaction between different territorial units. Then, that framework (or rather its assumptions) forms the basis to build the axioms behind a new understanding of spatio-territorial interaction and consequent hypotheses that can be confirmed, modified or rejected by empirical exercises. The analysis of the hypotheses is developed through an empirical application, which includes a simulation exercise and a real case-study that is based on a set of technical and scientific guiding principles that the literature demonstrates as consolidated – in this concrete case, developed under an econometrics/spatial econometrics approach.

Analysing the tools – the qualitative and quantitative concepts and modelling devices – allows to identify the invariant properties adopted to describe and model the interaction mechanisms of a territorial system. This analysis focuses on a selection of insights from approaches and models, that are part of the technical-scientific planning corpus, concerned with the understanding and transformation of spatio-territoriality. To achieve the general insights towards the properties of (new) territoriality, the purpose of this approach, is twofold:

i. to understand how the structure of socio-economic-spatial interaction is perceived, as it is often used by certain theoretical, philosophical and ideological frameworks;

ii. to allow defining the theoretical properties of a territorial structure, and therefore observe which postulates are used to guide planning actions.

Finally, this work contributes indirectly to identify and underline the objective importance of housing in modern societies, namely given the direct (and indirect) importance assumed in the planning practice, and the opportunities associated to its integration within a quantitative analytical tool. The thesis will go as follows.

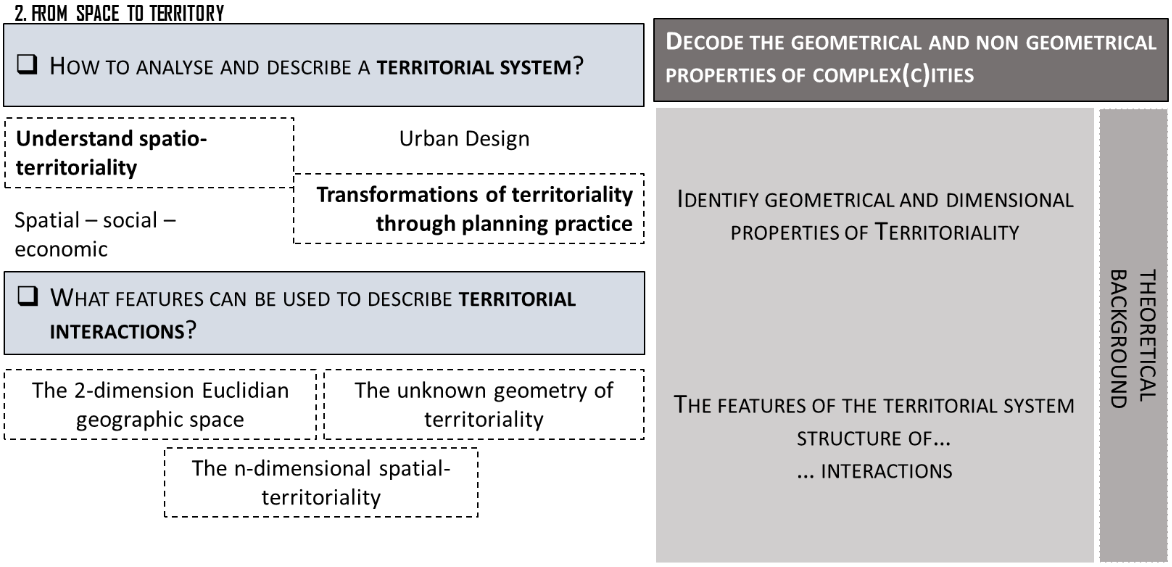


**Figure 1.1** Methodological framework: theoretical background

Chapter 2 presents the efforts for defining and delimiting the key features of territoriality related with geometric and dimensionality considerations to explain the phenomena behind it. First, the basic elements to understand the notion of territoriality – in their geographic, economic and social content – are debated through the lens of disciplines that support the scientific knowledge used in (territorial) planning. Regarding this last aspect, the analytic and practical frameworks generally used in planning is presented in order to underline how they translate notions of geometry and dimensionality in practice.

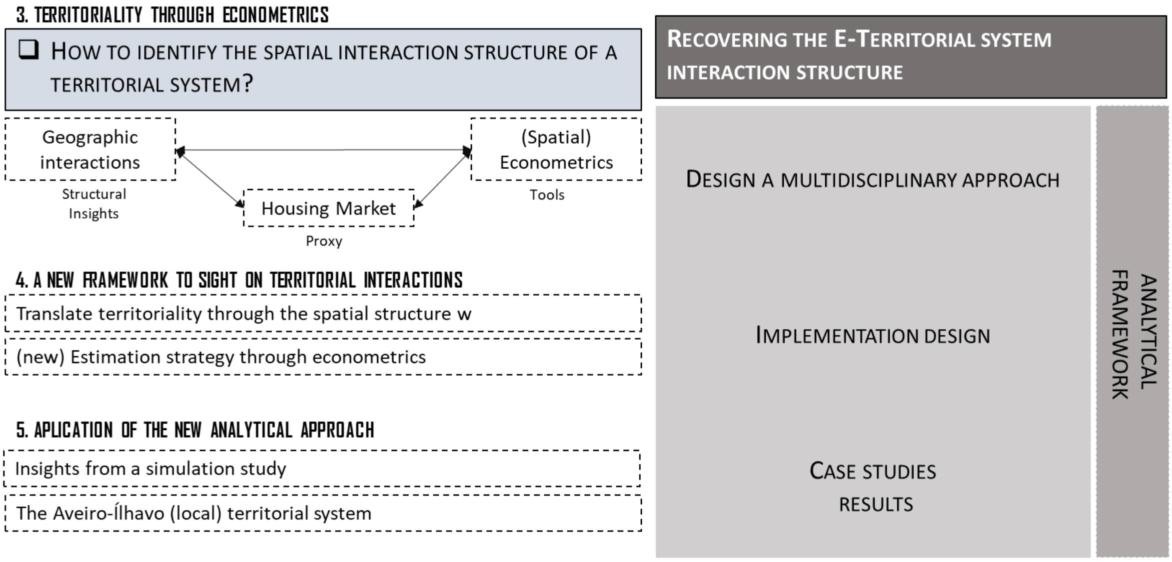


**Figure 1.2** Methodological framework: analytical approach

Chapter 3, 4 and 5 are the core of this thesis as they translate the conceptual and theoretical debates into a concrete strategy that tries to describe the hypothesis underlined by the discussion of the research questions.

Chapter 3 provides the multidisciplinary background that guides the development of a technical and scientific framework based on economic – and spatial econometrics in particular – analysis of housing markets. Supported by the territorial planning focus as an instrument dedicated to territorial configuration of housing units, the transversal and wide use of classical economic methods and models to support these decisions will serve as a reference. The focus will be on understanding the links between: i) housing, as a general object of territorial planning; ii) the market, considered as a system organized around capitalist principles, which is an essential device to guarantee individual's housing provision; iii) and finally, econometrics and spatial econometrics in particular, as the most consolidated and versatile framework to produce a quantitative (market) analysis that involves spatio-territorial measures.

Chapter 4 is concerned with the specific methodological references adopted, as well as the concrete specifications that allow testing the formulated hypotheses. For this, a simulation exercise was made, described in chapter 5, which was aimed at testing the methodological reference and minimizing possible sources of imprecision and uncertainty in an applied exercise; the simulation also illustrates the main properties inherent to the territorial interaction structures obtained in the theoretical component.

Chapter 5 begins with a description of the exploratory simulation exercise, under ideal conditions of observation. It illustrates the robustness of the principles and of the methodological approach, as it provides important guidelines to apply that methodology in real world empirical studies. In fact, as is desired in complex problems, the theoretical and technical dimensions are evaluated in a case-study: the territorial local system of Aveiro-Ílhavo. This choice was guided by the participation, of this thesis' author, in some previous studies, focused both, on similar research program and using the same case study. In fact, it is assumed that this work is inspired and supported by material and methodological developments from the research projects *Costs and Benefits of Land Use Patterns* (Carvalho & Abreu, 2013) and, most directly, from the project *Drivers of Housing Demand* (Castro, Marques, Batista, & Borges, 2013).

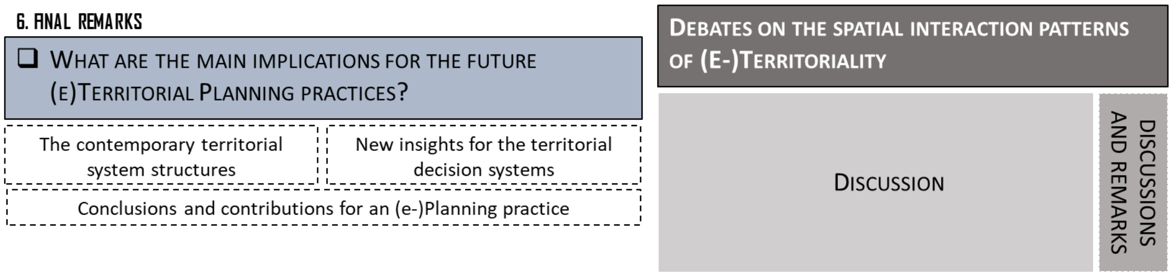


**Figure 1.3** Methodological framework: final remarks

Finally, chapter 6 includes a discussion of the results and the main conclusions. This discussion intends to analyse the suitableness of the approach developed in order to describe spatial patterns of territorial interaction structures, of an abstract and a local territorial system. The major limitations are also highlighted. In addition, a brief debate is made on the insights of these patterns, their match with the theoretical debates of the notion of space, and, specifically, on dimensional and geometric properties of territoriality. Finally, future research directions and the usefulness of the analytic and empirical approaches are assessed through the prism of territorial planning and relevance for the definition of public policies.

# 2. FROM SPACE TO TERRITORY

As has been discussed before, the concept of spatio-territoriality had different meanings in recent history, in order to describe the multiple configuration of objects on the earth's surface. These changes were followed by changes in the focus of planning, leading to an understanding of space according to what Hall & Tewdwr-Jones (2010) states as the function of planning: "a type of management for very complex systems [turning them] necessarily multidimensional and multi-objective in its scope" (p. 9).

The inquiry in this chapter shows that most of the geographic observations, and what can be called geography laws, have been based on the definition of a "synthetic space of location" (Sack, 1972) – a mathematical device with specific dimensional and geometric properties. Recent history of territorial planning and the scientific subjects that support it, suggest a shift from that formulation of geographic questions and assume an unknown dimensionality and geometry of spatio-territoriality. This makes possible to surpass the limits of the reductionist positivist approach to planning, namely tackling the difficulty to deal with the complex systems that are at the base of contemporary spatio-territoriality.

Section 2.1 is concerned with understanding spatio-territoriality in the planning practice. Despite the (usually) multidisciplinary perspective of territorial planning, Hall and Tewdwr-Jones (2010) highlight that "the central body of social sciences which relate to geography, and whose spatial aspects are taught as parts of human geography – economics, sociology, politics and psychology – does form the core of the subject matter of urban and regional planning" (p. 4). This relationship between territorial planning, geography and the various types of specialized knowledge is embraced in this section to address the concept of space, mostly as a mathematical analytical mechanism to turn possible the use of standard quantitative methods, and territoriality. The last concept is central to correctly specify the quantitative (geometric) properties that should be postulated on the answers of the research questions of this work.

In section 2.2 a brief analysis of the applied understanding of territoriality is presented. The history of territorial planning practices and their different approaches, tools, and political/administrative rules, translate theoretical definitions of space into real transformations of territoriality. For example, economic geography puts in evidence the effect of distance (on geographic space) as a driver of economic production, consumption and exchange. Following this approach, territorial planning focusses on the optimization of those distances to enable economic (market) development. Another example is the role of transport and communication infrastructures to promote social relationship/interactions and cohesion. This understanding of territoriality is translated into a territorial transformation agenda which abandons the simplest geographic distance on the Cartesian space and the belief that territorial dimensions are fully known to planners.

## 2.1. UNDERSTANDING TERRITORIALITY THROUGH GEOMETRY AND DIMENSIONALITY NOTIONS

### 2.1.1. THE 2-DIMENSIONAL EUCLIDIAN SPACE

Following its grammatical genealogy, geography can be defined as the practice to describe the earth: joining the ancient Greek 'geos', referring to the earth, and 'graphos', referring to the practice of writing. Geography thus means 'Earth description' or 'writing about the Earth'. The mathematical tool defined as the Euclidean space is a powerful abstraction to describe human experiences on the earth's surface (Unwin, 2013). This device uses basic geometric elements on a 2-dimensional reference frame to represent objects and measure some of its properties – points, lines, areas. This approach provides intuitive interpretations of perceived geographical patterns and opened – recently – the possibility to translate real world phenomena into mathematical models.

Properties of the Euclidian geometry have been extensively applied to represent the distribution of elements, through the practices of cartography. However, the geometric properties of the Euclidean space produce a fundamental feature to understand spatio-territoriality: the possibility to define a distance between two objects and, in this way, a generalized mechanism to distinguish them.

The quantitative turn on social sciences, at the first half of the XX century, adopted the geometrical properties and the increasing use of mathematical language in order to deduce/predict the behaviour of spatial objects. That was clear on geographic inquiries, as it previous tradition within topography and as Sack (1972) notes, "explanations of geographic questions involve explanations of some of the geometric properties of the events, if only their locations" (p. 69). That developments of modelling capabilities benefited from the application of geometric properties as an explanation tool in different scientific fields – namely, physics. That general use of geometry has opened geographic inquiry to the search for explanations, rather than descriptions.

Through quantitative reasoning, geography changed the use of Euclidian space from the pure descriptive geometric tool of earth's surface and gives it a central role to formulate general explanations for geographic phenomena: agglomeration structures (usually defined as geographic clusters, patterns or homogenous units) and, later, the relations between them, i.e. spatial interactions. As David Harvey (1969) recognizes, geometry "provides a convenient symbolic language" (p. 28), an assertion supported by the extensive efforts to establish general geographical laws, such as the pioneering attempts of Zipf's law.

The modern research program of geography is inspired by the achievements of physics and, as Sack (1972) recognizes, "most often geographers consider the synthetic space which geographic events are located to be the physical space of Newtonian physics"

(p. 69). Moreover, as argued by Couclelis (2005), the geometrical Euclidian space is endowed both in (Newton) physics (Hesse, 1962) as well as in geography, through a 2/3-dimensional Cartesian reference frame.

The recognition of the diversity of objects targeted by geographic inquiry resulted in a split between two major branches: human geography, concerned with the (groups of) individuals, and physical geography, focused on (groups of) biophysical elements (Unwin, 2013). Through quantitative approaches, based on rational reasoning, positivist faith and the search for simplification, modern geography practices focus on: i) the spatial identification and classification of (groups of) objects on the earth's surface ii) the (mathematical) models that describe its formations and the relations between them.

As said before, the distance threshold assumes a central role in both targets of geographic research. The distance relies on the Euclidian space as the dominant geometric model to explain the location and the distribution of objects and as a fundamental element to the models of spatial interaction. Here, the analogy with classical (Newton) physics is straight: Newton's laws rely on the key effect of (Euclidian) distance to describe the properties of each object's behaviour. However, motion is here understood as a general change on the state/properties of the geographic objects. The dynamics of geographic phenomena – the perceived change of its properties through time – was assumed to occur through an interaction mechanism similar to classical physics: the (geo-)gravitational field[3] of (geo-)gravitational forces (Isard, 2017).

In a similar way to physics, geographic interpretation of the spatial interaction properties of territorial units was based on the auxiliary properties given by the Euclidian geometric framework. Geographic interaction between geographic objects (spatial units) takes place through some kind of flow between locations – such as the movement of individuals (Vickerman, 1974) or the diffusion of ideas (Carrothers, 1956). These spatial interactions are similar to the energy flow assumed in classical (Newton) physics through a gravitational field described by the Euclidian space, i.e the geometrical model of the field (Hesse, 1962). There, as in geography, the (energy) flow can be measured in any point by a simpler model, where a (Euclidian) distance decay parameter plays a central role. This geometric interpretation of interactions in classical physics defines that the field (and the Euclidian space) is a general container of phenomena, exogenous to them. That interpretation matches the classical understanding of the earth's surface in geography as a container of phenomena rather than as an undistinguished feature of geographic objects themselves.

[3] The concept of field is widely used in physics and describes the action range of physical forces – such as gravitational forces. At each point of a field its intensity can be measured through the behaviour of a test body, which reacts to the presence of the other objects through a specific law. That law, on a gravitational field, includes a distance decay parameter.

Within the theoretical framework described before and inspired by the simplicity of physical laws to explain a wider range of phenomena, Waldo Tobler proposes one of the most recognized (and acclaimed) law of geography: ‘‘everything is related to everything else, but near things are more related than distant things” (Tobler, 1970)[4]. In its classical interpretation, this assertion is assumed to support a functional (mathematical) relation between spatial units (aggregated objects), through a well-known geometrical device – the Euclidian space as the geographic space. As Tobler (2004) assumed, TFL (Tobler First Law) was defined “in order to simplify the problem of depicting the growth of population in the Detroit region, (...) [was] to eliminate complicating factors. This is when [Tobler] invoked ‘‘the first law of geography” (…) doing this allowed [them] to concentrate on local effects – using the idea of a change in the ‘‘unit inhabitant,’’ and ignoring many other possible influences” (p. 304).

In classical physics, the geometric device itself served as the absolute reference frame – guaranteeing, for example, that it is possible to define the bodies/objects in different ways (scales) as it remains the exogenous “*synthetic space*” – at least a mathematical artefact to explain behaviour of objects. In geography, spatial laws are guided by the absolute role of the geometrical (Euclidian) representation of a specific piece of earth’s surface. Thus, defining spatial objects, more or less, relies on the optimization of geometrical distances between different elements and their properties.

The development of geometrical abstract models to understand spatial phenomena are not exclusively an effort of geography. In economy – and spatial economics in particular – the analogies with classical physics inspired most of the theoretical insights behind classical (micro)economics, as was remembered by Jolink & Daal (1989).

These analogies with classical physics are not restricted to Newton’s laws and concepts, but, as pointed by Mirowski (1989), they are linked to more foundational concepts: an analogy of value as energy, transmitted through a field – the market or value field – similar to the field of energy that supports gravitational interactions between physical bodies. In its own words, “the classical economists were heavily dependent upon the metaphor of value as length and a measure of value as a yardstick” (p. 200) and that analogy resulted in the direction of economic assumptions towards a belief about “a natural geometry and a natural algebra that provided the basis for quantification and mathematical analysis” (p. 200). This, argues the author, is the basis for subsequent efforts to “mathematizing” economics.

However, as the author describes, classical economics present a slightly different interpretation, namely: the field of forces analogy are not considered as being directly described by the geographic space itself, and the market mechanism geometry remains in

[4] The Waldo Tobler law will be mentioned on this work as «**TFL**» (of geography).

abstract terms. Moreover, the role of distance to explain interactions is substituted by the measure of value as the metric to distinguish the position of economic objects – the commodities.

Despite these more abstract definitions, for now it is important to highlight that analogies with classical physic are an important feature to understand geometric and algebraic assumptions that lead quantification and modelling developments in classical economics (Mirowski, 1984; Thoben, 1982). Some of that analogies adopted by economy were shared with geography, namely the assumptions of i) “action at distance” through the economic field produced by economic agents, where ii) the market forces interact to produce the “motion” (exchange) of commodities. Market prices measure the “distances” between each commodity through the demand and supply dimensions of economic interaction. The idea of prices (or, more general, value) as a distance, implies some kind of geometric reasoning and, in this way, economic laws can rely on geometric properties. Moreover, demand and supply interactions result in a (perfect) equilibrium – assuming, theoretically, that it can be reached – between market agents, where the value of commodities (exchange value) is guided by the geometric properties (demand and supply curves) that describes the behaviour of agents – establishing the (economic) model of interactions through geometric/algebraic properties.

The development of theories about the presence of exogenous elements that drive the economic equilibrium – such as the transaction costs or the general concept of externalities, as consider by (Coase, 1960), Dahlman (1979) and Schweizer (1988)– can be interpreted as insights that suggest the existence of an exogenous container of the economic field. These exogenous elements are included in the geometric properties, namely as frictions to the value-distance concept. This interpretation reinforces the analogy of the value field as a container (a general geometric reference frame) of economic phenomena, such as in classical physics. In fact, externalities highlight the presence of a (initially unknown) distance decay parameter that drives economic interactions and reinforces the explanations for the variations of exchange value/market prices through the geometric model properties.

The connection between economic phenomena, the geographic space and both disciplines with the analogies with physics laws – and the role of Euclidian geometry in particular – takes place within the development of empirical spatial economic models. The analysis of commodity exchanges with an explicitly (and immobile) location in the geographic space, such as land parcels – suggest that the classical (abstract, from a geographic point of view) economic models can explicitly consider the geometric distances of geographic space as the decay parameter. That connection is highlighted through the link of externalities and transaction costs with the transportation costs associated to market interactions: the motion of commodities in the geographic space depends on geographic distances; or, if commodities are immobile – such as land parcels – with the motion of economic agents to access them. In fact, gravitational models were adopted as an analytical reference frame in both disciplines (Niedercorn & Bechdolt, 1969).

### 2.1.2. TOWARDS A NON-EUCLIDIAN FRAMEWORK

As the understanding of socio-economic-spatial phenomena expanded, the limitations of the concepts of classical geometrical models emerged in geography and economy. In fact, the continuous transformations of communication technologies, geographic patterns and economic phenomena lead to reconfiguration of the (general) territorial structures.

In transportation, the increasing diversity, velocity and efficiency of mobility technologies have been exponentially increasing the possibilities of each individual to perform "face-to-face" interactions (Pereira, 1995). This change reshapes the distortions of mobility paths, changing them from the length distortions (historically recognized) to the effective definition of a geometric distance decay parameter in geographic models. In fact, not only is that parameter a frequent target of theoretical and empirical challenges, as distance is increasingly measured in terms that transcend the geometric Euclidian framework. These challenges to the geometric modelling framework have been reinforced dramatically by information and communication technologies, which have enabled interactions at a distance.

The transmission of messages (data) through (tele)communication infrastructures and its transformation into meaningful information through computational technology (Floridi, 2008), not only changes interactions of individuals but also enables a new set of economic exchanges, most of which are of an intangible nature (information services) (Floridi, 2014). These new commodities started to emerge clearly with the telegraph and its associated infrastructure, but it is within the modern communication technologies that a major transformation occurs: the instantaneous transmission of bi-directional information (Castels, 2004).

If classical infrastructures were asymmetric/unidirectional/asynchronous, the new infrastructure of telecommunications enables symmetric/bidirectional/synchronous transmission of information through computational and digital systems (Furtado, 2012). The development of ICT – in particular the internet and its different communication services supported by a myriad of digital networks – resulted in a convergence between phenomena usually considered distinct. Some examples are:

i) the increasing mutual substitution of interaction at distance and face-to-face, that contributes for the interchange of required interaction of the same type on socioeconomic activities;

ii) the multiplicity of types of socio-economic interactions, since at each interaction multiple types of interaction processes can occur (Audirac & Fitzgerald, 2003);

iii) the increasing interdependence between human interactions and automated interactions between physical objects, even if distant between them (such as autonomous vehicles or other autonomous processing devices and mechanisms (Webster, 1999).

Naturally, the fast pace of these transformations leads to an accelerated reconfiguration of interaction mechanisms and expected redefinitions of the traditional concepts that define spatial structures of agglomeration and interaction (Oldenburg, 1989; Varnelis & Friedberg, 2008). Moreover, these transformations had obvious consequences for the classical analogies, concepts and models, namely the absolute and universal role of the geographic space.

As distances between objects are increasingly defined by the channels of transportation and communication (i.e. the configuration of its infrastructure) (Morley, 2002), the Euclidian geometric 2D reference frame is not able to fully describe them. Despite the usability of geographic space to describe the infrastructure's configuration, the models that rely on the geometric properties of geographic space have been revealing they did not produce accurate model explanations for the wide range of geographic patterns. Those changes are widely recognized not only within geography research challenges but they are shared with important branches of economy.

*Some non-Euclidian directions on geography research*

In geography, debates about the notion of space have been drift in multiple directions (Cresswell, 2004; Tobler, 1993, 2004). It is possible to identify two major directions for these debates: a focus on conceptual questions (Crang & Thrift, 2000) or the replacement of previous "spatial" assumptions by new ones (M. Jones, 2009). The result is a multiplicity of theoretical and empirical approaches that coexist, with applications restricted to specific research problems – this can be understood as a split of geography in different sub-branches of specialized knowledge. The role of geography for planning's understanding of spatio-territoriality can be identified through the analysis of some relevant model's insights[5].

First of all, the abandonment of metric frameworks to embrace topological approaches, that can follow topological relations (eventually based on Euclidian topological relations). One example is the empirical work on the topological analysis of different kind

[5] Aware, this selection are somewhat arbitrary, given the profusion of approaches and possible choices.

of transport and communication infrastructures, given that interactions are increasingly assumed to be performed at a distance or by the mobility of its elements. For example, the transport and communication networks are considered as an explanation for different phenomena under study, including observed geographical patterns.

Another insight is provided through the "reformulation" of geographic analysis, with an explicit abandonment of its algebraic-geometric model properties. The concept of "space syntax" proposed on the «social logic of space» (Hillier & Hanson, 1984) can be considered an example of this contribution: following that approach it is assumed that territoriality can be described by new (non-Euclidian) geometric properties. An implicit assumption is that properties emerge from socio-spatial interactions that are not possible to measure directly. In the same line of reasoning, cellular automata (P. Torrens, 2012) approaches rely on the idea that interactions on an unknown space can be derived from local (geographic) interactions mechanisms that, in turn, lead to the emergence of observable macro patterns in the geographic space.

Finally, the adoption of non-Euclidian geometric frameworks, such as the fractal geometry approaches, have been proposed as alternative descriptive tools that provide fundamental properties of the observable geographic patterns. The work on Fractal Cities (Batty & Longley, 1994) can be considered a major example of this kind of effort, suggesting that this geometric reference frames can generate complex spatio-territorial patterns with simple (non-euclidian) geometric properties.

### *Some non-Euclidian evidences on spatial economic research*

In economics, despite the importance of classical physics analogies as a general modelling strategy, empirical assumptions on geographic spatial properties face important challenges. Usually, classical models of spatial economics – such as the Von Thünen, Weber or Christaller-Loch models (McCann, 2001) – are assumed to support the role of geographic space to full explain economic phenomena. However, as we can see in Figure 2.1, the abstract geometric shapes that can be obtained from them, showed, indirectly, the caveats of their spatial assumptions: the empirical explanatory power of those models relies on the geometric anisotropy property of the geographic space, a situation that is not usual in real geographic settings.

In fact, both, geomorphology and communication channel distortions are not possible to model under the Euclidian space framework (even using additional dimensions). If this framework is naturally limited to describe geographic phenomena, then this limits its capacity to produce consistent explanations, justifying why economists started to partially put aside the analogies on theoretical reasoning exercises (Walker, 1991).

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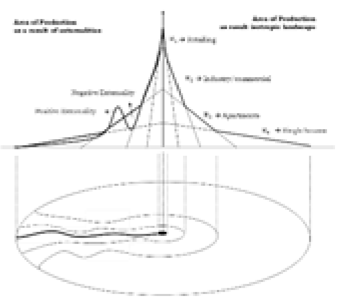
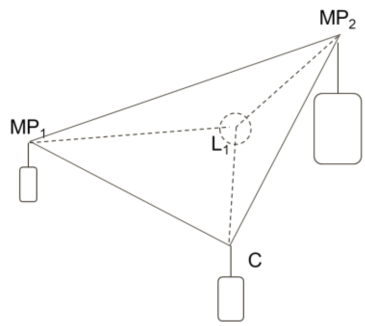
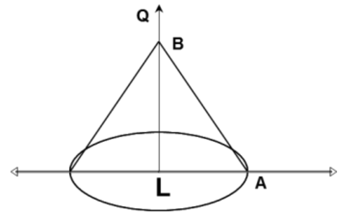
<tr><th>Von Thünen</th><th>Weber (and Predöhl)</th><th>Christaller and Lösch</th></tr>
<tr><td></td><td>
</td><td>
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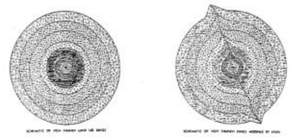
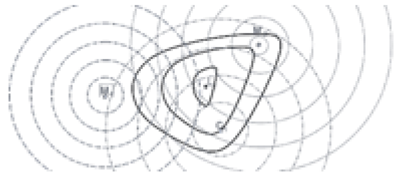
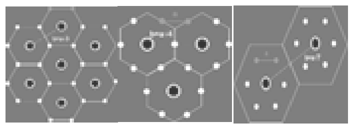
<tr><td></td><td></td><td></td></tr>
<tr><td>Purpose<br>Explain the geographic patterns of agricultural production sites, with and without externalities</td><td>Purpose<br>Explain the geographic location of an industrial unit to best attend the consumers demand of its products, describig how the overlap of market areas creates differentiated patterns on the geographic space</td><td>Purpose<br>Explain why different economic decisions, concerned with geographic locations for different kind of industries, services or public bodies can result in similar geographic patterns</td></tr>
</table>

**Figure 2.1** The classical spatial economic models

The fails of classical spatial economic models lead to the reduction of interest to the efforts that combine geography and economy for a while (Lawson, 1989). As Corpataux & Crevoisier (2007) point out, researchers moved towards a hypo-deductive approach, where the classical assumptions of spatial properties have a secondary place, given the role of a formal and pure mathematical model elegance and the fits of model with quantitative empirical data.

However, the role of space in economic phenomena remained as an unsolved problem from the point of view of mathematical modelling efforts. Moreover, the algebraic-mathematical improvements of economic models (econometrics) did not result in increasing explanation power and spatial economics advanced to less quantitative and empirical approaches, which contrast with the defence, by some researchers, of a central role of mathematical-algebraic-statistical reasoning to develop economic science. A compromise solution to these problems can be identified in the work of Paelinck & Klaassen (1979), which made major contributions to the advent of spatial econometrics.

Through spatial econometrics, economic models and their algebraic specification remained distant to geographic/geometric interpretations (Anselin, 2010; Paelinck, 2013). However, as spatial effects are a recognized cause of potential misspecification and measurement errors in empirical models, the proposed solution was to include additional algebraic model components that enabled researchers to specify an exogenous spatial component (Paelinck & Klaassen, 1979). As is shown in chapter 3, the spatial Weights (W) matrix is a modelling artefact that allows to incorporate different conceptual understandings of spatio-territoriality (L. Anselin, 1999; Elhorst, 2014) – without an explicit need to specify its geometrical properties.

Recently, New Economic Geography (NEG) (Krugman, 1991) has been interpreted as one of the major contributions, in decades, to the reconciliation between economy and geography. Unfortunately, as stressed by Corpataux & Crevoisier (2007), "spaces are ever more formal and lead us away from any form of concrete reality, while at an empirical level [NEG] just looks for correlations using numerical data without checking if the qualitative elements and relations of the model exist in the concrete situation" (p.294). Despite that criticism from the point of view of real explanatory power of the NEG models, its theoretical insights have been considered a major contribution to urban studies in general.

Two major ideas stand out. First, the NEG assumes explicitly that a hierarchical configuration of spatio-territoriality emerged naturally through the spatial, social and economic dimensions of those models as show by M Fujita, Krugman, & Venables (2001) and Masahisa Fujita & Thisse (2013), for example. That hierarchy describes a centre-periphery relation between territorial units within a territorial system caused by a spatial specialization of economic activities. Second, to explain that geographic patterns, the NEG points to centripetal and centrifugal forces as the mechanisms behind it (Masahisa Fujita & Mori, 2005) (Krugman, 2011). That explanation can be viewed as a return to the analogy between physics interactions and socio-economic interactions. And, as the concept of forces fields, in physics, faced important changes from its classical (Newtonian) framework, this analogy can be explored in order to explicitly assume unknown geometries in modelling efforts.

### 2.1.3. THE N-DIMENSIONAL SPATIO-TERRITORIALITY

The previous section shows that non-Euclidian geometries emerge, among other reasons, from the observational limitations and challenges of modelling efforts in geography and economy. As leading scientific branches that contribute to understanding spatio-territoriality, they provide a set of quantitative tools that shape the territorial planning practice. However, as is widely recognized, planning is supported by a *corpus* of knowledge that surpasses the previously described quantitative and geometrical properties, including insights from fields such as philosophy and, in particular, sociology.

The social concept of space is mostly understood through the prism of places (Cresswell, 2004; Harvey, 2006). This concept approaches territoriality, since it assumes as the object of inquiry the notion of spatial units, usually bounded in a geographic space, as well as the mechanisms of interaction that connect them.

Spatial objects on a social space can be defined at different geographic scales, through the selection of a specific set of social dimensions. Including on that definition a wider range of "objects" that ranges from nations, landscapes, anthropological places, or the socio-political-administrative geographic unis, it is possible to conclude that the notion of space is naturally n-dimensional[6]. Sociological models are usually theoretical and define the specific set of (social) dimensions that can be selected, where geographic space dimensions are usually assumed as a container. In fact, the reductionist and rationalist, mathematical, approach of geography and economics – that leads to definitions such as the TFL of geography – do no hold here and geometrical assumptions, if proposed, should be considered with cautions.

Moreover, the Euclidian space implies to consider the orthogonality of the considered dimensions. In economy and geography, besides being considered in theoretical descriptions of the phenomena, they are usually implicitly or explicitly assumed through straight projection on a 2/3 dimensional geographic reference frame. Further, sociological reasoning assumes that the dimensionality of the phenomena are unknown and geometrical properties are limited by definition.

However, the dimensions of social space or, even more, how to measure them in a way that can be integrated with more quantitative efforts remains an important research question. As will be showed, the works provided by different sociologists can be useful in order to provide an overview of the additional dimensions that can be considered to spatio-territoriality and the general properties that can be derived from these insights.

One major contribution from sociology to the debate on the notion of spatio-territoriality can be pointed to the work of Lefebvre – *The production of space* (1991). The author assumes as a research program to identify and describe the mechanisms and social dimensions that shape territoriality. As the title of that book suggests, the author adopted a framework based on a socio-economic approach: the key role of capitalist (market) organization of society, its rationalist concepts of space and its focus on the commodification of social interaction phenomena, to define the mechanisms and dimensions that should be considered. This work identifies three major territorial mechanisms with a specific set of dimensions associated to them. These mechanisms are assumed, by the author, as the key factors of the production of space, resulting in the

[6] Moreover, it obvious that through this different definition of spatial objects have an obvious question of scale itself. Some reflections on that are provided, for example, in Brenner (2000) and Marques (2012)

observable patterns in the geographic space. The three mechanisms are the "space of spatial practice", the "space of representation" and the "representational space".

First of all, and considered the most observable phenomena, the author considers the dimensions associated with the prosecution of economic production and consumption, plus its associated market interactions, as describing the space of spatial practice. Here, territoriality is a by-product of market mechanisms that result from the commodification of a different set of elements – for example the market value of territorial units derived from economic models. This commodification transforms some dimensions of the territoriality into geometric dimensions as they are incorporated and perceived in economics.

The second phenomena are described by the observable objects (physical, tangible), that can be identified in the geographic space but where the dimensions to provide a full description of them are not observable – at least, in a way that would enable explanatory models. The geographical location of these elements – historical landmark, places of interaction, etc. – can provide general insights on its geographical organization, but it lacks dimensional elements such as its history or social function.

Finally, Lefebvre (1991) suggests that territoriality should be interpreted with the additional dimensions of a representational space. This mechanism of territoriality is concerned with the individual perceptions and representations of that space and, in this way, are very difficult to "measure" and rarely expressed. That "space" and its dimensions are intangible from the point of view of geometrical properties and can only be analysed indirectly.

Following a Marxist dialectic (Sheilds, 1999), Lefebvre's understanding of territoriality can be interpreted as a suggestion that observed geographical patterns cannot be separated from the reasoning of an observer/researcher. Spatio-territoriality emerges from the relation between a geometrical, quantitative approach and the intangible, qualitative dimensions of the individuals. For example, a better understanding of the geographic and social organization of a territorial system needs to include not only the geometry location and relations between, for example, landmarks (squares, specific building, and other), but the additional (geographic distribution) of social dimensions.

The work of social geographer David Harvey (2006, 2009) can be viewed as following a similar framework. In fact, the researcher assumes Lefebvre's work as a point of departure to add new layers to its use for geography and the practices that are derived from this knowledge. Two major contributions can be identified. First, the assertion that even the "space of practices" is not well understood through the geometric properties of geographic space. In fact, as classical modelling attempts in geography and economy have shown, this geometric framework has clear limitations. However, by contrast to the research concerned with new geometric tools, Harvey (2009) suggests that scientific efforts in this field should combine different notions of space – absolute (geometric), relative (topological) or relational space (without a model that supports it).

In addition to Lefebvre's and Harvey's contributions, a great number of sociologist provides insights to understanding different spatio-territorial phenomena, without any pre-defined geographic assumptions. Here, a short review will be made of the major contributions on the works of Granovetter (1973, 1977, 1983), Robert Park (1984) and Massey (1999, 2005, 2013). This short (and disputable) selection of authors is made according to its direct link to the sociological research effort to understand spatio-territoriality in its social, economic and cultural dimensions, as well as its relevance for territorial planning.

The more general research program of Granovetter (1973, 1977, 1983) focusses the role of social relations that seem to exist in observable agglomerative organizations of individuals. Exploring the (topological) properties of the "social network" established by them, it is identified that social groups, and the interactions between them, are built according to mechanisms related with the strength of ties. Similar to previous efforts, here the hidden dimensions can be analysed independently from (geographic) geometric properties, avoiding the need to establish assumptions on these phenomena's role in geographic patterns. The role of the strong and weak ties concepts can be described as follows. The first is related to the creation of social groups in spheres that surpass the rational dimensions, such as the representations of space and representational of spaces – as an analogy, they can be linked with the modes of production of space proposed by Lefebvre that surpass tangible (geographic) dimensions. Weak ties are the links between groups that ensure the configuration and behaviour of a social system as a whole.

It is not possible to highlight a direct connection between the author's works and insights to the analysis of geometric and dimensional spatio-territorial aspects, but it is worth stressing two major contributions:

i) Strong and weak social ties can be associated with the aggregation and interaction of a territorial system;
ii) The social space, given that its geometry and dimensions are unknown, should be analysed separately from geographic space, but it can be argued that a geographical identification of possible configuration of weak ties in the geographic space can provide partial insights on that spatio-territorial structure built through social interactions.

In Robert Park's human ecology theories (1984), spatio-territoriality differentiation is assumed to be driven by a biological behaviour of social actors. The author argues that everyday competition for scarce resources (including land) is at the origin of observable geographical clusters of individuals and activities. The insight from this approach is that to understand spatial mechanisms the researchers should focus on dimensions related to the "biology" of individuals (age, sex, etc.) and the spatial behaviour (mobility) of that groups in the geographic space. Moreover, in contrast with previous ideas, this theory can put in evidence the role of a "space of practices", usually associated with the presence of an economic market that drives interactions.

Furthermore, as market in capitalist societies tend to be assumed as an device of individual competition, the theory of Park highlights its role as the major mechanism to drive spatio-territoriality formation – and, following that, the primacy of its measurable dimensions that, as has been shown before, can surpass the geographic space dimensions. On its work about the city, Park (1984) investigates these insights and argues that a city develops somewhat as a tree does – growing outward in a series of concentric rings or zones over time. That pattern not only describes a socio-spatial hierarchy as a result of competition for land as it seems to be a conclusion very similar to the classical ideas of the first empirical spatial models – focused on the explanation of geographic differentiation of land uses and land prices.

Finally, Massey (2005, 2013) returns to the emphasis on social drivers of geographic patterns to claim the need to consider explanations for a geography of difference – on gender, on race, and other socio-biological considerations. Within this thesis, and the arguments discussed in this section in particular, this additional reference to the work of Massey can be viewed as a way to reinforce the three major insights presented until this point:

i) the n-dimensionality of spatio-territoriality – stressing the need to include attributes such as the gender of individuals;
ii) the idea that, besides the recognition of n-dimensionality, social scientists usually do not assume any quantitative model approach to integrate them with the geographic space;
iii) therefore, most of the approaches rely on geographic space as a container, used to describe territoriality; this description uses geometric rules, but they are not assumed as giving some substantial property to spatio-territoriality but as mere instruments of analysis (observations).

The third point described above, remains the importance to consider insights provided by classical mapping of phenomena in geographic space (mostly considered nowadays through the field of topography). That approach had been considered the mastery of geographic tools, that implicitly provides insights about phenomena that occurs in hidden (social, economic) dimensionality of most of that observed phenomena. As Malpas (2007, 2012) argues, a return to that approaches can now be explicitly used as a middle compromise between geographic space and the increasing recognized n-dimensionality (and unknown geometry) of spatio-territoriality.

*<u>Some non-Euclidian evidences on the diffusion paths through geographic space</u>*

Following the revival of “topographical” thinking to understand territoriality, the empirical studies about geographical diffusion of information – such as ideas, innovations, fashions can be redeem as major sources of that insights.

Hägerstraand (1968) is usually recognized as the pioneer on more substantive efforts towards this approach – despite the famous study of the spread of cholera in London in the mid-19th century. As the author argues “in a society where there are no appreciable time or cost obstacles preventing one individual from coming into contact with any other individual, relations within “social space” cannot be appreciably modified by the constraints of geometrical space (…) the spatial interpretation of social phenomena would become quite uninteresting. So far, such conditions do not exist; therefore, spatial analysis has not completed the playing of its role” (p. 7).

The geographical studies on diffusion relies on a framework where i) the geometry of geographic space is adopted as referential frame container of the phenomena of interest and ii) the association of individuals to specific locations (and geographical units in particular) in order to record their interactions as geographic interactions between spatial units. The fundamental assumption of Hägerstrand's approach is that the dissemination of ideas occurs through and hidden dimensional process of social interactions that leads to the transmission of information by a large group of people, creating a systematic change in the relations of these individuals with the (biophysical) environment in a manner that produce observable (with the right tools) geographic patterns.

It is important to note that this analytical framework is assumed to be an indirect approach to measure the process of territorial transformation. Moreover, the source of ideas/innovations is assumed to be unknown, although its geographical origin can be identified by analysing its spatiotemporal diffusion; in other words, the framework tracks the territorial change through the geographic space and is not concerned with any theoretical or empirical explanation about the origins of these phenomena. As Hägerstraand (1968) argues: “in neither case can the natural environment be the main driving force (…) it favors or hinders the implementation of various new ideas, but only as one factor among many, not as a completely overshadowing determinant” (p.10).

Gould (1969), following the seminal work of Hägerstraand (1968), presents a review of the analytical/empirical works tracking the diffusion of ideas and innovations across the geographic space and presents the first efforts towards a taxonomy of the different types of diffusion processes. This taxonomy reveals an association between the types of social interaction (expansion, relocation) and specific spatial structures of geographic interaction (contagious, hierarchical). Major contributions of his work is the systematic application of a methodology that suggests that the transport and communication infrastructure is the major tangible driver of the observed patterns. Moreover, diffusion through communication at a distance and infrastructures tend to be more associated with expansion and hierarchical types. Still, diffusion that depends on individuals' mobility tends to be associated with relocation and contagious types. After that observation, the next steps were to produce insights about what dimensions explain the spatial diffusion patterns, trying to link them with social dimensions of individuals' interactions.

A first effort was presented by Hudson (1969), who observes "the earliest adopters are those most likely to be first exposed, and they are those having the greatest potential of individuals interaction: the largest centers. Very small centers are the last to be exposed since they must wait until the higher order places in their area have been exposed, and so on" (p. 46). In the same direction, Hägerstraand (1970) or Pred (1981) for example – adopting a framework that became known as the daily prism – conclude that the diffusion of spatial patterns is constrained by another set of dimensions: the housing location, the institutional and cultural elements that regulates interactions, among other.

These conclusions, which must be read taking into consideration the transport and communication technology available at the time, reinforce the major contribution of this research line: if sociologist show that spatio-territoriality is n-dimensional, transportation and communication infrastructures associated with the location of individuals (namely housing), can be considered a major proxy to produce observable pattern of socio-spatial interactions in the geographic space.

If the specific transportation and communication infrastructures influence the pattern of spatial interaction structures, which have been associated to the diffusion process, nowadays it is inescapable to take into account the following observation: "because information and communication technologies (ICTs) are loosening the traditionally close links between activity, place, and time, physicalist models such as the space-time path and prism of time geography may need to be reexamined in light of the new realities" (Helen Couclelis, 2009, p. 1557). In fact, as Hägerstraand (1970) anticipates: "a world-wide dialing [communication at distance] system seems to be a mixed blessing, since all too often people may forget differences in local tie around the globe" (p. 16).

## 2.2. TRANSFORMING TERRITORIALITY THROUGH PLANNING PRACTICE

The understanding of territoriality presented in the last section is reflected in the practices concerned with territorial transformations. Moreover, these practices comprise not only the plan itself – the set of urban design materials plus the regulations of land use, building projects associated with it – but cover planning theory and methods.

This section will review some of the major evidence on how this translation process occurs. Its motivations are of two types. First of all, those transformations, guided by specific 'translations' of the notions of spatio-teritoriality, produce a specific territorial setting. In fact, nowadays, the most important territorial structures are the outcome of territorial planning efforts. Secondly, the translation process is itself subject to variations. The abstract notions of territoriality, the interpretation of its general model assumptions and the multidisciplinary research programs that inform a planning practice are naturally not fully understood by those responsible for producing territorial planning outcomes in heavy constrained time periods.

As is argued in this section, territorial planning practices can be analysed through the three major geometric and dimensional perspective on spatio-territoriality. Although different practices, tools and outcomes are usually associated with specific periods of the territorial planning history, this analysis cannot be restricted to that chronologic dimension. For example, the "master plan", which represents a major element of classical planning practices, is still an important outcome of contemporary planning activities.

### 2.2.1. PLANNING TERRITORIALITY AS THE FILLING OF GEOGRAPHIC SPACE

Taylor (1998) argues that the roots of territorial planning practices can be traced to the autocratic power and hierarchal administrative organization of the modern nation-state (E. J. Hobsbawm, 2012), which can be translated into three fundamental geometric insights about territory:

i) the primacy of the biophysical space (geographical space), with the major concern of establishing rules for its use and occupation;
ii) the focus on the design of the built environment, associating the plan to architectural projects, either by the use of the same language and technical detail, or by the relation that the design establishes with the building (or buildings) itself – the master plan or blue print;
iii) and a concern for the production of a legal framework that defines the "laws" for land use.

Within this context spatio-territoriality was translated in its multiple properties through the geometrical references frame of the Euclidian space. As spatial concepts are derived from the dominant faiths and ideas of policy-makers and planning professionals, the wider cultural influence of concepts from classical physics were translated through the rationalist ideas of socio-economic functionalist organization. Examples of major design projects to define the geographic shapes of spatio-territoriality combine the restructuration of landscapes through urban agglomerations with its functional divisions – configuring a blue-print approach.

## Rational and authoritarian geographic geometries of classical urban design

This type of territorial planning practice can be defined as filling geographic space with the material elements of urbanity, transforming the complex geographic biophysical support through a reductionist, materialist and geometric approach.

The geographic geometry of the blue-print spatio-territoriality designs is assumed to be based on economic insights from Taylorist and Fordist models of production, where the division of functional activities (housing, commerce, agriculture, etc.) and the division of labour (inhabitants) are key elements. Some of the best known examples of this notion of spatio-territoriality are the models of Howard (The garden city), Wright (Broadacres project) and Le Corbusier (Contemporary City for Three Million Inhabitants.)

*Howard – The garden city*

Howard's (2016) garden city proposed a design to meet the demands of a society were cooperation guides the public life. This project claims for a moderate decentralization of urban landscapes, organizing cities into archipelagos of small/medium size urban places, with a compact, efficient, healthy, and beautiful design, achieved by the equilibrium between build landscapes and open/natural spaces. The idea is to shrink swollen cities like London and their dangerous levels of concentrations of wealth and power.

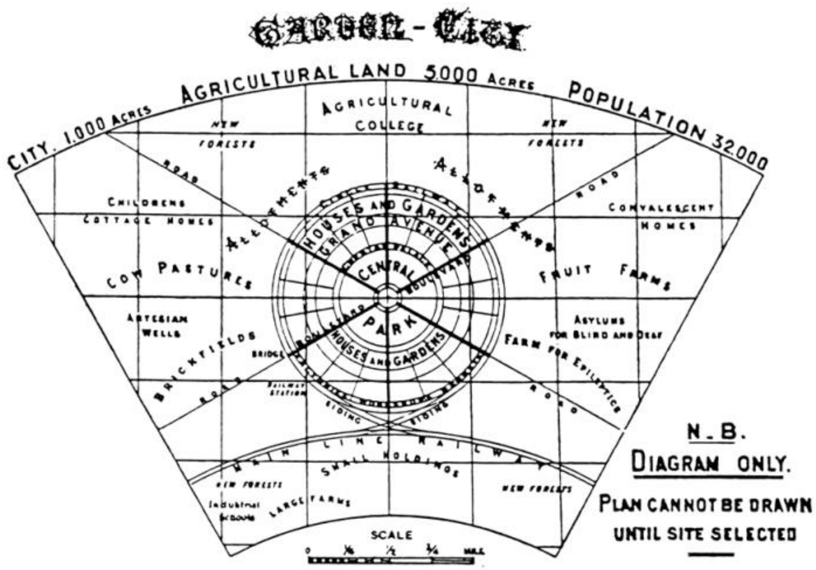



Image source: Howard (2016)

**Figure 2.2** Howard Garden City Plan

- Integrate old (agricultural and natural environment) and new production activities:
  - Natural resources are sources to be collected/provided by nature;
  - Geographic space as an intersection of the biophysical dimensions (with its complexities) with the rational, geometric objects of modernity.

*Wright – Broadacres project*

Wright's (2016) proposal takes the decentralized idea of Howard even further, motivated by the values linked with virtuous individualism. The Broadacres project focused on decentralization and autonomy of each neighbourhood substituting Howard's ideal of community with the individual family. Thus, this urban project provides a home and the basic resources (ownership of a great parcel of land to produce fundamental resources) to each family, which then have the necessary conditions (in Wright's view, its freedom) to choose its lifestyle. The designer however recognizes that society needs some kind of coordination for which he advocates the supply of some basic infrastructures (and services), namely a network of superhighways *to join the scattered elements of society*.

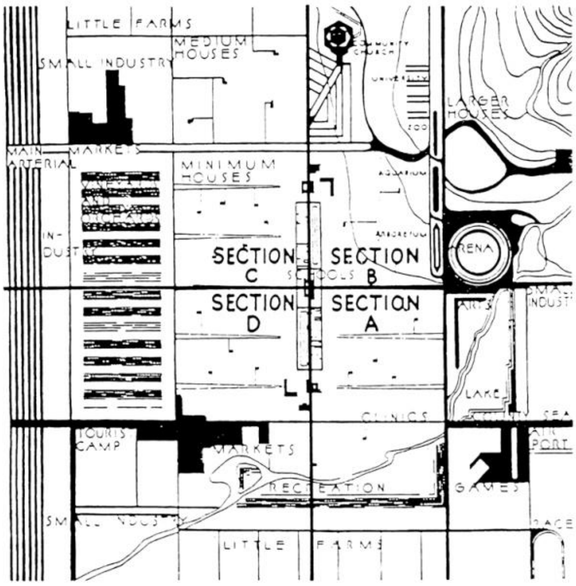



Image source: Wright (2016)

**Figure 2.3** Wright Broadacres plan

- Division between core production functions (agriculture/food production) with the modern industrial capitalist production system;
- Core production is ensured through capitalist principles, such as guarantees on the property of land, allocation of the strictly necessary land to basic food needs of each family;
- Other production activities are organized in specific/decentralized centres of production.

*Le Corbusier - Contemporary City for Three Million Inhabitants*

Le Corbusier (2016) embraces the ideal of capitalism and its focus on the big industrial production complex. He sees great cities as large bureaucratic entities, which coordinate production. Therefore, the city should be organized as a hosting structure following the functional separation of the work-force – "'the Radiant City,' a city worthy of our time." This city is the place of the technocratic elite of planners, engineers, and intellectuals which command/manage the city, and should be located on the geometrically arrayed skyscrapers of glass and steel which raise out of parks, gardens, and superhighways and which are the command posts for their region; their subordinates are relegated to satellite places in the outskirts.

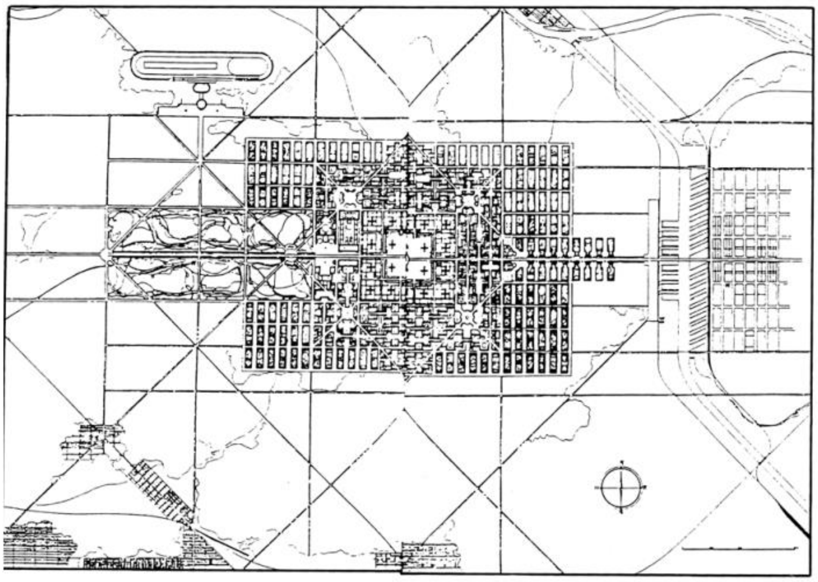


Image source: Corbusier, (2016)

**Figure 2.4** Corbusier Contemporary City

- The territorial mass production plant:
  - Different set of industrial activities are organized within geographic polygons;
- Individuals are organized in the geographic space in order to promote production and consumption efficiency – market interactions efficiency:
  - Hierarchical organization of individual houses follow their importance in the capitalist organization;
  - Not only following the Euclidian 2D Cartesian Space, but considering a 3D reference frame where social organization is designed:
    - Individuals on the top of social hierarchies defined by economic organization should inhabit the high floors of buildings at the central locations.

Another practice behind these blue-print approaches is the transformation of territoriality based on mathematical models of spatial configuration. As shown previously, the classical, rationalist and quantitative, notion of the space-territory is based on a mathematical formalism that has as reference frame the Euclidian 2-dimensional space.

Insights from classical geographic and economic models have been assumed in these urban design proposals. Most of all, the idea of optimization through geographic distances between different geographical functional structures is an implicit guideline of urban design.

### 2.2.2. ALTERNATIVE "GEOMETRIC" NOTIONS TO CHALLENGE CLASSICAL PLANNING PRACTICES

There is no consensus on the exact time different approaches to planning theory and practice emerged. However, it is possible to establish key moments that, by their repercussions in the field, mark the transition between the previous concepts and practices towards a new understanding of the multiple dimensions of territorial planning.

The publication of "The Death and Life of Great American Cities" (Jacobs, 2016) constitutes one of those moments (in this case, a forerunner of change). This work presents a severe criticism of the traditional planning practices and its understanding of territoriality. The author stresses the authoritative and "social re-engineering" associated with the understanding of spatio-territoriality that is presupposed in the plans concerned with the physical space. These plans, argues Jacobs, restrict certain types of social interaction and the way individuals relate with space itself. The illustrative example of this critique is based on her analysis of the abolition of backyards, as spaces of private nature that have a socializing role. According to the author, these spaces had a key role in the promotion of strong interactions in local communities, since the proximity and safety offered by backyards encouraged these interactions.

Within the frame of this criticism and dispute, two new complementary movements arose, proposing a redefinition of the planning activity. The first movement theorizes about new approaches to design spaces that better reproduce the notions of spatio-territoriality of its inhabitants. The other movement was more concerned with the adoption of new planning assessment tools to provide a better knowledge about spatio-territoriality in both ways: what are they today and how citizens are likely to see them in the future.

## 'Enlighten' urban design deconstructing geography

The proximity of architecture (which is the area of most modernist urbanists) to cultural means made the design of territorial systems a target of cultural matter. This cultural approach to urban design emerged in response to the dominance of modernist principles, focusing on their contradictions. These groups had expression in the informal organization of the "*Situationist International*" and, according to their most acknowledged activist, Debord, their thought can be resumed to:

"old neighborhoods, the streets have degenerated into highways, and leisure is commercialized and adulterated by tourism. Social relations there become impossible. Newly built neighborhoods have only two themes, which govern everything: traffic circulation and household comfort. They are the meagre expressions of bourgeois happiness and lack any concern for play. (…) We require adventure. Not finding it any longer on earth, there are those who want to look for it on the moon. We opt first to create situations here, new situations. We intend to break the laws that prevent the development of meaningful activities in life and culture" (Debord, 2008, p. 96).

It is interesting to highlight the situationist current for the promotion of a psychogeography (Debord, 2008) of the territory, as the analytical instrument of excellence for observing the "true" nature of territorial systems – an approach founded on the seminal work of Simmel (2012) – and promoting territorial transformations.

The work "the naked city" (Figure 2.5), carried out by the author, consisted in the (re)creation of a map of the city of Paris, in which the usual geometric referential (Cartesian Euclidean space) was replaced by a network of places (topological space), obtained by cutting a traditional map; the layout of the different territorial elements/units corresponds to the "psychogeographic" organization and interpretation of the author's own territory.

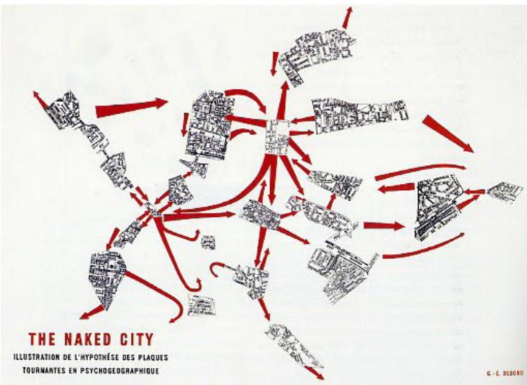



**Figure 2.5** Debord the naked city

Situationist proposals were not limited to contest modernist thinking (functionalist, rationalist and autocratic), but indirectly demanded the rejection of the traditional geometric rigidity. At the same time, they presented an alternative that included considering other dimensions in the analysis and intervention of planning that reflects the social identity of the past, present and future. Territories are seen as historical landscapes because they are scattered with structures that marked the events of the past; these objects, this signature in the design of the built spaces, are symbols of the process of territorial development and transformation that cannot not be erased, even if neglecting all their material history, because they remained and were transmitted by the psychogeographic perception of each individual of that territory.

Situationists demanded the formation of an affective territory, where the territorial units establish connections resulting from the individual perception and the relation between the individual and the territory, in the expectation that design would serve the inclusion of the inhabitants by means of the enrichment of these psychological and social relations.

The impact on territorial planning, and urban design in particular, has been one of the main concerns for Kevin Lynch (1960): this author developed an approach for the analysis of urban form that provides a coherent and structured methodology, oriented towards practical application. Lynch argues that people perceive cities as consisting of underlying form elements such as “paths” (along which people and goods flow), “edges” (which differentiate one part of the urban fabric from another), “landmarks” (which stand out and help to orient people), “districts” (perceived as physically or culturally distinct even if their boundaries are fuzzy), and “nodes” where activities – and often paths – meet.

At this point, the basic elements of the perception of the urban space were defined, as well as the identification and geographical location of these elements in the territory, from which is built a model of the "urban tissue" that served as substrate for the intervention. It is especially at this stage, that Lynch's methodology crosses the situationist approaches, arguing that residents are responsible to identify the leading elements of urban design and interpretation of these psychogeographic maps is due to the urban designer. The assumption is that residents in a given territory have an innate desire and need to know the neighbourhood, for which they create images ("mental maps") about the urban environment. Moreover, these maps are traduced by the geometric language that contains the elements described above.

The form (urban, material) of territory thus emerges from the overlap and interrelation of sets of representations (of images and mental maps). In Figure 2.6 the author illustrates different representations of a given territory from the use of different mental map expression mechanisms.

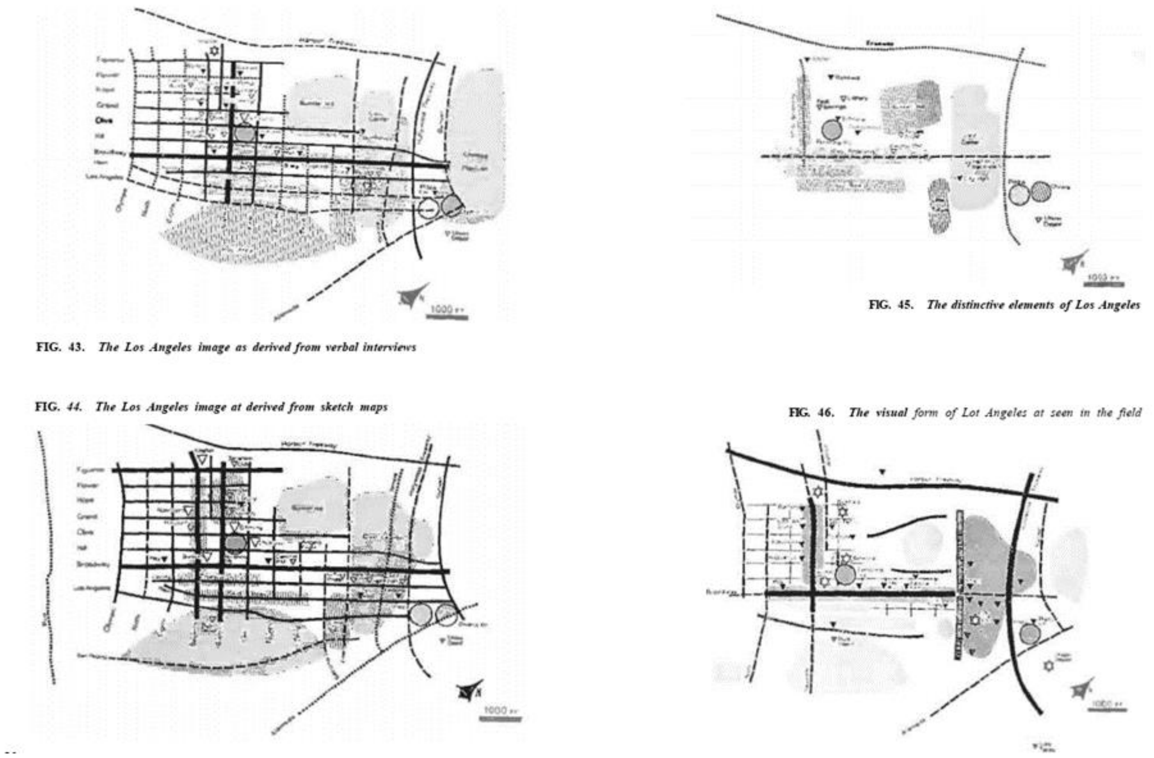



**Figure 2.6** Kevin Lynch "*image*" of the city – examples from Lynch (1960)

The situationist current and the alternative proposals for territorial analysis and intervention – as described above – gradually took place in society, as the modernist model, despite its different facets, depleted its solutions and was subject to criticisms – for example, as mentioned by Jacobs (2016).

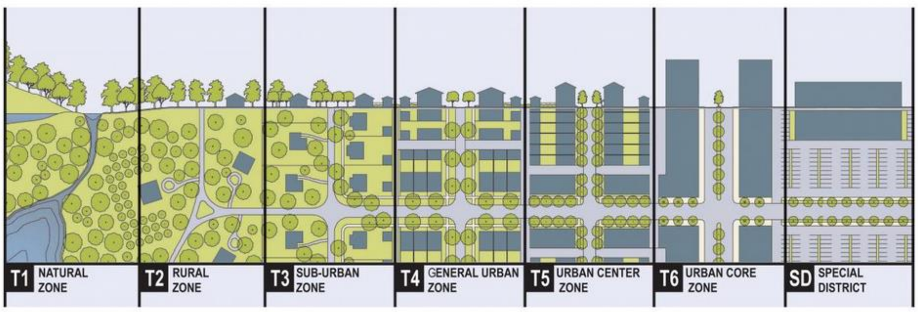
Along with the situationist current, the current social and economic environment was at the centre of social movements. As awareness of the socio-economic injustices and adverse effects of certain norms of economic organization grew, movements were formed that tried to change the same norms, which were closely intertwined with the territorial component. From the civil rights movement in the USA (where racial problems presented a significant geographical dimension) to environmental movements (with a more widespread presence - from the USA to Europe), this set of movements rapidly converged in the affirmation of new paradigms of the exercise of territorial planning.

This can be shortly described by a turn from the previous narrow view of a geographical space – Euclidian, Cartesian - to assume definitively the concept of territory - assuming that spatial units are essentially defined by social practices (social interactions and its phenomena, such as the cultural environment, its institutions, etc.). As said before territorial planning practices were shaped by new frameworks – communicative, procedural, participatory – which begins to be mainstream keywords of the planning practice.

Although, regarding urban design, alternative analytical models had a slow rise (Birch, 2011). It is already in the 1990s that a synthesis is made around the movements that demand a reformulation of the urban design approach in territorial planning processes. Of these initiatives, the "New Urbanism" movement (“Charter of the New Urbanism,” 2000) is one of the best known contributions.

Among major new guidelines to transform territoriality it is possible to highlight some geometric insights, such as:

- The modernist functionalism, which lost part of its *raison d'être* because productive activities are increasingly associated with non-industrial activities (growth of services and small industries), the focus is to translate territorial units on geographic bounded areas where new and different uses are integrated, and an assumed struggle against the geographic segregation of the different social classes.
- In addition to and reinforcing the situationist ideas mentioned above, it was intended to diminish the hierarchical organization effect, established by the infrastructure of transport and communication. Within this scope the work of Christopher Alexander - “A city is not a tree” (2013), claims for a change on the built-up of territorial infrastructure: for example, change roads and its hierarchical structure to a less-hierarchical network of streets within the neighbourhoods.
- Finally, a claim to re-integrate the complexity of ecological structure on spatio-territorial transformations (Campbell, 1996) implies a change of “filling geographic space” practices to a view and understand of territoriality where the complex geometrical shapes of biophysical elements should be considered. In this particular the concept of Rural-Urban Transect (RUT) urban design (Figure 2.7) framework (Duany & Talen, 2002; McDonnell, Pickett, & Pouyat, 1993) shows how that can be achieved through different type of territorial units.




Source: Center for Applied Transect Studies (https://transect.org/rural_img.html)

**Figure 2.7** The rural – urban transect plan

There are several criticisms of the proposed synthesis of “New Urbanism”. As Audirac (2011) refers, the movement are criticized to be based on an (geographic shape) environmental determinism. The point is that the designed geographic configuration of space have an inherent sociability, urbanity sense, participatory citizenship, socioeconomic integration, and social equity associated with them (Harvey 2000; Clarke 2005). However, the principles suggests that design principles should translates a spatio-territoriality that should not be considered driven by the dimensions of Euclidian space geometry but as a translation of the multiple dimensions that integrate individuals in an ecological structure. The RUT (Rural – urban transition) scheme on geographic space is only a geographic reference frame for that multidimensional view on territoriality.

## Towards new territorial (power) model "geometries"

As said before, another point of classical planning practices is the use of model insights, from geography and economy, to guide planning solutions – traditionally relying on the belief of rationalist, mathematical scientific models. Unfortunately, the observable shortcomings of its major spatio-territorial insights resulted in the reinforcement of the criticism that shaped the social and political dimensions related above. As argued by Lee (1973) on the review of some of that classical models and tools "trying to do everything at once simply means that all are more likely to be done poorly", reinforcing that "contrary to what has often been claimed, what was learned had almost nothing to do with urban spatial structure; the knowledge that was increased was our understanding of model building and its relationship to policy analysis" (p. 17).

The first solution purposed in order to guarantee modelling tools that contribute to better planning decisions was to open the decision making process to a broader set of stakeholders, rather than the production of model insights by technicians. Advocate planning (Arnstein, 2016; Davidoff, 2016), procedural planning (Faludi, 1973), or, later, participatory planning (Burke, 1979), community planning (Healey, 1997) and prospective planning are different approaches which embody this perspective.

From the point of view of the discussion in this thesis, the shared decision making approaches are especially relevant because they can be understood as an implicit recognition of the uncertainty and mistrust of geometrical territorial assumptions. The point is that to understand the desires of different social groups can be a method to obtain a better understanding of territoriality.

This approach reveals another kind of challenges. How technicians can analyse social groups' ideas about territoriality (its preferences?) and translates them into planning tools? A wide range of approaches has been developed:

- the "observational" studies, that relies on a reinterpretation of geometric properties to match stakeholders desires, such as Lynch the "good form of cities" or Hillier with the search for the most dominant geometric layouts of built environment;

- the focus on planner's as social managers and mediators – and its multiple approaches towards the participation in planning process.

If the geometrical considerations of observational studies were summarized before, the roots of planner's as social managers should provide additional insights about the resulted geometrical (and dimensional) interpretations of territoriality provided by planning transformations. In fact, the need to incorporate the understand of territoriality (desires and wishes) of different groups of citizens arises a new set of analytical / model approaches.

Notice, however, that the objections of Lee (1973) don't reject this approach entirely. The author mentions that the development stage of these models, considering the necessary techniques and tools, did not offer the necessary conditions for empirical applicability yet. The author suggests that new models should be developed in three major directions: i) improve the integration of techniques and tools from different approaches, to match the requirements (of dimensions cover by them) set by the territorial planning activity; ii) focus on the development of models, techniques and tools that allow a general understanding of the existing phenomena and processes of urban occupation and transformation rather than to focus on predictions; iii) place the efforts in the development of forecasting models for a limited number of key dimensions and variables (for example, population projections), transforming the integrated efforts of forecasting into analyses of prospective nature (controlled by scenarios), that help the decision-making process.

### 2.2.3. SURPASS GEOGRAPHIC DIMENSION TO GUIDE PLANNING TRANSFORMATIONS

Facing the drawbacks of classical planning practices and its simplified geometrical and dimensional reference frames, the search for new approaches on planning activity introduces procedural and participatory methodologies in order to gather the notions of spatio-territoriality of different stakeholders. Contrary to expectations, modelling efforts are reinforced but now focused on the assumptions provided by that social knowledge production component of planning practices (Weintraub, 2002).

As a result, the planning theory debate claimed for a framework where the integration of both modelling approaches and stakeholders preferences can be considered through an integrated tool. Moreover, that approach should represents a change of contemporary territorial planning practices to the so called "optimal compromise" (B. Roy, 2013; B. Roy & Vincke, 1981), instead of the search for "best" (mathematical optimization) solutions. That framework expected to guide territorial planning transformation through an understanding of territoriality that is shared by both elements: the models used to provide structured knowledge about it and the unstructured knowledge retained by stakeholders views on that. Those modelling attempts were defined through the applied research programs of Planning Decision Support System (PDSS) (R E Klosterman, 1999; Richard E Klosterman, 1997; Timmermans, 1997) and Spatial Decision Support Systems (SDSSs) (Malczewski & Rinner, 2015).

Despite the increasing data and consequent operational information stored by planning practitioners, knowledge production about territoriality remains a daily challenge. More than geometrical considerations – as the geographic space reference frame and its geographic units remained consensual planning tools – one the major unanswered challenge is to understand how territorial units can be related with each other. As Batty & Longley (1994) describe “when cities in one location are more dependent on others halfway across the world than on their immediate neighbors or even their suburbs, then it is time that we seriously took stock.” That question is linked with the increasing consciousness of the unknown dimensionality that drives the spatio-territorial system transformation(s).

A recent purposed solution to deal with it is what Brömmelstroet, Pelzer, & Geertman (2014) points as a need to increase the use of computing technology in order to update quantitative models and (quantitative) methodologies to help planning practices. The authors argues that computation technology allows to integrate a higher number of social, economic and spatial variables that can approximate model efforts of the usual dimensionality limitations. That is possible as previous SDSS and PDSS stores a growing volume of geo-information in digital systems and a new set of semi-automated approaches have been available, such as the knowledge discovery in (geo)databases approaches.

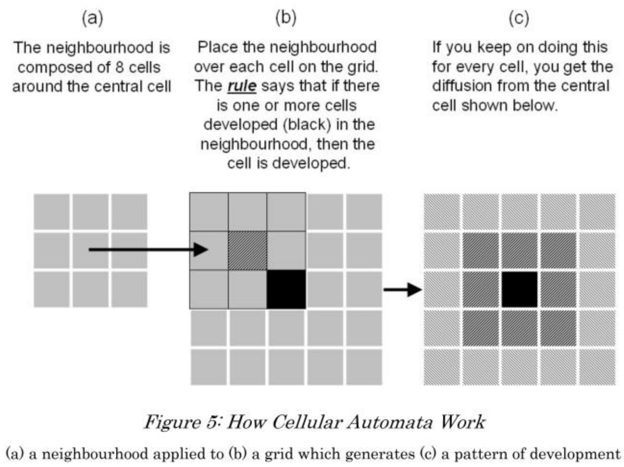
Within the dominant liberal capitalist policy framework, public administration and territorial management have been increasingly focused on the provision of (capitalist) market mechanisms to solve territorial planning challenges (among others). The logic of “invisible hand” puts in evidence the market as the device where stakeholders share its knowledge about a specific commodity – for example, spatio-territoriality – and achieve consensus about it properties – for example, revealing its price preferences.

As the societal context provides a central role to market as the best device to ensure good allocation of land between different functions (uses) (the device of “planning” itself), the analytical approaches that tries to model it in order to produce insights about spatio-territoriality regains new importance. In fact, the transition from classical modelling approaches to an economic market modelling paradigm inspired on computational simulations and agency based ontologies can be viewed a deeply extension of that societal paradigms that guides society and territorial planning practices in particular.

It is combining the insights of computational modelling efforts, computational mediated communication platforms and that societal context that highlights the role of individuals interactions (through market mechanisms) that emerged some new modelling efforts: Cellular automata (CA) (Benenson & Torrens, 2004) or agent-based model (ABM) in general (Gilbert, 2007).

That model approaches have its roots on the emphasis on individual drivers of social interactions, on the general systems modelling approaches and its integration with the insights of computational theories (computational systems) towards the belief on the possibility of codify and simulate social behavior. The idea that real world can be modeled through an automaton agent through simple mathematical and computational rules, derived from the new branches of mathematics – chaos and fractal geometry, and computation – meta-algorithms.

The pioneering model proposed by Schelling (1969) can be pointed as one most recognized demonstrations of those ideas. Focused on understanding how stablishing simple behavioral rules to individuals, result in dramatic consequences on a geographic space. In its known example, the author proposed a system where individuals (agents) follows a simple rule in housing location choice – the preference to live in a place with at least 33% of residents of the same ethnic group. The Schelling model defines its spatial unit as "cellular automaton" - in line with the definition developed by Alan Turing on the field of computational systems (P. Torrens, 2012). Thus, in an abstract geographic space (a polygon divided into equal parts constituting the spatial units where individuals reside), with an initial random distribution of individuals of two ethnic groups, the results of a simulation of random interaction between individuals, resulted, after a few number of interactions, on the emergence of a complete spatial segregation patterns (Benenson & Hatna, 2011; Schelling, 1969).




(retrieved from Batty (2007))

**Figure 2.8** The "mechanics" behind a cellular automata on a geographic lattice

A system of cellular automata has as main characteristics:

- Self-organization. It refers to the fact that transformation dynamics do not require any external elements to guide and manage the process to reach perfect state of organization, even starting from the initial situations of high turbulence and "chaos" (Goldstein, 1999; Wolfram, 1984).
- Self-similarity. The dynamics of the interaction process leads to the reproduction of structures, which can be considered similar (Benenson & Torrens, 2004; P. M. Torrens & O'Sullivan, 2001). This approach assumes spatial structures can be formed without identifying, a priori, all the elementary structures of the system – which approximates the approach to the fractal and independent properties of scale in the context of geographic space. (Wolfram, 1984).

A set of new techniques to model territorial systems grounded on what comes to be known as complexity theory have been proposed (Batty, 2007; Batty, Couclelis, & Eichen, 1997). Through this framework, both, territorial units and its inhabitants are assumed as a set of abstract automaton agents that, interacting locally, through a set of simple rules and initial parameters, produces the emergence of observable new spatial structures (P. M. Allen, 2012).

Jin and Wegener (2013) argue that ABM/CA approaches to territorial planning are mainly concerned with the integration of the land use and transportation dimensions of territorial systems: RELU-TRAN, SIMULACRA, LUISA are some of the most important references of this framework. However, the authors highlights that it is a hybrid modelling system (URBANSIM) that seems to be most useful in real territorial planning contexts. In fact, as described by Waddell (2002), Urbansim:

i) tries to integrates different dimensions of territorial planning (for example, it is not only concerned with land use or transport planning, but integrates models to deal with housing – supported by explicit models of housing choice and housing building – and other dimensions of the planning practice).
ii) presents a unified interface, with efforts to integrate different modelling frameworks – from neoclassical econometric models, classical general equilibrium (optimization) models, to the ABM and, eventually, CA.

The role of that new approach to design planning decision support tools to produce insights to a better understand of geometric and dimensional notions behind spatio-territoriality, have showed little evidence of its real value in general. Even considering the versatility that UrbanSim suggests, Batty (2008) or E. Silva & Wu (2012) argues that this models are far away from a wide operational use.

The efforts of territorial planning related above, despite it innumerous pitfalls and remained challenges, shows some important clues:

- Although, most of these tools are being based on a definition of basic units in the geographical space, a little guide is provided to understand how they can be defined as bounds of a territorial unit on a territorial system. The association of an infinity of attributes to these units reinforces the need to acknowledge the multiple dimensionality of the phenomena and an explicitly embrace of the uncertainty concerned to its specifications (in terms of its number and how they can be measured).
- The properties of the cellular automata, when approaching and in some way contrasting properties, described in the context of fractal geometry, are another evidence of the important debate to abandon the geometric analytical framework of Euclidean Space as a major referential explanation tool.
- The idea of emergent properties of the territorial systems can be linked with the recognized importance of spatial interaction mechanisms (Batty, 2009). Unfortunately, even the most recent modelling efforts – such as cellular automata approaches – relies on neighborhood conceptions usually defined through the geographic space. This reinforces the need for the most general debate that is taken on this thesis in order to stablish a strategy where geometrical and dimensional Euclidian assumptions of geographic space can be relaxed.

This short overview of literature insights on territorial transformations behind planning practice reinforces the research problem highlighted on this thesis and its research questions, that can be resumed on the need to embrace the unknown dimensionality (and geometry) of spatio-territoriality.

# 2.3. SUMMARY

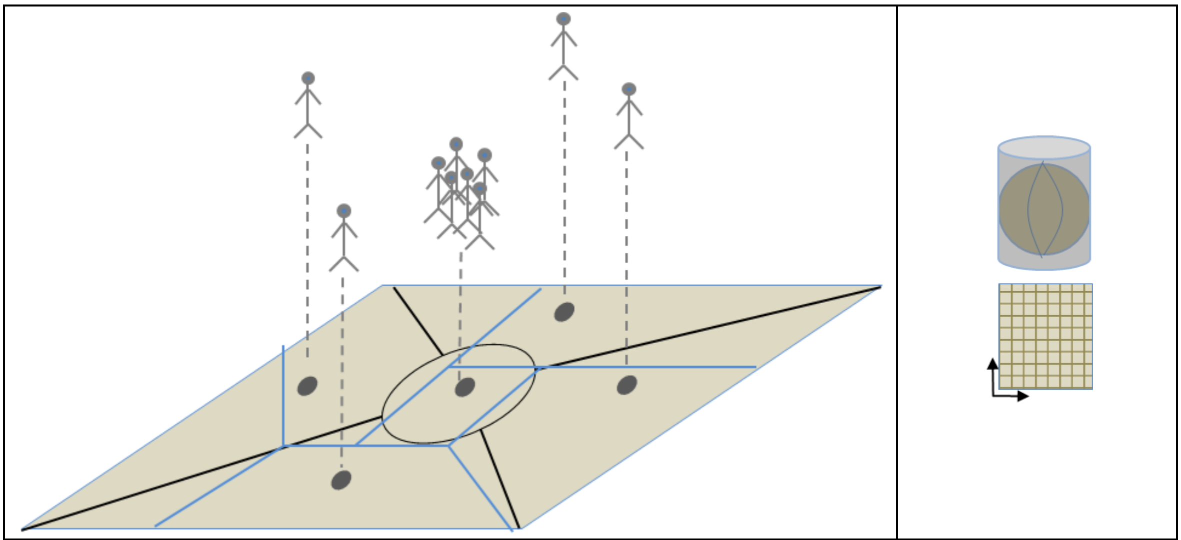
## 2.3.1. THE LAYERS OF COMPLEX(C)ITIES

As was argued in this chapter, the accumulated knowledge on spatio-territoriality and its transformations in territorial planning, and connected scientific disciplines (such as geography, economy and sociology), can provide a general postulate about the interaction of territorial units in a territorial system and the hierarchic nature of these interactions. The hierarchic structure of territoriality, and its relation with geographic patterns, can be understood through three layers of knowledge, as follows:

**[1]**

The geometrical 2D Euclidian framework, as a referential frame, describes the disposition of spatio-territorial objects as a result of individuals' beliefs and desires. How these beliefs and desires can be translated, with more or less restrictions, to fill the geographic space is a question concerned with the distribution of socioeconomic and political power. As was shown before, pioneering planers were empowered with a disproportional authority to transform spatio-territoriality according to its beliefs and desires (when they are similar to the dominant political powers of that epoch), that its projects were so extensive that remains today as important marks on the territoriality tissue.

Following this, one layer of knowledge about the postulates of a hierarchical structure of relations should consider geographic space as a result of that power to "fill geographic space".



Hierarchy of territorial units designed through a filling of "objects" on the geographic space | Euclidian geometry and Cartesian 2 dimensions

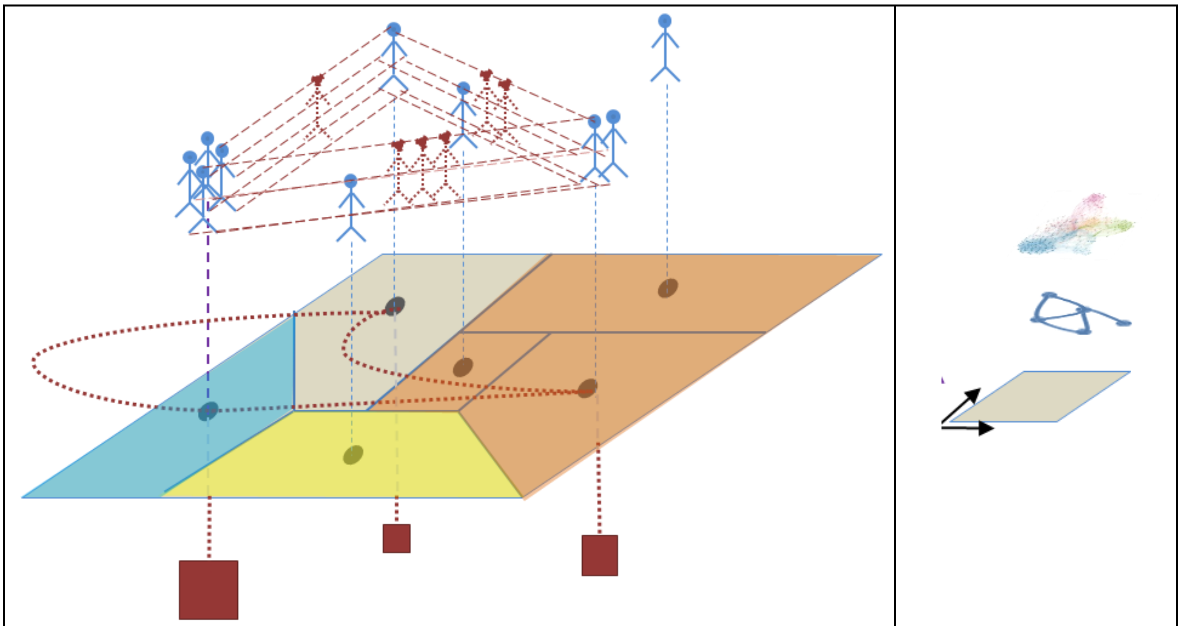
**Figure 2.9** Territorial planning and the notion of space: hierarchies defined as geographic space relations

**[2]**

Through power differences in the transformation of a territory, a layer of social and economic forces takes action. It adds (and claims!) for additional dimensions that should be considered for filling the geographic space. Moreover, as the boundaries of the filled geographic spaces are easily penetrated trough communication technologies, the interactions of individuals shared with the observable patterns on the geographic space, fill it with a sense and shared consciousness of a collective structure.

This communication – mostly physical– can produce *per se* different social and economic distributions on the geographic space. This collective behaviour changes the rational logic of space described before and claims for the social and economic dimensions that fill the observable geographic space.

The hierarchy is not only now designed by the dimensionality of objects on a 2/3D Euclidian reference space, but it presents the general property of organization of socioeconomic and spatial hierarchies. The territory as a hierarchical spatial and societal system (including the economic organization) emerges as a layer that overlaps the physical geographic hierarchy with the abstract centre-periphery hierarchic configuration, imposed through the power of wealth and the domination of communication technology.



The hierarchy of territorial system built up through physical communication (mostly transportation) technologies | The non-geographic geometry

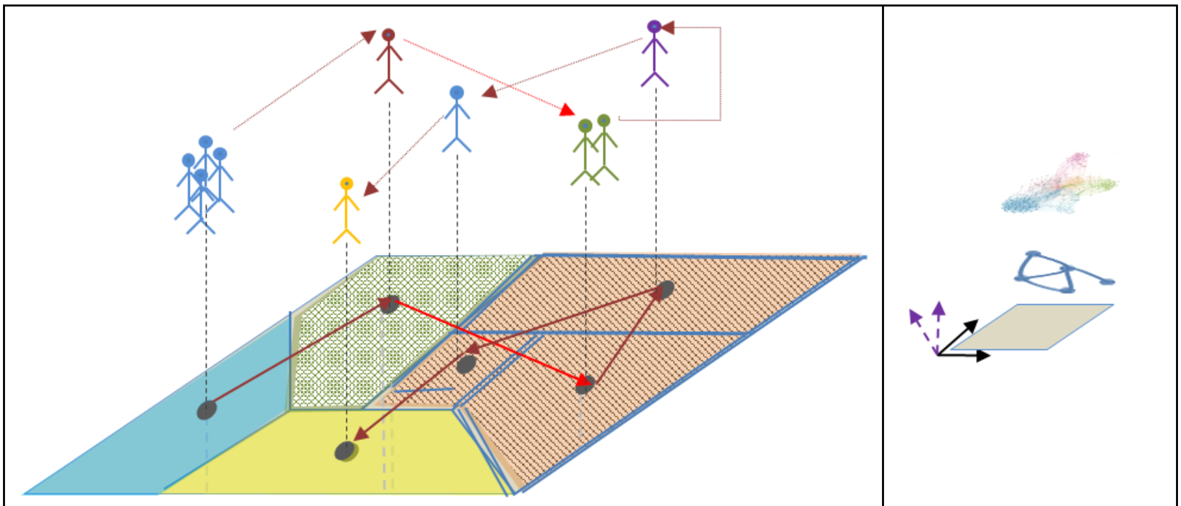
**Figure 2.10** Territorial planning and the notion of space: hierarchies through the unknown geometry

**[3]**

The third layer of a spatio-territorial hierarchical property of its interactions can be summarized by the famous assertion of McLuhan (1994): "The medium is the message". This expression is a recognition of the role of mechanisms that mediate communication and their increasingly transformative role, by enabling the convergence between face-to-face communication with communication at a distance.

The outcome of this convergence is the explosion of new dimensions that reshape spatio-territoriality: the dimensions concerned with the content itself (and the amount of information) transmitted in communication channels. In other words, the content is another source of distortion when analysis the filling of geographic space.

This layer includes the control over the content that guides the mechanisms of hierarchical organization, and contributes to the steady state of permanent socio-economic-spatial transformation. The interactions are well described by the topological insight of Castells – the "space of flows" which are free from the geographic scale – meaning that, regardless of the geographical scale of analysis, the hierarchical property prevails – an insight that matches the traditional standard principle of territorial planning practice itself.



| The hierarchy is driven by information and communication (plus transportation) technologies | The unknown geometry and dimensionality |
|---|---|

**Figure 2.11** Territorial planning and the notion of space: hierarchies through an unknown geometry and the unknown dimensionality

## 2.3.2. DECODE TFL GEOMETRICAL AND NON-GEOMETRICAL PROPERTIES

The Tobler First Law (TFL) (1970) of geography gives valuable insights to understanding the structure of a territorial system. However, the traditional geometrical and dimensional assumptions adopted to apply it on modelling efforts face important challenges.

The identification of spatial interaction in the geographic space through the use of Euclidian space as a universal explanation mechanism shows important limitations. Two major drawbacks can be linked to:

i) the observations of the "friction" of distance (Cliff, Martin, & Ord, 1974; Curry, 1972); and
ii) the modifiable areal unit problem (MAUP) (Openshaw, 1984).

Both are especially relevant as geographical resolution increases (small scales) – a problem that was also discusses in Marques (2012). In fact, Tobler himself (2004) recognizes TFL is not always true (Sui, 2004) and shows that statistical correlation is likely to be higher at short distances in the geographic space. This is usually assumed as evidence of the underlined mechanisms (forces) of aggregation that support the delimitation of a territorial object as an independent territorial entity, rather than as consistent with the interaction between objects.

The first point (i) is reflected by the observable model inaccuracies which are related to the way in which distances are specified or measured. Moreover, it highlights a major difficulty of the analogy between physics models and territorial models, especially when the adopted framework has a restricted perspective of the geographic space, which is a major property of the behaviour of territorial objects[7].

The second point (ii) highlights the problems raised by the aggregation process and the scale adopted for modelling territorial phenomena. Although territorial phenomena are continuous, they need to be geographically aggregated to make the description of their properties and mechanisms feasible. Although different methodological frameworks exist to perform that "division", the exact outline of the boundaries that define the geographic limits of a territorial unity remains a difficult decision.

Note that the uncertain nature of territorial unit's limits (Helen Couclelis, 1996) and the geometrical boundaries of the geographic space (Burrough & Frank, 1996) are well recognized in territorial planning, where that difficulty is faced with a pragmatic attitude. As technically different spatio-territorial quantitative or qualitative framework are available, the leading focus on the definition of zoning and it normative issues makes this

[7] In contrary to Newton gravitational laws, that stated the distance decay parameter is reasonable invariant and equal to 2. In geographic analogies, that parameter needs to be estimated for each observational study (Carrothers, 1956) Isard (2017).

issue a secondary research priority in the challenges to understand spatio-terroriality. In general, different territorial divisions needed for territorial planning are achieved through implicit and explicit accords between all stakeholders.

Returning to TFL, its additional expression, that states near things are more related than distant things (Tobler, 1970), highlights the central role of the relational or positional measures associated with objects. As showed before, besides the major traditional Euclidian distance (even if not restricted to the distance measured through a geographic space/Cartesian reference frame) is only one possible choice. Throughout this chapter, a set of distance concepts, and tools to measure it, have been described, following the progresses in geography and economy knowledge of spatio-territoriality. Moreover, specialized applications, specifically designed for territorial planning practices, have been described. Among these, it is important to highlight more recently approaches, framed by the adoption of practices concerned with increasing citizen participation in territorial planning processes. In fact, in areas where the uncertainty is greater, it begun to be usual to apply methods that transform citizens non-structured knowledge about spatio-territoriality properties into insights that can help to define the geometrical and dimensional properties to develop models or even the decisions themselves. This is a major recognition of the limits that usual modelling efforts face to assess territorial planning.

Despite these efforts, an unknown geometry and unknown dimensionality seems to be needed to tackle the geographic patterns of the complexity of spatio-territoriality in the planning practice. Moreover, as an object of inquiry in a permanent state of transformations – nowadays arguable accelerated – a return to geographic space as a support of analysis rather than as a fundamental explanation of spatio-territoriality is desirable.

The n-dimensionality and unknown geometry are easily observed as the distortions on the geographic shapes. However, more than pure observational perceptions (qualitative), it is necessary to measure the relations (interactions) between spatial objects to ensure – between other needs – that accurate territorial planning decisions are made. This thesis seeks to contribute to this goal. As is shown in next chapters, this goal can be pursuit through a re-interpretation and re-adaptation of existing tools. For this, some major guidelines established in the theoretical background, are followed:

i) For an unknown dimensionality and geometry, it is necessary to choose ways to measure the relation between objects that do not rely on strong dimensional and geometrical assumptions; this was recognized from many spatial social and economic models that adopted general statistical approaches;
ii) Moreover, the widely use of statistical modelling approaches – and mostly classical economic models which are statistical in its nature – needs to be release from the geometrical background that conditions its specifications;

nonetheless, as assumptions are really needed – and since it is not credible that an universal and complete model is possible to achieve – only the minimal assumptions and, preferably, informative ones, should be defined;

iii) Finally, as it is not possible to focus, at same time, different elements of spatio-territoriality, a researcher should choose between identifying the spatio-territorial structure of agglomeration (the objects) or, assuming that its research program will be focused on the interaction structure; on territorial planning, the major challenge is clear the focus on the study of spatial interactions – a problem where drawbacks are higher as the usual frameworks remains grounded on classical assumptions.

# 3. TERRITORIALITY THROUGH ECONOMETRICS

This chapter is concerned to describe the followed econometrics background, able to perform the descriptive quantitative analysis of the spatio-territorial structure, embracing the uncertainty of its dimensionality and geometry. It organized as follows.

Section 3.1 describes the most important motivations to choose the hedonic housing prices framework and the standard econometrics estimation technique. The presumption of a notion of space as codified on housing markets will be found through the briefly analysis of the role of housing and housing market in Portuguese territorial planning system. Moreover, from an economic perspective, the importance of value, and housing value in particular, is highlighted as a guide to different territorial planning practises – from the design of territorial plans and its zoning systems on the geographic space, to the role of housing value as a tool to the compensation schemes. The section will ends with a brief reference to the role of reduced form housing price models to help policy design and decision making on territorial planning in particular.

The chapter follows with section 3.2, which reviews the chosen standard econometrics tool: the hedonic prices framework. Assuming the value of spatio-territoriality embedded in house attributes, this tool provides a simple mechanism to investigate and measure spatio-territorial properties – from identification of territorial units and its market values, to explicitly explore the spatial interactions between them through the observation of spatial dependence measures. Moreover, the role of spatial assumptions and model specifications, on these models frameworks, is reviewed to open the doors for a specific methodological approach described in the remaining chapters.

## 3.1. THE "PRESUMPTION" OF SPATIO-TERRITORIALITY

In national policy designs, housing and its prices are often understood through macro socioeconomic phenomena, such as migrations, labour structures or investments. But these macroeconomic phenomena produce major effects at the geographic small scales of spatio-territorialities. For example, Hall (1980) identifies that, in the USA, in 1977, nearly 20% of the population changes residences annually, and nearly half of this moves occurs within the same Standard Metropolitan Statistical Area. This observations puts in evidence the role of the individual life-cycle determinants – such as marriage, birth of children, divorce, death of a partner, entering or finishing stages in one's education, income changes – which brings policy-making to the microeconomic market analysis, namely the usual utility optimization (neoclassical framework).

In the same work cited above, Hall (1980) identifies that residential change seems to be grounded on "place utility and spatial search strategies (…) [that can be] postulated to be a form of group adaptation to perceived changes in the (personal) environment" (p. 86). The works presented by Laska & Spain (1980) and Pahl (1970), for example, reinforce that features of territorial structures can be used not only as criteria, but can be identified as motives which promote the rates of residential changes at local geographic scales and that the market mechanism can be considered a reliable proxy for assessing territoriality.

The research efforts on modelling residential choice analysis was explored mainly from its pure economic mechanisms both in the intra-urban location choices theories (Huu Phe & Wakely, 2000; Quigley & Weinberg, 1977; Straszhem, 1987) and by bid rent theories. The last model are specially linked to classical spatial economic models, pointing to the seminal works on land price developed by Wingo (1961), Alonso, (1964) and Muth (1969), and extensively developed to be included as housing choice models for territorial planning assessment tools (B. Lee & Waddell, 2010).

The link between different economic mechanisms with spatio-territoriality properties is usually not clearly assumed on economic model efforts. Besides the targets of classical spatial economics models (mostly concerned with land prices), are within the housing market modelling approaches where attempts to incorporate spatio-territoriality can be found in more detail. For example, the Butler *et al.* (1969) taxonomic classification, of market price relevant set of housing characteristics, highlights, between others, the role of surrounding built environment, its geographic accessibility and the neighbourhood amenities. However, that recognition is not accompanied by standard guidelines to measure them. Moreover, relevant questions about the interlinkage between economic phenomena, the notion of space defined by these attributes and model specifications remained as a fruitful open debate on social sciences and urban studies in particular.

## 3.1.1. SPACE ON TERRITORIAL PLANNING AND HOUSING MARKETS

### 3.1.1.1 The links between housing markets and territoriality

Houses represent the most valuable single asset owned by most individuals. As pointed out by Arnott (1987) "the market value of a housing unit is typically several times an occupant's income and the value of a nation's housing stock is a significant proportion of its total capital stock" (p. 963). In fact, as an economic good, the direct costs with a house, in the EU, represents 18% of the total final consumption expenditures of households and housing contributes about 30% to the EU's GDP[8] (Gerstberger & Yaneva, 2013).

In a society organized mainly through the adoption of capitalist principles, it is natural that territorial planning guidelines mainly focus the regulation of housing provision by market mechanisms, rather than by direct provision. Bourne (1981) describes that "governments play a large and increasing role in almost all aspects of housing production and consumption. They act as financiers, insurers, regulators, speculators, administrators, builders, landlords, and frequently destroyers. Even in the most market-oriented of economies, the role of the state in housing is pervasive" (p.191), constituting the housing market as one of the most important tools of state intervention. As Hallett (1988) summarizes in the review of «Land and housing policies in Europe and the USA», "under a 'capitalist' system, land and town planning policies should have, as one objective, that of helping the casualties of the system" (p. 14).

The interconnection of markets and territorial planning, which shape territorial housing policies, have witnessed important developments within the movement of new public management (Kaboolian, 1998). The adoption of the neo-liberal agenda, in order to replaces the traditional direct public actions – for example the planning of infrastructures, general interest services (such as health and education centres) and, specifically, the housing market operations, substantially decreases the role of public initiatives. Sager (2011) points to the role public administration will have regarding the management functions, rather than production/provision, and highlights how decisions should be assessed regarding the relation between the self-organization of market mechanisms, and their regulation to ensure better equilibriums.

The close relation between territorial planning (in general), housing market (in particular) and the relation of both elements to the production of the territorial system, highlight the need to explore data which provides a reliable market information, following the need for efforts to produce useful insights to help territorial planning practitioners understand and transformation of spatio-territoriality.

[8] Contribution measured on the category of national accounts defined as "gross fixed capital formation"

Most market data collection, processing and analysis are concerned with pure economic/financial use. Although there are several possible uses of it, the following examples points to the role of housing market prices as an analytical tool to understand territorial systems (Barlow & Duncan, 1992), namely:

- Land use rules, such as maximum loads, number of housing permits and other regulation, should be provided by housing market analysis, namely prospective and predictive analysis of demand drivers and preferences (Palmquist, 1984; White & Allmendinger, 2003).
- Housing market value is central to define the financial budget for public policies (Jones & Watkins, 2009). In particular, the market value of housing stock and housing transactions is the standard reference for compensation schemes to ensure the management of territorial transformations, as well as for financial solutions of housing development (e.g. housing credit, ownership policies), and is also often fundamental as a financial source of resources to the provision of public services and goods, through revenues on taxes based on housing market values (Almy, Munene, & Ogana, 2013).
- Housing market is typically assumed as a proxy to measure the quality of life. A great number of empirical works have described the impact of services and goods – namely the ones provided through territorial planning prescriptions - that changes housing prices as a response to better or worst perceived quality of life;
- Territorial planning is facing challenges to deal with increasingly complex mechanisms, namely to define responsive land use regulations through increasing dynamical spatio-territorial changes; planning housing land use is recognized difficult but the role of housing market prices are assumed critical on integrated planning decision support tools – as showed by Wegener (1994) or Waddell (2002), housing market modelling is an important module feature of that tools.

#### 3.1.1.2 A brief overview of the Portuguese territorial planning system and the role of housing market behind it

A recognized target of the Portuguese territorial planning tools is to ensure one of the basic constitutional rights – the right to housing. The Base Law of the Environment and Spatial Planning (Law no. 48/98) focus to achieve that objective through, both, a) the processes, principles and legal rules that should guide land use management; and b) answer the present and future land use needs – namely the delimitation of land allocated to urban uses (housing).

Across the hierarchical territorial planning system policy framework, is the Municipal Master Plan the recognized most important planning tool. Its legal documentation must define, not only the cartography of the land use zoning system, but also the legal rules concerned with land transformation processes – such as the land built occupation index to ensure a correct number of housing units for population present and future expected needs.

The Portuguese planning instruments (and the territorial planning tools in general) follow the prescription for practices grounded in analytical efforts: i) focused on the production of pictures of the territorial system – guided by technical expertise to transform data into useful information; and ii) a set of procedural rules to engage planning process with the political system and the different stakeholders, in order to produce a decision-making environment regarding strategic goals – translated then into technical solutions by experts.

Despite its theoretical concepts, several authors highlights its ineffectiveness's. For example, Correia (2002) suggests that there is a decoupling between the dynamics of urbanization and the guidelines (and rules) stablished by the planning tools. The author assumes that the lack of efforts on data collection and development of analytical tools to support better decisions is a reason for that mismatch. In the same line of criticisms, Carvalho (2003) highlights that "thinking about location, typology and residential design is now, as always, a substantial part of planning activity, currently gaining new complexities"[9] – remarking that this leads to the need to better technical assessment efforts.

Following this consensual diagnose, a major review of planning tools took place recently. Carvalho & Oliveira (2013) note that the newer legislation presented an ambitious agenda, that claims for a set of objectives, namely: "ensuring the sustainable development, territorial economic competitiveness, employment creation, and efficient organization of the land market, in order to avoid real estate speculation and harmful practices to the general interest"[10] (Article 2 (b)). However, as the authors highlights, these objectives claims for a multiple dimensional understand of spatio-territoriality, which add additional complexity layers to the previously and non-resolved difficulties of the territorial planning system.

In particular, Carvalho & Oliveira (2013) underlined the challenges between land and housing markets, pointing out that "the land and real estate market are by nature speculative, because it is subject to hoarding, to externalities or lack of transparency, and

[9] Translation note (original text): "pensar a localização, a tipologia e o dimensionamento residencial é, agora como sempre, uma parte substancial do ordenamento, ganhando atualmente novas complexidades"

[10] Translation note (original text): "garantir o desenvolvimento sustentável, a competitividade económica territorial, a criação de emprego e a organização eficiente do mercado fundiário, tendo em vista evitar a especulação imobiliária e as práticas lesivas do interesse geral"

because it depends on administrative decisions"[11] (p. 6). In a context where the Portuguese policy, regarding housing provision, relies on market mechanisms, a special attention from practitioners it is crucial and required. Carvalho (2013b) recognizes that prevails a lack of technical skills to deal with this market-oriented environment by municipal/local territorial systems professionals.

The study of housing market values is unavoidable as it is implicit in most of the new legal guidelines for territorial planning, both at local and more global scales: it is the housing market value, and the housing attributes values, which should be adopted, as the referential value indicator to guide public territorial policies. For example, Carvalho (2012) and Krause & Bitter (2012) highlight the role of a market valuation analysis as a way to define mechanisms of compensations between land owners, to ensure a minimum of justice (and feasibility) of territorial planning projects.

From other perspective, and as was mentioned before, it is important to highlight that housing valuation is usually the most important source of funding public (local) infrastructure, through a real estate tax revenue (Yinger, Bloom, & Boersch-Supan, 1988). In Portugal, the housing valuation for tax purposes is the basis of the *Imposto Municipal sobre Imóveis – IMI*, which is one of the most important tax revenues of municipalities (A. Pereira, 2010). This revenue is crucial to pursuit most of the territorial planning purposes and follows a close relation with the assessment of its market value (Pires, 2012).

As a conclusion market mechanisms have an important role in territorial planning, such as: i) the spatio-territoriality, produced by territorial planning decisions is incorporated in the housing values and its provision of citizen quality of life can be measured indirectly by this proxy; ii) housing market analysis helps to design better territorial legal rules to guide transformations (such as the examples described above, related with execution and compensation mechanisms); and, iii) as we argue later in more detail, it can be the focus to develop a useful approach to better identify and describe the complexities behind spatio-territoriality.

### 3.1.2. TERRITORIAL COMMODIFICATION

The need to include a valuation tool to identify the relation between territoriality and the housing market price mechanisms is not only a topic discussed in planning literature, but is an important driver of planning practice. Crespo & Grêt-Regamey (2013) describe that simpler house hedonic price models – a standard econometrics approach, applied at

[11] Translation note (original text): "o mercado fundiário e imobiliário é por natureza especulativo, porque sujeito entesouramento, porque muito sujeito a externalidades e porque muito pouco transparente, desde logo porque dependente (sem poder deixar de o ser) de decisões da Administração"

the local scale – can provide practitioners, decision makers and other stakeholders with a valuable tool in different tasks of the territorial planning process.

A convergence between territorial planning practitioners and spatial econometrics researchers, behind the efforts establishing of hedonic prices housing frameworks, has been recognized. O'Sullivan (2003) points out that spatial planners can help econometricians to explicitly identify the hidden territorial structures, able to be captured by econometrics frameworks, through theoretical insights to understand the source of observable (geographical) spatial effects. While for planners, which usually consider that phenomena following a holistic perspective, the analytical efforts to observe (and quantify) territorial patterns can produce a better understand of relations in the geographical space, embracing more clearly territorial systems as following an n-dimensional and unknown geometry.

Housing price models – and hedonic housing prices models in particular – face important challenges. As described, for example, by Malpezzi (2003), spatial heterogeneity and spatial dependence have been embraced mainly following a standard economic definition of space concept. Nevertheless, spatial econometrics recognizes the need for additional (territorial) theoretical guidelines in order to address the open specification challenges, and guarantee consistency of econometric hedonic price models (Anselin, 2010).

Despite the fast change of the spatial analytical approaches in econometrics – for example the relatively new sub-field of spatial econometrics – and the prevalent drawbacks related with data reliability and availability, important barriers remains for a more general use of these techniques in territorial planning practices.

### 3.1.2.1. Towards territorial value

Market prices is the most important focus of economic analysis and the mechanisms that ensure its formation constitute the major object of study on theoretical and empirical economic efforts. The conditions by which the exchanges (transactions) of goods and services between different individuals occurs are usually assumed as general mechanisms of (socio-economic) development. As pointed, for example by Stark & Clippinger (1999) or Thévenot (2001), the market can be described as collective device that allow compromises to be reached, not only on the nature of the goods to produce and distribute but also on the value to be given to them.

Through that general development path, markets have been facing an increase sophistication and nowadays, the market assumes an important institutional role. In this context, the socio-economic organisation of society is viewed through the prism of wealth accumulation, where the "capitalist" system relies on increasing dominant "perfect competition" market mechanisms to achieve it. As a result, the growing freedom (of institutional rules) in commercial trades, being the market a single collective institution with a diminishing direct dependency on the systems of collective governance (namely the political system).

The key models of classic economics (namely the conception of a market of perfect competition, with its associated postulates) (re-)emerges today, as an unwavering reference framework to analyse socio-economic phenomena. These core models are based on a set of postulates about the "psychosocial" characteristics of the agents – selfish, rational, totally informed – and their mechanisms of action – a behaviour guided by an exercise of maximisation of the individual benefits (utility) gained through market exchange[12].

The market mechanism regularized the consumption and production activities through a shared measurement unit to define the value for an object. The value assigned by each individual is then used in the exchange process – the market – which is usually assumed as a perfect (and instantaneous) mechanism to reach the regularisation between the preferences of the demand and supply agents, leading to the definition of a consensual value that accomplishes the exchange – the market price.

From the literature on the concept of value it is possible to understand the multiple dimensions that lead to the definition of a market price – some of them are clear embody on market mechanisms, but others are not explicitly considered – only as part of model assumptions. On this behalf, Brown (1984) identifies that market value results of a multi-dimensional notion. First, the author highlights value arises from a conceptual realm that translates the preferences for specific "physical" qualities of the commodities, which match the abstract, moral and immaterial conceptions. Second, a circumstantial aspect arises as a relational realm: since value is assigned in specific contexts (including specific spatial locations), the subject is aware of the existence of the commodity within a set of possibilities. Finally, the objective realm of value emerges from the confrontation, in a given context, of the commodity in the face of a set of constrains: its utility, its eventual scarcity and the individuals' budget constraints.

This reference to the concept of value, the definition of market as well as to the focus of the economic analysis in its mechanisms, serves here to underline the role of the market price, as a referential of the value assigned to a good or service and as the result of a social interaction process between market agents – more or less explicitly in economic models. In fact, through the refinement of the classical models, the theoretical postulates that led to the balance between the preferences of the agents of demand and supply had turned

[12] The formalisation of this behaviour is the target for several lines of development of the socio-economic sciences, being the "utilitarian school" one of the most solid and disclosed examples, which, as we will see further on, is the basis for many of the developed empirical approaches.

that models more reliable. Then, those theoretical insights are the basis of classical analytical techniques that, as detailed later, allow to easily obtain i) the identification of the elements (attributes) considered in the decision-making process, and ii) the estimates for parameters (weights) that describe the importance, in the market, of each of those elements.

### 3.1.2.2. Spatio-territoriality and the market value

The market price is usually assumed as the proxy for the objective value of a commodity. But, as the multiple definition of value suggests, market mechanisms include all of the previous dimensions, even if it is hard to distinguish the key parameters that rule all of them.

Empirical efforts on microeconomics were increasingly concerned with the development of agent behaviour modelling in order to understand market outcomes. The marginalist school of economics introduced modelling postulates to define individual's behaviour (the "homo economicus"), which brings a "mechanistic" and "deterministic" quantitative approach to the market analysis. In fact, at the time the set of its theoretical postulates was developed, positivist and reductionist principles prevailed in the efforts of scientific development. The theoretical, technical and philosophical contexts constituted the necessary ingredients for the origin of empirical benchmarks, of theoretical-quantitative nature, based on the mathematical formalism – econometrics.

The development of the econometric tools applied to microeconomics (to the phenomena related with the individuals' behaviour), led to two empirical approaches: i) the structural models and ii) the models in their reduced form (Sims, 1982) to analyse the value assigned through a conceptual market mechanism. As mentioned by Sims (1986), the two approaches are methodological variations that allow to accommodate the different research issues and the availability of resources (data or computational capacity, for example). They differ themselves by the greater or lesser detail with which the socio-economic mechanisms are described through mathematical language. Therefore:

i. The structural models seek to specify, with maximum detail, the market mechanisms; these are developed following systems of multiple equations, that describe the different components of the market, namely, the mechanisms of formation of the value of goods, by several types of agents and the mechanisms for determining the market price (or, in other words, for the consensus on the value of tradable goods).
ii. The models in their reduced form, based on the definition of a wide set of theoretical propositions, obtained through deductive reasoning. However, this theoretical building approach is less demanding, since they are not focused on the

mathematical modelling of those mechanisms and its explicit empirical analysis. After all, the theoretical framework allows: the selection of a representative set of determining factors in the transaction price formation (global parameters of market functioning) as well as the guidelines to specify the relation between these set of elements and the transaction price.

In the first case, the challenges concern the agents' diversity and the impracticability of considering a model for each individual. Furthermore, the formation of value is a multidimensional process, making the estimate of the models parameters more complex and potentially impractical. A usual commitment is to restrict the modelling to a restrict set of mechanisms of the market; for example, focusing the analysis on supply or demand, or the interaction between both but assuming a representative agent and the average behaviour. Within this context, we can highlight three barriers to the spread of structural models for general descriptive purposes: i) the necessary simplifications to model agents' behaviour empirically restricts their capacity to reproduce the observable aggregate behaviour; ii) the necessary assumptions to apply this modelling approach are often not easily testable, turning the models highly dependent on the perception of the researcher; and iii) the complexity associated with specifications of contextual variables or complex externalities – for example, in housing market, the planning regulations, the macroeconomic fundamentals, the credit market access or environmental externalities.

In the second case, the challenge involves finding a mathematical formalisation and a statistical estimation technique which overlaps the theoretical assumptions and is focused on obtaining good approximation of market prices (focused on increasing statistical model explanation power). After all, the adopted solutions are usually analytical – with attributes which are proxies to the above-mentioned supply and demand mechanisms.

Regarding the challenges (and limitations) of the structural models, the reduced form counterparts are the ones that have been having a wider dissemination in the economic analysis. In fact, this modelling approach places a great part of the agents' behavioural dimensions in the field of the theoretical abstraction (assumptions), merely seeking to identify (statistically) regularities (model parameters) that emerge from the market equilibrium. Moreover, this simplified methodological framework has proven to be especially helpful in the framework of public policy decision-making. These models also have the advantage of being less data intensive: they can be easily fed with data from open sources and/or in public domain.

Naturally, models in their reduced form have limitations. As mentioned by Timmins & Schlenker (2011): i) these models do not help, unequivocally, to specify the individuals interaction mechanisms themselves – since they are established on a theoretical and aggregated (agents) level; ii) the explanatory capacity of these models is dependent on the representativeness and randomness of the collected data sample, used in the selection of relevant attributes; and iii) the incorrect specification of the model, either by the inadequacy of the adopted estimation techniques (for example, the estimate of a linear model when there are non-linear relations between variables) or by an incorrect connection between the theory and the specification of the model (for example, leading to endogeneity of the variables adopted for the specification of the model or to omissions of key variables) conditions the efficiency or adequacy of the estimates obtained.

In another way, note that the market is not just an abstract concept: in addition to the institutional dimensions that support it (transactions law, etc.), it is also possible to associate them with a physical existence, the physical infrastructure, located on specific positions of the geographic space. Both features of market mechanisms point for the possible existence of exogenous factors (indirectly related to the *forces* of demand and supply) which can play a relevant role for the establishment of market prices but which are hard to measure. This is the case of: i) organisational aspects of the physical infrastructure where the transaction occurs, ii) their relative location concerning the different (proximity) agents or iii) simple aspects such as the rules for the occupation of the physical space of the market and the type of transactions that can happen there.

As we sought to show in the previous chapters, the integration of the geographic space in the explanatory factors of socio-economic phenomena is a source of great analytical complexity – either descriptive or explanatory – thereby justifying the option, regarding the objectives of this work, for the models in their reduced form. Moreover, the adoption of this type of economic modelling approach to assess different key tasks on planning activity (land management, recently efforts on costs and benefits sharing) reinforces the arguments in favour of the adoption of this kind of modelling strategy. Additionally, the descriptive nature and the focus of this work on identifying “insights” of territorial patterns brings this research closer to the reduced form approach.

## 3.2. HOUSING MARKET ANALYSIS: EFFORTS TO EMBED TERRITORIALITY

As Hall (1980) identified earlier, "beyond its recognition in neoclassical theories of location, the search process, as it relates to residential choice, has not been comprehensively analyzed for its role in residential decision making" (p. 80) (…) "neighborhood characteristics are showed as important elements of the household's environment but its relative importance in housing valuation has not received a consensus in the literature". It was the Lancaster Consumer Theory which created the theoretical framework for an econometrics analysis of housing markets in its connection with abstract classical spatial economic models and the general empirical challenges: the hedonic pricing mechanism, purposed by Rosen (1974). As houses were assumed as composite goods, it turns possible, and theoretically feasible, to encompass spatio-territorial features in an integrated estimation framework.

However, integration of territorial attributes faced important challenges, as Straszheim (1974) and Freeman (1979) identified. Most of the difficulties can be linked to the lack of theoretical guidance to specify the spatio-territorial structures and, in this way, to produce consistent estimates – a problem which has been well identified in a more general view by the spatial econometrics literature (J. Paelinck & Klaassen, 1979) – as we see later.

At this point it is important to highlight that spatio-territoriality is not only well established as a dimension incorporated in housing choice processes – and in the equilibrium modelling analysis of housing markets in particular – but it seems clear its econometric modelling framework can be an important empirical strategy to produce additional information concerning the analysis of the territorial structures.

### 3.2.1. THE HEDONIC PRICES FRAMEWORK: HOUSING MARKET MODELLING

Malpezzi (2003) reviews the efforts on housing market analysis behind the hedonic price model (HPM) framework and defines that the basic econometric tool can be specified simply as a mathematical linear function, such as:

$$\boldsymbol{Y} = \boldsymbol{\alpha} + \boldsymbol{\beta X} + \boldsymbol{\varepsilon} \qquad \text{Equation 1}$$

…where Y is usually the house market price (usually the market price by square meter of living area) achieved on market equilibrium conditions and X the set of house attributes, describing the house features relevant for the demand and supply side of the market.

#### 3.2.1.1 Specification of model relation

At the specification level, standard HPM are a reduced form of market model behaviour, i.e., a model specification which relies on the observation of market outputs (market transaction prices) and its relation to a set of attributes, describing the individual good itself. Demand and supply relations are not explicitly modelled, but assumed through model specification assumptions – for example, assuming the conditions that lead to the definition of a perfect market mechanism.

As pointed out by Rosen (1974), the mathematical function describes a market in a clearing condition, where the amount of commodities offered by sellers must be equal to amounts demanded by consumers. Both consumers and producers base their decisions on maximizing utility and equilibrium prices are determined so that buyers and sellers can be perfectly scheduled . In market equilibrium, the price is determined by the distributions of consumer tastes as well as producer costs, which can be nonlinear. Rosen did not formally present a functional form for the hedonic price function, but posterior studies have shown that the housing market can imply a nonlinear pricing structure (Sheppard, 1999).

To ensure linearity on the specification, it is usual to apply, after data diagnosis, a variable transformation technique in order to achieve linearity. The usual transformations are the Box-Cox transformation, the log-log transformation and the semi-log transformation (Duranton, Henderson, & Strange, 2015; Wooldridge, 2008). Box-Cox transformation and log-log transformation have some important pitfalls, specially when we try to achieve simplicity on model specification. The first option is driven by the data characteristics itself, and does not ensure a full comparability between data samples. It can make it difficult to fix other model specification issues and model parameters interpretations are not standard. In the second option, the most important pitfall is related to discarding all non-continuous variables – which is problematic in housing analyses, where most of its attributes are measured through categorical variables. In fact, semi-log specifications have a largely use in literature and, as we see later, that specification answer specific challenges of the empirical case-study developed in this work.

### 3.2.1.2 Defining the set of house attributes

Standard econometrics – and its hedonic price framework in particular – only produce BLUE[13] parameter estimations if, among other requisites, the independence, randomness and full specification of relevant attributes X is ensured.

Lancaster Consumer Theory defines that the composite attributes can be assumed independently of each other, which requires that empirical applications ensure the independence and randomness of the collected variables which describe house features. Moreover, that independence assumption is a requisite to use the usual classical

[13] best linear unbiased estimator

parametrical statistical technique – the regression framework and the most simple estimation technique (the Ordinary Least Square (OLS) algorithm).

In practice, guaranteeing the independence and randomness of independent (X) variables is not trivial. A different set of techniques has been applied to surpass this challenge, which follow two different strategies: stated preferences or revealed preferences. The last option is the most useful in reduced form modelling approaches, given that the set of attributes can be obtained from the analysis and processing of datasets, which are not usually produced directly for econometrics applications; this approach reduces the costs of data collection and usually ensures a larger number of available observations, from which more robust samples can be built.

Despite the sophisticated efforts within data collection and processing, it is not possible to identify a consensus concerned with the full list of house attributes which should be collected. That difficulty is usually related to different aspects:

i. Despite increasing data availability, the restrictions of information about housing markets remain relevant, which makes it difficult to comprehend the full set of market drivers; moreover, the full set of goods transacted is extremely difficult to ensure, given the level of decentralization of housing market records;
ii. Houses are described by a myriad of features, most of which are difficult to translate and measure in quantitative ways;
iii. The territorial features which surrounds each house and its relative location in the territorial system produce a myriad of different characteristics – environmental, social, economic; despite difficulties in collecting and measuring these attributes, it is also difficult to identity which ones are really relevant to the market.

In recently years, an increasing number of source of digital data can be identified regarding public and private services – for example, fiscal authorities, real estate listings portals and other. This data, when accessible, can be processed in an easy and semi-automated way. Knowledge Discovery in Databases (Fayyad, Gregory, & Padhraic, 1996; Liao, Chu, & Hsiao, 2012; Tan, Steinbach, & Kumar, 2006) is a versatile framework, useful to answer the needs of parsimonious microeconometric reduced form models (Batista, Castillo, Marques, & Castro, 2017). Applying a set of semi-automated algorithms, the KDD can ensure: i) the identification of the set of attributes that describe the characteristics and behaviours of agents (of supply and demand), ii) identification of the attributes of the commodities relevant for the mechanisms of formation of the transaction price and iii) identification of the intrinsic characteristics relevant for the market functioning – for example, the "type" of market, the "form" of the price-attributes relations, beyond others. To the territoriality analysis, presented later on this thesis, used dataset is retrieved from the KDD process developed in Batista (2010).

Another challenge related with data characteristics is the multicollinearity: a statistical highly correlation between two or more collected attributes (Wooldridge, 2008). This is problematic because the independence assumptions of model variables do not hold. Multicollinearity is usually associated to difficulties in measuring, in empirical applications, specific dimensions and is strongly related with data collection and selection tasks. Since it is usual to measure specific dimensions of an object through a set of attributes (proxies) it will be expected, naturally, that some of them are highly correlated. An easy way to deal with this pitfall and at the same time minimizing the information lost – as we can simply discard arbitrary one of the highly correlated attributes – is to perform a principal components analysis (PCA) (Hair, Black, Babin, Anderson, & Tatham, 2006). This statistical framework is concerned with a statistical summarization of data information through a set of new variables that are orthogonal, by construction, between them. Then, statistical correlation is removed and a high level of statistical independence is ensured.

Note that the questions of full independence and randomness surpass the general issues related before: specific idiosyncrasies of houses can produce different market equilibrium conditions. In fact, the territorial and time dependence of houses are well documented phenomena which causes important estimation problems and specifically the violation of independence and pure randomness assumptions. Given their importance for this work, a detailed analysis will be presented in sections 3.2.2 and 3.2.3.

#### 3.2.1.3 Heteroscedasticity

Another element on empirical works is to ensure that, when applied to OLS estimation, the variance of the error is not correlated with the set of dependent variables. Heteroscedasticity is identified as the non-homogenous variance of the disturbances or error term. In hedonic models this can occurs only across some specific groups of observations or can be observed across all the sample with some specific structure (reflecting, for example, an hidden spatial structure) (Fletcher, Gallimore, & Mangan, 2000). Although Gujarati (2004) argues that heteroscedasticity does not cause OLS estimates to be biased, OLS estimation is inefficient (for example, low measured statistical explanation), because their variances are no longer minimized, even if the sample size is increased. A major drawback is that confidence intervals and t and F tests are possible unreliable.

Empirical works showed that heteroscedasticity is usually identified in most of hedonic housing price models, which needs to be carefully investigated. There are two main sources of heteroscedasticity: the use of specific statistical methods and some theoretical economic reason, captured by the sample data, but not well modelled/specified.

The most common statistical source of heteroskedastic can be related to the functional specification. Diewert (2003), for example, argues that the residuals from a semi

- log hedonic model are less likely to be heteroskedastic than those from a linear model – which is especially relevant for housing price models, as the linearity between housing market prices and its attributes are not commonly observed empirically.

Theoretical reasons for heteroscedasticity usually arises in the presence of not well-modelled spatio-territorial mechanisms. As argued later, the major spatio-territoriality structures are usually defined in econometrics as the spatial heterogeneity and the spatial dependence (spatial interaction) phenomena, which are challenging to modelled and the major sources of heteroscedasticity by the wrong modelling of its theoretical behaviours.

Heteroscedasticity can be tricky to deal with, but the correct specification of the econometric model will minimize it. Spatial heteroscedasticity in particular is the target of an increasing effort behind spatial econometrics, as is shown later.

#### 3.2.1.4 Space-time challenges and the nature of data samples

The standard motivation of the econometric models described before is to show a credible causal relationships (Morgan & Winship, 2007) between housing prices and a set of attributes observed in market transactions. The causal relation is presupposed to be codified in the sample dataset in order to ensure that a causal inference approach can be developed to recover it. Incorrect specification of spatial and time phenomena, therefore, results in wrong causal analyses: first, estimations are usually conditional to the correct specification of relevant attributes and misspecifications of time and spatial dimensions can be classified within this well-known misspecifications and variables omission bias; second, time and spatial phenomena tend to be mechanisms which affect all measurable attributes (even, the physical characteristics of houses). As a result, if space-time dimensions are not well fixed, most statistical dependence related with these phenomena can arise on the model measurements, calling into question the key technical assumption of randomness and independence to stablish causal relations.

Causal relations are established theoretically and then, on empirical studies, data is collect to answer that specific structure and its statistical assumptions. As a result, the data collection task has an important role as a first effort to meet the basic conditions between model purposes and the chosen model estimation techniques.

The role of space and specifically the spatial nature of different processes guiding market operations origin multiple theoretical explanations and consequent model specifications. When the modelling focus is to obtain detailed descriptions on the structure of a population (a set of goods, or individuals), the analysis usually is performed after removing/fixing the dynamic (time related) intrinsically captured by a data sample. That sample is usually classified as a cross-section data set, where data is stored for a specific time interval which ensures both the statistical assumptions of randomness sampling and steady quasi equilibrium. However, in some cases, the time dependence structure is the focus as it can be explored to estimate and predict market outcomes: a) for a single variable, the data collection follows a time-series data scheme (use the value of a specific variable – for example, prices – at regular intervals); b) to investigate the dynamic (time) changes for a set of variables, a panel data scheme is followed.

As mentioned previously, houses are a special kind of good, distinguished in this sense by its spatial immobility. This spatial condition implies that more than a set of abstract spatial properties or spatial processes are, in some way, captured by market processes. As the definition of spatio-territoriality has been changing substantially across history, it is naturally more difficult to link both concepts – spatial phenomena as viewed by economics and econometrics, and the broadened definition behind the spatio-territorial nature of reality, with its unknown geometry and dimensionality.

Following this discussion on the building of data samples, it seems clear that the cross section scheme will be an option which provides the best conditions to analyse spatio-territoriality. Moreover, the literature on hedonic models applied to housing markets is rich on this type of data sample schemes and analysis framework:

- First, taking the characteristics of market operations described before, it is obvious that housing transactions represent only a small part of all housing units. It is obvious that long periods are needed to ensure a reasonable randomization of the sample in relation to the housing stock.
- Second, territorial phenomena as a whole are shaped by different territorial transformation time-lapse regimes that are very difficult to fix individually. In fact, the experience of statistical authorities leads, for example, to fix the census operations usually at a time interval of 10 years – it ensures a good equilibrium between the cost to collect territorial detailed data and the time related regimes of a great variety of spatio-territorial transformation processes.

## 3.2.2 IMPORTANT MODELLING ISSUES 1: THE SPATIAL STRUCTURES

### 3.2.3.1 General insights about spatial effects

Statistics have a long history as a tool to describe patterns of geographic data. As shown before, the origins of quantitative approaches in different social sciences (and, even, natural sciences, such as epidemiology) can be rooted to the seminal study of cholera spread in London, in the mid-19$^{th}$ century.

The statistical, combined with geographic, location analysis of infected individuals suggested to researchers that the cholera disease mechanism of spread were not explained by air transportation of microorganisms (the explanation advanced by scientific dominant theory at that time), but by the ingestion of contaminated water. That conjecture was sustained by the observation of the spatial structure of data: the spatial patterns of infected individuals suggested a close relation between them with the locations of drinking water wells.

This type of geographical analysis provided accurate explanations of different phenomena and led to the development of the subfield of spatial statistics. These quantitative efforts were concerned mostly with the development of measures of spatial dependence – the statistical relations between georeferenced objects in the geographic space. One of the most recognized results was presented as the Moran's I-statistic (1950), updated later by Getis & Ord (1992) – both can be considered important contribution to spatial analysis and are today extensively used.

Measure of statistical (spatial) dependence is useful, but not a sufficient effort to understand spatio-territoriality: in the late 60s, accompanying the increasing availability of microdata (and georeferenced data at small geographic scales), econometricians collected evidences that an increasing amount of data did not lead to an increasing efficiency of the standard econometric models. The explanation for this phenomenon was rapidly identified with the insights of spatial (geographic) statistics described above: as observations with an increasing spatial detail are considered, the average effect which hides spatial dependence is revealed. In other words, ignoring spatial properties of data was the possible source of bias and loss of efficiency.

Following that hypothesis, Paelinck & Klaassen (1979) claims for an approach which draws upon spatial theory to various branches of economy and geography. These efforts to explicitly incorporate spatial processes in econometrics are usually considered as the foundation of a new sub-field of applied economy: spatial econometrics.

With the objective of incorporating the theoretical insights to specifying spatial structures on econometrics analysis, the set of standard techniques – including the hedonic prices framework and its application to housing markets – were reformulated to expressly address the properties of georeferenced data. As is shown later, that efforts follows a view of spatio-territoriality as a system that produces two major phenomena, observed in the geographic space:

- Spatial heterogeneity – a set of geographic bounds where objects are grouped in order to ensure a certain level of homogeneity.
    - This is a phenomena which is widely recognized and is usually addressed following: 1) the *a priori* definition of the geographic extensions which enclose a set of market operations and its properties (as we see later, in line with the concept of spatial submarket), 2) the homogenous polygons of geographic space, tacitly assumed following administrative or planning units, assumed as proxies to homogenous units.

- Spatial dependence structure (or, more generally, an interaction structure) – grounded on the observable spatial autocorrelation between objects, as observed in different empirical applications of spatial statistics.
  - Empirical observations of spatial dependence phenomena in a myriad of empirical works suggest that spatial structures will have the following properties:
    - Asymmetry of relations – influences between objects on different locations have a structure which usually follows some type of hierarchy; for example, even in "gravitational" interaction potentials, not all places contributes with the same energy to the spatio - gravitational energy field; as a result the geographic structure of gravitational like interactions takes into account the effects of parameters such as the "mass", in addition to the geometrical ones – the distance.
    - Action at distance – the recognition of some phenomena with a specific outcome located at a specific position in a geographic space can be explained by causal factors located in other, non-contiguous locations (from a geographic space perspective). Given that the geometry and dimensionality of spatio-territoriality is unknown, the TFL on the geographic space should consider dependences at geographic distance.
    - Non-linearity – territoriality is a recognized complex phenomenon. Modelling efforts on predefined geographical places should assess the type of relations which better describe the structure of spatio-territoriality attributes.

Concerning econometric models of hedonic prices for housing, Fingleton (2003) identifies four major spatial properties and challenges:

- First, housing is a durable good in a fixed location of geographic space. Accordingly, houses within the same neighbourhood capture the value of shared amenities (the surrounding of houses). In addition, houses within a neighbourhood tend to have similar structural characteristics (because they are usually built at the same time), which reinforces the homogeneity of locational contexts.
- Second, different forms of spatial segmentation (spatial clusters) are easily observable, for example, on housing intrinsic characteristics (old or recent, etc) or population neighbourhood characteristics (household income, race, unemployment rate, etc.), but it is not easy to stablish a standard and general approach to house segmentation which incorporates all of these multiple dimensions.

- Third, some neighbourhood variables are difficult to quantify because they are unobservable or complex and techniques to measure them are not easily developed.
- Finally, there is the problem of selection and identification of the neighbourhood boundaries in the geographic space.

The following sections will be concerned specifically to review the usual strategies to surpass these challenges.

### 3.2.3.2 Spatial heterogeneity

*Roots: the concept of submarkets*

The spatial challenges related with the agglomeration structure, observable in housing markets, puts into question the reliability of a unique model equation, even in housing markets defined at the local scale. In fact, the idea of (spatial) submarkets in hedonic housing price models can be pointed to the works of Straszheim (1974) or Palm (1978).

Basu & Thibodeau (1998) resumed the concept of submarkets as a "geographic area where the prices per unit of housing quantity (defined using some index of housing characteristic) are constant". Examples of economic explanations pointed to justify the formation of submarkets are related with: (i) weak competition, resulting from the inelasticity of housing demand and supply across different locations (Schnare & Struyk, 1976); or (ii) a general demand spatial discontinuity pattern (Orford, 2000), where individuals reveal different preferences in different locations, while remaining within the same spatial submarket.

Adair, Berry, & McGreal (1996) argue that the failure to accommodate its existence will introduce bias and error into standard estimations. Goodman & Thibodeau (2007) extend that argument emphasizing that housing submarkets are important in house price modelling for several reasons. Firstly, the assigning of properties to housing submarkets is likely to increase the accuracy of the prediction of the statistical models. Secondly, identifying housing submarket boundaries within metropolitan areas increases the chance of researchers deriving better spatial and temporal variations in their models of prices. Thirdly, the accurate allocation of properties to submarkets improves the abilities of lenders and investors to price the risk related to the financing homeownership. Finally, the provision of submarket boundary information to housing consumers decreases their search costs

In order to identify the boundaries of submarkets, most criteria have been developed through data driven approaches or specific revealed preferences. For example, Goodman

& Thibodeau (1998) suggest the segmentation can be defined by the general groups of demand and/or supply factors, which then can be observed to assess if there are geographical patterns or not.

Maclennan & Tu (1996) and Watkins (2001), for example, suggest that demand/or supply factors can be captured analysing the geographical agglomeration patterns of the set of internal characteristics of housing available in the market, such as dwelling types, structural internal characteristics (numbers of bedroom and building style) and the neighbourhood characteristics.

Alternatively, some authors point out that housing markets may be spatially segmented by a set of social attributes, such as age, income, and race of market agents or households (M. Allen, Springer, & Waller, 1995; Gabriel & Wolch, 1984; Munro, 1986; Schnare & Struyk, 1976).

*Specifications strategies*

The specification of spatial heterogeneity can be classified into discrete heterogeneity and continuous heterogeneity. The former consists of a pre-specified set of spatially distinct units, or spatial regimes (Anselin, 1990), between which model coefficients and other parameters are allowed to vary. This type of specification will be easily performed assuming that spatial units can be defined *a priori* following specific methodologies concerned with the concepts described before – namely, the submarket. An alternative specification, to avoid the uncertainty of geographic boundaries, is grounded on statistical models which address a continuous heterogeneity specification. In this approach the regression coefficients are allowed to change over the geographic space in a continuous model specification which combines the regression model with a model for spatial regimes in its parameters. Two main approaches were suggested in the literature:

- Identifying a functional form, grounded both on data and on statistical theoretical assumptions –defining a type of spatial regimes (for example, the expansion method described by Casetti (1972) or recovering its statistical properties from data, assuming heterogeneity as a special case of random coefficient variation (see, for example, Gelfand, Kim, Sirmans, & Banerjee (2003) or the applications of functional data analysis, in Ramsay & Silverman (2007) or more specifically to this problem Bhattacharjee, Castro, Maiti, & Marques, (2016));
- Recovering the information hidden in the data sample through an explicit assumption of a local (geographic) structure – a procedure recognized as geographically weighted regression (GWR) (Fotheringham, Brunsdon, & Charlton, 2000).

*Other drivers behind spatial heterogeneity and submarkets*

Most attempts to understand the nature of spatio-territoriality described in chapter 2 can be viewed as focused on assuming a complexity of hidden processes which emerged as spatial (geographic space) agglomeration structures: from the spatial competitions and segregation of sociologist reasoning, to the environmental studies related with landscapes and the uniqueness of places, or the market oriented spatio-territorial growth of the urban structure (Muth, 1969), between others phenomena.

Marques (2012) presented a detailed review of the attempts between the use of econometric frameworks to analyse housing markets and the need to ensure that the multi-dimensionality of spatio-territoriality will be considered, eventually linked with the concept of submarkets. It suggests that three main alternatives are usually followed: i) the use of traditional administrative boundaries, ii) identification through criteria, defined *ex ante* considering several urban dimensions (demography, history, morphology, socio-economic), and iii) applying classification methods, including (spatial) cluster analysis, on a set of attributes collected to ensure the representation of the multiple possible explanations for the spatio-territorial agglomeration structures.

#### 3.2.3.3 Spatial dependence

Spatial dependence has been observed early on housing market studies (see for example Kain & Quigley, (1970) or Cubbin (1970)). In a broader sense it emerges by the degree to which objects at some location on the geographic space are similar in some way to other objects or activities located nearby – a feature observed on all georeferenced data (Can, 1990). The sources of observed spatial dependence can be pointed to four major explanations:

- Firstly, spatial dependency is a part of the observed agglomeration structures in the geographic space. Specifically, in housing development process, it is well known that a great number of housing development projects occur at the same time at specific locations, which leads to housing characteristics being highly correlated (S. C. Bourassa, Cantoni, & Hoesli, 2005; Gillen, Thibodeau, & Wachter, 2001).
- Secondly, the spatial dependence can arise from the geometric and dimensional framework used to measure it: the prevailed Euclidian geometrical reference frame to analyse spatial data – for example in econometrics – can result in modelling bias caused by a not well-fixed spatial heterogeneity. Moreover, as described in chapters 2 and 3 specifying a true spatial dependence structure eventually means to consider another geometrical and dimensional framework or an approach which minimizes that assumption.

- Thirdly, model misspecification or the precision of georeferentiation can result in spatial autocorrelation (Luc Anselin, 1988; Orford, 2000): missing important variables, an unsuitable functional form and the spatial aggregation of data samples are the major examples of this drawback which leads to spatial autocorrelation.
- Fourthly, spatial autocorrelation also arises from the valuation process, as the transaction price agreed between buyers and sellers will affect the price of the surrounding area (Bowen, Mikelbank, & Prestegaard, 2001), especially where a comparison method is used – which is very common in the residential real estate industry.

The first two points recall the previous discussion on spatial heterogeneity: the importance of the adopted geometric reference frame. Following the general interpretation of TFL, houses that are close in some geometric reference are likely to have similar attributes and prices; then a high spatial autocorrelation will be an intrinsic characteristic of that data. Recognizing this phenomena Pesaran, 2006 and Chudik, Pesaran, & Tosetti (2011) define it as strong spatial dependence and show it can be fixed through the expansion of standard models with spatial-specific regressors. In other words, the problems of spatial heterogeneity and strong spatial dependence are closely related and can be fixed through the same strategy: identification and correct specification of the spatio-territorial units. The authors show this approach leads to a consistent increase of the accuracy of hedonic models estimations and the eventual remaining spatial dependence will be significantly lower.

The specification challenge described above can be easily answered following the use of dummy variables (Wooldridge, 2008) as additional repressors. These variables can be used as simple regressors in two ways: a) a standard dummy binary variable, which describes if an observation will be inside or outside of a previously defined spatio-territorial unit– which should be interpreted as a proxy to fix the effects of all (hidden) characteristics of the agglomerative structure; or combining the information about the spatio-territorial unit and the value for the other attributes in the model– a slope dummy variables – which gives a more accurate model specification of heterogeneity. This was the framework adopted, for example, by Marques (2012), and will be followed in the empirical application.

These auxiliary spatial variables not only provide an integrated framework to specify the spatial heterogeneity (and submarkets) on the same equation model setting, as it will eventually mitigate the strong spatial dependence – usually verified within the homogenous spatial structures. Note, however, that it relies on the accuracy of spatio-territorial units' identification. This is an important challenge which surpasses traditional economic knowledge and which should follow insights from the other scientific disciplines in urban studies and the needs of territorial planning practices in particular. A solution will be presented later, through the case study.

To conclude, it is necessary to highlight the somewhat arbitrary use of spatial fixed effects is related to the extent that the different spatial mechanisms differ as a function of the designed geographic structure. Incorrect specification of geographic units can further produce correlations, resulting in model parameters estimates that can be biased or inconsistent.

### 3.2.3 IMPORTANT MODELLING ISSUES 2: CROSS SECTION DATA AND TIME EFFECTS

As described before, on reduced form models all market interaction complexity is hidden; market outcome (housing prices) are driven not only by the complex spatio-territorial processes behind it but, following the characteristics of that market, even in a cross-section setting (a period where as quasi steady market equilibrium is assumed), a bias caused by time dependence mechanisms can be observed.

Time changes in housing prices are easy to understand: since the price emerges at the specific moments the transaction occurs, it is obviously defined by the market conditions, which are much more dynamic than the rhythm of market operations. Even slight changes in housing price drivers will produce a time dependence path on housing prices as that market are closely related with a complex network of socio-economic and spatio-territorial mechanisms. It is the case of housing markets, where land availability or the rapid accessibility to financial credit solutions play an important role as a source of time dependence processes. In particular, housing transactions face important drawbacks on market operations, explained by the nature of the good, such as its durability, its value ratio to purchasers' wealth or its long-time of production.

Even the specific market operations are intrinsically time dependent: supply and demand takes a long time range on its interactions – as the evidence of high transaction costs literature suggests; moreover production and consumption processes are not instantaneous as production effectively takes a long time to answer demand needs (housing built process is intrinsically long).

As a result, the assumption of market equilibrium in small time units are usually not reliable. Fixed temporal effects on cross section data – which is supposed to be time independent – are strategies to remove the effects of that hidden time-variant phenomena that changes housing value within the period were cross section data was collected. As followed regarding the spatial dependence effects the work of Pesaran (2006) embraces this source of dependence in the same way: it assumes time dependence is another source of common correlated factors – the author use a panel data sample; it follows that the same approach can be used to fix time dependence: the specification of time related (T) auxiliary variables on the model.

As in spatial dependence example, time fixed effects strategy is usually operationalized as dummy (binary) variable (each one assigns, for each sample record, the specific time where it is observed). Some uncertainty comes from the need for an arbitrary (or theoretical grounded) definition of the fixed time interval (days, months, years) to consider, but this can be adapted to each empirical analysis.

## 3.2.4. ECONOMIC INTERPRETATIONS OF SPATIAL INTERACTIONS

### 3.2.4.1 Standard econometric models

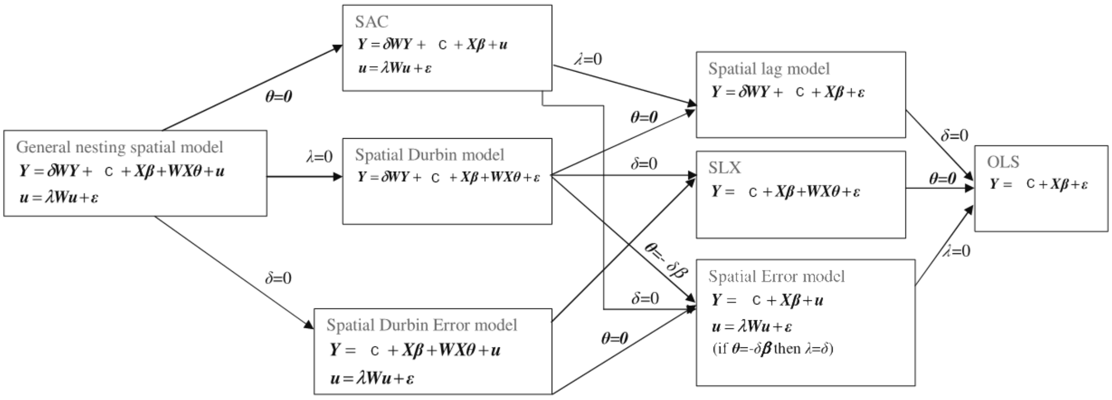
As was argued before, spatio-territoriality analysis will tend to be assumed as described by an unknown geometry (plus an unknown dimensionality). Since, in social sciences, it is only possible to make observations through the geographic space, both uncertainties mean that the type of spatial correlations structure is difficult to specify.

In econometrics the answer to this problem embraces an aprioristic assumption: the definition of geographic relations – following the insights of TFL and its interpretation through the geographic space. That assumption is used to specify a functional term, which defines the geometry (geographic) relations of spatial dependence[14] – W – described as "spatial weight matrix" in the context of dependence driven by geometrical geographic/ spatial specifications[15].

Holding for now the specification of W and assuming that all heterogeneity effects are fixed (plus that time dependence effects are fix too), an *a priori* strategy to specific spatial dependence follows different economic interpretations. It is possible to consider effects on all model components: on dependent, independent or even on the unobservable stochastic component of the econometrics model – Elhorst (2014) details all possibilities (see Figure 3.1).

[14] As pointed by Gilles Duranton et al. (2015) it "*allow the outcomes for an individual to be influenced by the choices, outcomes, and characteristics of other individuals who interact with the individual, and by other characteristics of the location of the in dividual. In practice, these spatial variables are typically constructed as linear combinations of the observations in neighboring locations, aggregated with a sequence of scalar spatial or group weights.*" (p. 124)

[15] Note that in general, dependence structures can be of different types and, even on spatial setting can be grounded on different topological frameworks – for example, a network approach or, as usual in spatial econometrics, a geographic approach. As described by Gilles Duranton et al. (2015) that dependence structure is "*summarized in a (spatial) weights matrix), constructed on the basis of the definition of reference groups— the set of individuals or firms that may impact other agents' outcomes.*" (p. 124)




source: Elhorst,(2014)

**Figure 3.1** The different spatial dependence models

Each kind of possibility described in previous figure arises from specific economic theoretical interpretations. Although there is some conceptual confusions and a lack of guidelines, the debate within spatial econometrics is focusing on three major types of interaction effects. Elhorst (2014) describes its mathematical - statistical model specification on a cross-section data framework[16], plus some examples about its economic interpretation. Following that, to an econometric model such as:

$$\boldsymbol{Y} = \boldsymbol{c} + \boldsymbol{\beta X} + \boldsymbol{\varepsilon} \quad \text{Equation 2}$$

The author highlights the following hypothesis to specify spatial interactions.

1. *Endogenous interaction effects among the dependent variable (Y)*

$$\boldsymbol{Y_i} = \boldsymbol{\delta W Y_j} + \boldsymbol{c} + \boldsymbol{\beta X_i} + \boldsymbol{\varepsilon} \quad \text{Equation 3}$$

This type of spatial dependence occurs when dependent variable of a particular territorial unit i depends on the dependent variable of other units (j) (and vice versa). As described by the author "this type of specification are typically considered as the formal specification for the equilibrium outcome of a spatial or social interaction process, in which the value of the dependent variable for one agent is jointly determined by that of neighbouring agents" (p. 7). It points for a situation where an equilibrium was reached and remains stable across the period where the observation is taken. On that equilibrium prevails a stable and quasi-instantaneous interchange between territorial units.

The author gives as an example a situation where a public policy in one territorial unit interacts with the public policy in a neighbouring units – through market mechanisms.

[16] It is assumed a standard mathematical – statistical specification (linear relations) which turns easy to understand how spatial dependence can be coupled within the model specification and the use of OLS estimation in particular.

2. *Exogenous interaction effects among the independent variables (X)*

$$\boldsymbol{Y_i = c + \beta X_i + \theta W X_j + \varepsilon}$$ Equation 4

This type of spatial dependence specification will describe effects on the dependent variable of a territorial unit i, that came, additionally, from the independent explanatory variables observable in neighbourhood territorial units j. Note that, in this case, if the number of independent explanatory variables is K, the number of exogenous interaction effects it also K, as it is challenging to consider that phenomena only affects specific independent variables.

On empirical works, this type of specification arises to describe situations where perfectly closed markets fail. In these cases, it is assumed that the raising of global market equilibrium is enabled by drivers which surpass the boundaries of a specific spatial (sub)market. As the author advances as an example for the case of empirical observations on the economic growth of regions: its variation is driven not only by the territorial unit's internal drivers (such as income level, saving rates, population growth, among others) but the neighbourhood levels of these drivers contribute to that growth – which usually is considered to enable the convergence process between submarket (regions) through the global market equilibrium.

3. *Exogenous interaction effects among the error terms (ε).*

$$Y_i = c + \beta X_i + \mu,$$

$$with \ldots$$

$$\boldsymbol{\mu = \lambda W u + \varepsilon}$$ Equation 5

Finally, a spatial dependence process can be assumed as a phenomenon that is not directly observed and measured through the usual market mechanisms and its outcomes. These kinds of situations will be helpful when the theoretical model, which drives the observation of spatial autocorrelations, is unknown. In these situations, it is useful to consider the specification problem as an omitted (or unidentified) variable challenge. Then, the specification of a spatial interaction structure through the stochastic model component is one possible strategy to fix unobserved shocks[17] which follow the spatial patterns defined on that model component design – the W.

[17] We can define economics shock as an event that produces a significant change within a market, despite occurring outside of it. Economic shocks are unpredictable and typically impact supply or demand throughout the market.

As a general notion, it is possible to define – following the standard OLS – each model component as:

- Y denotes an N x 1 vector consisting of one observation on the dependent variable for every subject (house) in the sample (i = 1,…,N);
- c is a constant term parameter that will be estimated;
- X denotes an N x K matrix of exogenous explanatory variables;
- b is an associated to X, K x 1 vector with unknown parameters that will be estimated,
- $\varepsilon = (\varepsilon_1, \ldots, \varepsilon_N)^T$ is the (transposed) vector of stochastic terms, where $\varepsilon_n$ should be assumed to be independently and identically distributed for all N, with zero mean and variance $\sigma^2$, in order to ensure one of the basic conditions for unbiased estimations
- The (spatial) interaction effects were added, such as:
- W Y denotes the endogenous interaction effects among the dependent variable;
- W X the exogenous interaction effects among the independent variables;
- W u the interaction effects among the disturbance term of the different units;

W is usually a nonnegative N x N matrix describing the spatial configuration or arrangement of the spatial units in the sample.

#### 3.2.4.2 Housing market prices and spatial econometrics specifications

Can (1992) is considered one of the pioneering researchers to apply spatial econometric strategies to housing hedonic price models. The author chooses the Spatial Lag model specification based on the assumption that the source of spatial dependence is the behaviour of real estate. As argued by the author: “a realtor will appraise a house given price history of houses in immediate vicinity in addition to other substantive properties (…) home owners initiate or forego improvements based on the anticipated return on their investment considering housing prices in the immediate area” (p. 458). On the other hand, the works of Meen (1996) and Meen (1999) suggest that the spatial analysis of price diffusion can be viewed as some kind of disturbance within a unique (national) but segmented housing market. This approach relies on the spatial error model as the specification strategy, sustained by the idea that price diffusions is guided by exogenous (to the housing market determinants) structures such as population movements (including migration) and spatial policy/management structures.

As the option seems contradictory but is essential to define the starting point of any spatial analysis, a short review about the debates concerned with spatial econometrics model specifications are presented in the following paragraphs.

As noted by Anselin (1999, 2002) the statistical inference following Spatial Lag or Spatial Error models are very few. In fact, the model specifications are concerned mostly with theoretical assumptions. The Spatial Lag model assumes that spatial interactions are explicitly revealed by market mechanisms: the (average) outcome (housing prices) for a territorial unit j is achieved through its relation with the outcome observed in all other territorial units. This interpretation restricts territorial interactions to some kind of invisible hand economic mechanism which governs the territorial system. On the other hand, the Spatial Error Model is concerned with an understanding of spatial dependence as a proxy to an underlying mechanism. In the literature, these kinds of phenomena are usually described as shocks – exogenous (to the market) mechanisms which may not be only economically driven, but a proxy between economic phenomena with social, environmental or, in general, territorial dimensions.

LeSage (2014) examines the specification challenges within a regional economic analysis and argues researchers should follow only two main specification alternatives: the Spatial Durbin Model (SDM), advocated for the assumption of a global spillovers (economic) mechanism or the Spatial Durbin Error Model (SDEM) advocated for the assumption of a local spillovers mechanism. The different type of spillovers are somewhat artificial. Indeed, the author suggests that the global spillover specification is usually chosen when the focus is mainly on economic behaviour, where economic adjustments are assumed following a well-known spatial structure: its effects are incorporated directly on market drivers. The local spillovers embrace economic relations which are imposed by a specific geographic structure as it "involve only neighbours, but not higher-order neighbours (…) [nothing] that neighbours need not be defined as only regions in close physical proximity"(p. 9). This implicitly assumes that the "local" is the proxy to an assumption of a spatial structure which is exogenous to market determinants: the definition of proximity follows the generic definition of the TFL of geography – assuming the geographic space is an exogenous container of economic phenomena. In conclusion, SDEM specification is oriented to an economic model highly sensible to the spatial structure behind it: it assumes economic phenomena take place in a spatio-territorial structure eventually defined by non-economic drivers – which justifies the inclusion of the spatial error model specification in addition to the spatial lag of independent variables.

Jointly, all of these insights support the choice of a Spatial Error model to investigate the nature of spatio-territoriality that overlaps standard econometric models. As Griffith and Paelinck (2011) argue, researchers interested in this theme should follow "the doggy-bag principle ("never throw away your leftovers"): "considering residuals as informative should transcend the usual practice of trying to neutralize them (…) meanwhile, pure spatial "randomness" also could be interpreted as spatial complexity, and might encourage continued analysis rather than finishing it by discussing “ideal” parameter properties” (p.215).

# 4. A NEW TOOL TO UNDERSTAND TERRITORIALITY

The previous chapter show the role of housing on territorial planning, and how its characteristics capture spatio-territorial features. This, combined with the consolidated econometrics and spatial econometrics framework, provides the justifications to choose hedonic housing price models (HHPM) as the analytical background to support the study of e-territorial structures at the local scale.

This chapter presents the econometric framework which supports the empirical study on the spatial interaction patterns of a local territorial system. It is organized as follows.

Section 4.1 shows the flexibility of spatial econometrics in other to perform spatial analysis, summarizing i) how the spatial structure of interactions embrace different notions of spatio-territoriality – specifically, how spatial assumptions result in specific modelling strategies; ii) the structural insights provided by previous empirical observations of regional housing market prices diffusion and its match with the concept of hierarchy that shapes the understanding of spatio-territoriality in planning.

Section 4.2 presents a new econometric estimation strategy to recover W from data. It is an extension of Arnab Bhattacharjee and Jensen-Butler (2013) combined with new estimation perspectives from Arnab Bhattacharjee (2017) and Basak, Bhattacharjee and Das (2018). As an empirical application within the debate on territoriality in urban studies and the need for a more versatile analysis of territorial planning practices, the methodology is an extension of insights to the ex-post inference of W grounded on minimal assumptions by Bhattacharjee et al. (2012) and Marques (2012).

## 4.1. TRANSLATING TERRITORIALITY THROUGH THE SPATIAL STRUCTURE W

The paper by Harris et al. (2011) – "In Search of ' W ' " – is a key example that highlights one of the major spatial econometricians concerns: the uncertainty on the choice and the role of the specification of a spatial structure – W. As seen in chapter 3, LeSage and Pace (2014) argue that the most important questions about W are not exclusively related with statistical and model estimation issues. The authors support the use of W as an exogenous model component, based on the knowledge of other spatial sciences, in order to help econometricians focus on the coherence of spatial spillovers, rather than only on the parametrization of W through the (statistical) goodness-of-fit criteria.

Following this line of reasoning, the next two sections show the endeavour to incorporate a notion of space in spatial econometric models, that consider only the hierarchical property of an explicitly unknown geometry and dimensionality for territoriality. First, the usual econometric modelling strategies for the description of spatial structures are presented; second, modelling guidelines are retrieved from a review of insights on the spatial diffusion of housing market prices – the "ripple effects" on UK housing market – and recent spatial econometrics efforts to incorporate a flexible notion of space.

### 4.1.1. GENERAL CONSIDERATIONS ABOUT W

Despite its usually low interest from a mathematical-econometric perspective, the specification of the geometrical properties of interactions are very relevant for researchers: it is the most important assumption to understand the spatio-territorial phenomena incorporated in that model.

Arnott (1987) identifies two problems related to the geographic nature of the problem: i) the underlying geographic processes are frequently non–stationary, including at smaller time periods / after time-space fixed effects, and have complex spatial structures of variety dependency; ii) data sets frequently contain relatively few observations, with only one realization of the process, complicated by acute boundary effects. The same author argues that within that challenges "the choice of W [which] is frequently arbitrary (…) specifying W incorrectly could lead to wrong conclusions" (p.1078). Also Bennett & Haining (1985) had assumed previously that "the proper specification of the linkage structure between sites (…) can be critical both in terms of process behaviour but also because all our inferences are conditional on the chosen structure (…) if the chosen structure is arbitrary it is not clear what interpretation can be placed on the results of statistical analysis" (p.2).

In fact, a close look on the nature of W arises an important question: what drives the specification of spatial interaction structure (W)? Usually W is defined "*a-priori*" which needs to match theoretically with the choice of spatio-territorial mechanism described previously. Moreover, for spatial econometricians, it is important to ensure two key technical properties:

- The first one is directly related to estimation issues. As is presented by Elhorst (2014), W requires some conditions for each real data generation process. In the context of cross-sectional analysis, W needs to be chosen in order to achieve stationary conditions of the parameters $\delta, \lambda$ – as highlighted in chapter 4. This is a necessary condition to ensure the consistency in all parameter estimators obtained through standard techniques.

- The second requisite is how to guarantee that W follows a standard geographic understanding of space to avoid the disputes from other scientific fields. As spatio-territorial units are usually defined as polygons on the 2D geographic space, the spatial structure are usually based on topological relations rather than on distance measures – they can be applied, but it usually some care to ensure the conditions described in the previous point.

Following the technical conditions and assuring that spatial and time heterogeneity is fixed, the usual W specifications follow two major topological (first order) geographic space relations, as described in Figure 4.1:

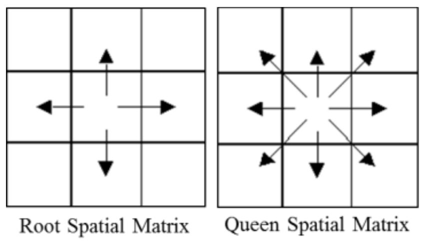



**Figure 4.1** Topological spatial relations (examples) used on standard W specifications

The choice of W specifications in econometrics is usually guided by model specification issues (to better describe expected theoretical spatial patters), implied estimation techniques and computation constrains (Luc Anselin, Florax, & Rey, 2004). Two solutions are usually implemented: first, in a practical and simply way, researchers impose restrictions on one or more parameters, to simplify the model and calculations; second, different specifications are theoretically assumed to ensure practitioners interests, preferences and beliefs about the notion of space implied in the economic phenomena.

Elhorst (2014) argues that, in economic studies, practitioners are usually focused on answering econometrics and statistical problems to ensure the consistency of model estimations. Moreover, as the author highlights, the choice of spatial econometric models with exogenous interaction effects – namely in the error terms (ε) – does not pose special econometric or statistical problems, whereby they are able to consider different notions of space. In its turn, as Plümper and Neumayer (2010) argue, practitioners have a lack of theoretical foundations to specify the spatial dependence structure, which leads Corrado and Fingleton (2012) to ask for more substantive theory in empirical spatial econometric modelling to guide W specifications. As argued before, this research can contribute to this challenge: as will be shown, the territorial analysis framework purposed here, is focused on the territorial information that can be provided following a data driven estimation strategy for this model parameter.

For econometricians the chosen option to deal with spatial dependence is guided by its predictive capacity or improvement on model estimation power. In fact, they do not have a primary interest in the role of the spatial configuration of territoriality. Even more, as shown before, the territorial interactions can be analysed using different assumptions that partially explain the mechanisms behind it.

Two main families of approaches are commonly followed, based on a mixture between tacit knowledge and quantitative methods, namely:

[1] Based on tacit knowledge and standard theoretical notion of space:

- Experts configuration of an *a priory* spatial dependence structure based on the knowledge of the patterns of spatio-territorial interactions – in general or in specific domains (transport system, real estate market, social relations, etc.)
- The standard assumption of dependence driven by geographic space properties concerned with relations between objects – the geometric (or topological) relations on geographic space.
    - As described before, given that spatio-territorial units are usually defined as polygons in a geographic space, it is easy to define the topological contiguities or even its geometrical (distance based) neighbourhood relations.

[2] Based on quantitative approaches and alternative notions of space:

- Exogenous estimation – where spatial linkages are assumed to be completely out of the market – that can be:
    - Indirect, based on measures of exogenous phenomena – for example, using other types of spatial and socio-economic distances, such as differences on technological skills, social mix;
    - Direct, by a deep analysis of housing market processes which are hidden in the model – for example, an analysis of housing market demand drivers or as a result of economic measures such as spatial substitutability.
- Endogenous estimation – where a deep analysis on housing market model outcomes is performed and includes:

- The statistical analysis of disturbance, founded on the assumption that exogenous effects (such as spatial transformation processes) or wrong modelling specification relies on a disturbance structure that can be modelled;
    - It can be applied to the different types of economic spatial spill-overs effects described above.

LeSage (2014) highlights an important issue: the notion that the explanatory variable effects and inferences are sensitive to use of a particular weight matrix "as perhaps the biggest myth about spatial regression models" (p.218). He stressed two important pitfalls: i) the flag of W specification as the culprit of model sensitiveness rather than the general model specification itself; ii) misinterpreted spatial regression estimates, mostly in the cases where spatial lags terms - $\delta W Y_j$ are considered. As demonstrated in detail by the authors: "most variants of W would likely share common elements and this often makes the results from the various W more similar than different. If the estimates and inferences are not all that sensitive to the specific weight matrix used, it is difficult to see how current economic theory can shed light on a specific "ideal" weight matrix" (p.247).

One important source of the myth behind the key role of W in model sensitiveness are empirical works focused on observation-level approaches and the inferences from that spatial regression models. LeSage et al. (2009) argue against these approaches in order to analyse the role of W: the standard regression model and its interpretation is to summarize measures of the direct, indirect and total average effects on the dependent variables – which is usually the point of econometricians, rather than a fine tune guided by goodness-of-fit strategies. In fact, the exogenous effects on disturbances are usually guided to guarantee a low signal-to-noise settings, instead of interest for exogenous (to the economic phenomena under study) mechanism of spatial dependence expected by economic theory.

The geometric considerations surpass the usual economic dimensions, which is pointed by LeSage et al. (2014) as an important advantage, which leads to questions about the notion of spatio-territoriality outside spatial econometrics modelling efforts. Even more, the most recent efforts to specify W following "economic variables may lead to some forms of interaction between W and X (see ) that are difficult to detect" (p.247). In fact, as argued here, the adoption of an unknown dimensionality and geometry of spatio-territoriality claims for a more flexible approach, with a focus on multidisciplinary debates on the notions of space and how to understand it.

### 4.1.2. INSIGHTS FROM THE SPATIAL DIFFUSION OF HOUSING PRICES

The decade of 1980, in the UK, was shaped by profound socio-economic changes, combined with the laissez-fare orientation towards public policy, that modified housing policy (Atkinson et al., 1994). Following that, the real estate market assumed a leading role as the housing provision mechanism.

Combining the central role of housing in quality of life and the indirect commodification of spatio-territoriality, enabled by housing market transactions, turned housing price modelling efforts into a focus of inquiry behind regional and urban studies – and territorial planning in particular. In fact, the motivations to analyse housing market prices were broaden as its role as a proxy to study the territorial transformations processes becomes clear.

Empirical studies conducted by Giussani & Hadjimatheou (1991), extended by Meen (1996,1999), put in evidence that the housing prices in the UK market follows a specific spatial diffusion pattern. These efforts pointed to the importance of spatial econometrics to understand spatio-territorial mechanisms, rather than its traditional focus on goodness-of-fit. Despite some modelling challenges, these pioneering empirical works remain as a consensual observation that the spatial mechanism of prices diffusion can be accurately described by an analogy with the idea of “ripple effect” (usually observed on water).

The work of Meen (1996) shows that the cross-sectional spatial dependence for a set of time intervals revealed a spatial price diffusion pattern which can be explained by an unknown and hidden spatio-territorial interaction mechanism connecting the territorial units. The author suggested three types of explanation hypotheses: (i) an adjustment by some kind of market mechanism which guarantees the price movements across the spatial units of the territorial system; (ii) the price variations due to changes on price determinants as an adaptation to the absorption of that transmitted shock; and (iii) structural differences in territorial units, exogenous to the market, such as some kind of spatial structure that surpass the market dynamics; that structures can be, for example, stablished by the governance or spatial management institutions and how they specify the paths of shock diffusion across the territorial system and its housing markets; Meen (1999) points some additional explanations, such as spatial structures, that emerges from patterns of migration movements.

One example, usually highlighted by the authors to explain the diffusion pattern, is the spatially differentiated institutional policy concerned with financial conditions of demand agents: those policies are taken to target a predefined (policy oriented) sequential absorption mechanism in order to re-establish a long-run territorial equilibrium. One example are specific – spatial oriented – programs through the “debt” gear (spatial discrimination of access conditions, incentives to specific targets, and others). Meen (1999) suggests it is the action of these designed (but hidden from the market) exogenous spatial interaction mechanisms that leads to the long-run price convergence expected by the spatial ripple effect in price diffusion.

Following this theoretical and empirical framework, three major questions remain open to reinforce the true logic of a ripple effect analogy. Namely:

a) Evidences on convergence to approve the analogy: the extent to which convergence is re-established over time (as implied by the ripple effect analogy). Peterson, Holly, & Gaudoin (2002) provide support for the ripple effect hypothesis via the use of cross-correlation analysis, reinforcing the evidence of a stable (time-invariant) spatial mechanism; Steven Cook (2005) shows an increasing support for an asymmetrical spatial pattern based on a time series co-integration analysis (between each spatial submarket time series) and Holmes (2007) provides increased support for the spatial-time convergence mechanism of a ripple effect based on the analysis of a panel data for a 30 year period.
b) The diffusion process and the implication of hierarchy: the degree to which some areas remain the leaders/the origin of that ripple effect – in other words, how the hierarchical order of that phenomena is stablished and how stable it is. A structural hypothesis of a stable center-periphery spatial structure were mainly supported following the works of Steven Cook & Holly (2000) and Cook & Thomas, (2003): assuming slightly different structural assumptions – namely the asymmetry spatial structure – the authors show empirical evidence on how that asymmetric structure leads to an identified and stable spatial convergence in the long run (Steven Cook, 2006).
c) The role of a geographic space framework: the empirical study carried out by Arnab Bhattacharjee et al. (2005) found significant spatial dependence in regionalized housing market of England and Wales, but its results suggest that a simple interpretation, in terms of (geographic space) contiguity and distance, is insufficient.

The literature of the spatial diffusion of shocks through the prices in housing markets highlights that the spatial interaction structures are important proxies for a more general understanding of territoriality. The analogy described above provides important clues on the observation of specific spatial patterns. The patterns usually surpass an explanation based on the behaviour of housing market price drivers, showing that other exogenous phenomena, such as the (spatial) configuration of institutions, migration or the role of transport networks are also important. From this it results that usual explanations based on geographic space properties are limited.

The empirical strategy followed under the ripple effects literature about housing prices diffusion is unusual in spatial socio-economic sciences. As argued in previous sections, most economic models (and spatial econometrics in particular) try to simplify the understanding of spatio-territoriality given a central role to the standard geographic space properties. Even the early literature of "ripple effects" on housing market prices did not totally disengage from that view: the methodologies to measure it are designed with the assumption of a geographic structure. However, as Arnab Bhattacharjee & Jensen-Butler (2005) show, if spatial assumptions are relaxed, the usual geographic space structure only partially explains the observed spatial patterns of a spatial diffusion of housing prices, suggesting that geographic space assumptions are strictly restricted.

# 4.2. A (NEW) ESTIMATION STRATEGY

## 4.2.1. ESTIMATING W UNDER MINIMAL ASSUMPTIONS

The clues about possible model drawbacks caused by pitfalls on W specification have been gaining attention in the spatial econometrics literature. The adoption of strategies concerned with the replacement of usual geometry understanding of spatial phenomena (guided by geographic space assertions) can be viewed as an implicit recognition of these difficulties. Examples, such as the use of economic attributes as a proxy to an unknown geometry and dimensionality of space ("distances" measured by prices differences, for example), or the adoption of topological relations, retrieved from the study of socio-economic networks analysis, are examples of attempts to enlighten spatial econometrics with other notions of space.

Unfortunately, the work of Harris et al. (2011) – "In Search of ' W '" – reveals the maintenance of a great level of discomfort with the use of these strategies. As noted by LeSage (2014): the increasing complexity behind W specification diverges the focus from regional economic analysis. The author points that complex W specification makes it more difficult to understand spatial economic mechanisms. Moreover, it diverges the focus from economic research to the questions of spatial analysis mostly when these questions are pure theoretical assumptions behind econometric models, difficult to explore within the field.

The standard geographic space specification of W is usual assumed by econometricians when the phenomena seems to be geographic in nature. However, joining i) the insights from the evolution of the notion of spatio-territoriality – namely, as described in chapters 2 and 3 and ii) the properties of housing to capture spatio-territorial properties it emerges that W specifications should follow a notion of spatio-territoriality that surpasses the standard, rationalist and reductionist, geographic 2/3-dimensional Euclidian space.

Empirical evidences from spatial ripple effects phenomena on the diffusion of housing prices shows that an exogenous hierarchical spatial interaction structure can be captured following a standard (spatial) econometrics approach. With that recognition in mind, it is obvious that the estimation of W from data under minimal assumptions is the promising framework to answer the challenges of an unknown geometry and dimensionality of space. This is one of the major assertions in this thesis and follows directly from similar claims on the framework developed by Arnab Bhattacharjee et al. (2013), its adaptation to the spatial analysis through the patterns of housing market prices (A. Bhattacharjee et al., 2012) and the discussion of that methodological approach to ensure useful insights on applied territorial planning practices (Marques, 2012) – which is one of the major justifications to assume them as a starting point.

Marques (2012) applied this empirical research program, at the local scale (the Portuguese municipalities of Aveiro-Ílhavo) ensuring that the notion of space in the spatial econometric analysis is free of strong assumptions regarding its dimensionality and geometry. That framework combines the advances to recover the spatial structure W from data, provided by Arnab Bhattacharjee et al. (2013), that relies only on the assumption of symmetry for the structure of spatial interaction mechanisms. It clearly found evidences of important non-standard spatial dependence patterns, when spatial weights are allowed to be relatively free and unrelated to traditional geographies based on distances and contiguity. As expected, this conclusion confronts the standard notion of space, from urban studies literature, with the changing empirical (territorial planning practices) knowledge – towards a complex geographic pattern of contemporary territoriality. However, those conclusions are mostly derived from an economic interpretation: the symmetric structure is compatible with the assumption of the regularization mechanism that results as an instantaneous market price equilibrium between demand and supply.

Despite the positive clues of that conclusion, the symmetric structure of relations, between different territorial units, can lead to counter intuitive observations. For example, how to explain that an effect of a central urban place (for example, a traditional CBD) on a rural territorial unit (on the margins of the territorial system boundaries) should be the same in both directions? Can the quasi-universal assertion, on urban studies, of a territorial system organized as a hierarchical structure be explained only by its power to stablish reciprocal dependence relations with other territorial units? These question suggest that the general understanding on the role of a territorial system cannot be generalized, as this type of structure implies an endogenous interpretation (to the market mechanism of instant housing price adjustments) rather than to a general (exogenous) structure which configures the medium-long term spatio-territorial system.

As argued in chapters 2 and 3, the conclusion towards the need to embrace an unknown geometry and unknown dimensionality, to understand and transform spatio-territoriality, claims for flexible modelling specifications. The field of (only partial identifiable) socio-economic-spatial forces generates spatio-territorial hierarchies which are only partially possible to measure and understand. For example, it is possible to define hierarchies distinguishing territorial units following its accessibility index (number of connections, for example), (real estate) territorial value, number of inhabitants or population density.

If hierarchy is an obvious property of the territorial system, the number of dimensions that contributes to define territorial hierarchies are unknown. The usual approach is to choose on specific set of dimensions following the specific analysis objectives. Unfortunate, in practice – and in territorial planning in particular – that restriction is sometimes opposite to the general multi-dimensional aspirations of the planning process: produce a "big picture" of spatio-territoriality. This is a central reason to embrace the efforts towards a new methodological approach that assumes explicitly the unknown dimensionality. Moreover, the debate on the notion of space and its geometry in particular, depends of that considerations about dimensionality as only remain two major research directions: the search to close the set of fundamental dimensions of spatio-territoriality or, the alternative – followed there – embrace the lack of knowledge to do it and try small steps, such as describe spatio-territoriality patterns with minimal geometric and dimensional assumptions.

In conclusion, if it can be argued that the symmetric assumption does not directly or explicitly constrains the assumption of unknown dimensionality and unknown geometry. Effectively, it is not fully appropriate to capture the recognized hierarchical nature of spatio-territorial phenomena. However, as will be described in the next section, the framework developed by Arnab Bhattacharjee and Jensen-Butler (2013) and applied by Marques (2012) can be easily adapted to assume a more informative spatio-territorial assumption: the substitution of the symmetry by the hierarchy in spatio-territorial relations.

### 4.2.2. THE ASYMMETRICAL ASSUMPTION

The ripple effects analogy, within the UK housing prices spatial diffusion literature, showed that a consistent estimation of the spatial auto-covariance matrix Σ can be obtained, from residuals of a standard econometric model (as showed by Meen, 1996, and Arnab Bhattacharjee & Jensen-Butler, 2005). That spatial statistical property inspired Arnab Bhattacharjee and Jensen-Butler (2013) to propose an estimation method where the spatial interaction matrix (W) is obtained, via an optimization algorithm, that identifies the optimal spatial structure derived from that spatial auto-covariance estimator under minimal assumption. As it is straight deduced, the assumption of symmetry[18] in spatial relations is an obvious estimation strategy as it matches both the statistical properties of covariance and usual implicit assumption of standard W geographic specifications.

In this work, that important insights and estimation framework will be partially followed here. As in Arnab Bhattacharjee and Jensen-Butler (2013) and the application developed by (A. Bhattacharjee et al., 2012) to the housing market (and Aveiro – Ílhavo territorial system in particular), here will be considered: i) the same spatial econometrics specification strategy – such as the spatial error model and its postulate that the (exogenous) spatial interaction structure is codified in the model residuals as it is presented as an exogenous information that frames housing market interactions; ii) the general estimation assumptions that ensures W can be recovered from the estimated spatial auto-

[18] One important insight for the symmetrical assumption is grounded on the statistical properties of the covariance matrix (symmetrical by definition), which makes easy the mathematical deduction of a estimation strategy.

covariance matrix under minimal structural (spatial) assumptions, and, finally, iii) the overall assumption that an unknown geometry and dimensionality of spatial phenomena can be described under an observation strategy that uses minimal structural (spatial) assumptions on geographic space that not relies on (strong) geometrical and dimensional conditions.

Following that, as in Bhattacharjee et al. (2012), a cross-section HHPM will be estimated in a first stage. Spatial heterogeneity is fixed through the *a priori* identification/specification of spatio-territorial units (homogenous to some degree/the known dimensions), plus time fixed effects within the time-interval – to ensures the assumption of a market in a quasi -equilibrium condition. That initial (first stage) global territorial system (Aveiro-Ílhavo) HHPM is specified as:

$$Ln(\boldsymbol{P}_{€/m^2}) = \boldsymbol{\alpha} + \boldsymbol{\beta H}(\boldsymbol{F},\boldsymbol{T},\boldsymbol{L}) + (\boldsymbol{\lambda W u}) + \boldsymbol{\varepsilon} \quad \text{Equation 6}$$

The model[19] includes:

- H is a set of housing attributes, classified as:
  - (F) are a set of physical house attributes for which a Factor Analysis is performed – to follow the cross-sectional model purposed by Andrews (2003) of physical structural attributes (which creates orthogonal variables, that better match standard econometric model assumptions).
  - (T) time (fixed effects)
  - (L) territorial attributes (such as, for example, dummy variables to fix known small neighbourhood effects within a spatial unit)
- $\varepsilon$ are the idiosyncratic disturbance model components with an implicit $\lambda Wu$ spatial dependence structure which will be recovered following a second stage analysis.

Performing estimations on the standard model, the residuals obtained will be used to identify the $(\boldsymbol{\lambda W u}) + \boldsymbol{\varepsilon}$ model component assuming the following general condition:

- W describes a spatio-territorial granular condition and the interactions, if they exist, lead to bounded row and column norms such as max $\{||W||_1, ||W||_\infty\} < 1$.
- For each observation (house) i, $\varepsilon_{it}$ holds the assumption of a linear stationary process with absolutely summable autocovariances – in other words, time effects should be fixed and, as N >> T (number of cross-sectional observations are superior to the time steps), that conditions guarantees that the dependence structure (if it exists) is driven by the spatial structure and not

[19] Following section 4.2.1, as standard in econometrics, to deal with potential non-linearity on the relation between market price – and housing attributes, it is assumed a semi-log specification transformation (take the logarithm of Y) in empirical application.

contaminated by time effects. Moreover, it is assumed that estimation conditions hold (Chudik et al., 2011; Pesaran, 2006).

- λ and W are not identified separately, then the inference on the spatial interaction structure will consider that λW ≈ W
- $\varepsilon$ are spatial homoscedastic – this is the crucial assumption 1 imposed by Arnab Bhattacharjee & Jensen-Butler (2013) that ensures spatial autocorrelation in the model is solely due to a spatial interaction structure, described by the spatial weights matrix, and its autoregression coefficient.

Note that the estimated spatial autocovariance on Arnab Bhattacharjee & Jensen-Butler (2013) is easily obtained through a panel data setting. However, in housing market, these data structures are rarely available: housing market transactions are relatively rare events[20] and become rarer as we move to smaller scales; moreover, to ensure as closely as possible, the conditions of market equilibrium, the time length consider to recover market data needs to be limited. That challenge was faced by Marques (2012) which presented a straight strategy to proceed with spatial auto-covariance estimation from a cross-section dataset: the residuals obtained on the global model estimation (the 1ª stage described before) will be rearranged in a data structure which guarantees a match of residuals between similar houses across each territorial unit. The procedure is the following:

i. Find, for each house i in the territorial unit j, a house that bears the closest correspondence in the vector of structural properties H(F) from the remaining set of houses N-i located in the remain territorial units Z-j. The match is performed by a greedy search on the minimum Euclidian distance between the vector of house attributes of house *i* with the vector of house attributes of each house in spatial unit of each other Z.
ii. The residual for each house i in territorial unit j is then organized (matched) with residuals of the matched houses in the remaining spatial units *j* as described in the following table.

**Table 4.1** Matrix of matched residuals

| $\hat{u}$ | $j$ | … | $Z$ |
|---|---|---|---|
| $i_j$ | $\widehat{u_{i_j}}$ | … | $\widehat{u_{i_Z}}$ |
| … | … | … | … |
| $N_Z$ | $\widehat{u_{n_j}}$ | … | $\widehat{u_{n_Z}}$ |

– $\hat{u}$ – are the set of residuals recovered from models for each spatial unit as $j \in \{1, \dots, Z\}$ and Z is the number of territorial units within the territorial system;

[20] A housing transaction oftentimes only occurs once in a household life time.

– $i_j$ – is a house i located on the spatial unit j and the total number of houses (for all spatial units) is N.
– $\widehat{u_{n_z}}$ – is the specific house model residual, recover in the hedonic price model j, for a house (in market j) similar to the house $n_Z$ which is locate in the spatial unit i (with $i \epsilon \{1, \dots, Z-1\}$.

iii. Finally, from the matched residuals matrix, the cross-spatial autovariance matrix is easily estimated with its cell as the average of paired covariance between each spatio-territorial unit.

Following the theoretical background presented in the chapters 2 and 3 of this thesis, it is possible to assume asymmetry as one of the structural recognized structural properties of spatio-territorial phenomena. Some of the most relevant theoretical evidences are provided by: i) the dominant hierarchical administrative organization of the political territories, ii) the centre- periphery spatial structure of (new) economic geography modelling efforts, iii) the recent socio-economic changes, towards an increasing divide of the new (digital) socio-economy into command and control territories and other territories – the mass consumption centers, the prevalent territorial underdeveloped clusters and others, iv) finally, the most important example within the approach followed here, the asymmetric spatial patterns of housing market price diffusion.

It is assumed that estimated spatial covariance codifies the information of $(\boldsymbol{\lambda W u}) + \varepsilon$ model components and the estimation strategies should be concerned with methodologies to recover $\boldsymbol{\lambda W u}$ under minimal assumption. At this point, the challenge is to define a new methodological approach that retrieves the asymmetric spatial structure W, from the estimated cross-spatial covariance matrix.

Arnab Bhattacharjee & Jensen-Butler's (2013) methodology retrieves an estimator of $\boldsymbol{\lambda W u}$ that ensures the properties expected for $\varepsilon$ on the usual regression framework: that approach can be viewed as a pure optimization problem where the focus is to obtain the estimation for $\varepsilon$ which ensures the statistical BLUE conditions of standard regression models. As a result, the minimal assumptions established in that approach follows firstly mathematical decision criteria and the recovered $\boldsymbol{\lambda W u}$ component is a “sub-product” of that approach – although Marques (2012) provides evidences of it as a valuable insight to spatial analysis.

To develop a more informative approach to choose the required minimal assumptions to separate $\boldsymbol{\lambda W u}$ from $\varepsilon$ it is possible to follow a stricter informative assumption about the effects of exogenous shocks: the hierarchical diffusion through the spatio-territorial system. On regression modelling approaches, the causal estimation guidelines matched that estimation problem and provides an easy to apply statistical framework (Gelman, 2011; Pearl, 2009).

### 4.2.2.1 Identifying the spatio-territorial hierarchy

The strict assumption of causal inference is to stablish a hypothesis for the "causal order" of effects. That step, in the context of spatio-territorial structure of interaction, is to establish the order that occurs in the spatio-territorial housing prices diffusion. Following that, the symmetrical assumption are replaced by an asymmetrical assumption and a new estimation framework needs to be developed.

That ordering implies that the spatial interaction component $\boldsymbol{\lambda W u} \approx \boldsymbol{W}$ that are retrieved from $(\boldsymbol{\lambda W u}) + \varepsilon$ spatial covariance estimation should present a very sparse structure, i.e. at least half of the *n(n-1)* elements need to be assumed as "zero". This is the general minimal assumption which translates the concept of asymmetric, hierarchical and causal, structure of relations on that matrix notation.

Relying on the researcher/expert's knowledge to *a priori* specify which elements of *W* should be zero is obviously problematic: it follows a similar approach to the standard theoretical a-priori W specification which not only has been criticized by the spatial econometrics literature, as it is not suitable for the idea of the minimal structural assumptions that ensures the view of an unknown spatio-territoriality dimensionality and geometry. Technically, the first challenge is how to identify the (potentially) non-zero elements on W from the data.

The answer can be found on the estimation insights presented by Arnab Bhattacharjee (2017) and Basak, Bhattacharjee, and Das (2018): under homoscedastic 1ª stage model disturbances, the cross-spatial covariance matrix can store an hidden structural hierarchical ordering which follows a structure described as a network acyclical graph for its causal relations. That acyclical graph – identifiable in different applications where hierarchical structures are dominant – is very similar with the assumption of an hierarchical spatio-territorial system and its representation as a triangular spatial weights matrix, on matrix notion.

The acyclical graph proposed by the above cited authors, describes the topological relations of causal effects for a ripple effects analogy within the diffusion of exogenous shocks through a hierarchical spatio-territorial system. Putting together all insights of this frameworks, it is possible to match the hierarchical relations through the statistical estimation quantities, namely: the top territorial unit, it is assumed as the origin of the ripple effect as it functions are restricted to transmit the (internal) processed exogenous shock (information) across the spatio-territorial units above – it results that its internal variance is minimal when compared with the other territorial units, which will receive its information. In other words, that territorial unit is the origin of information diffusion assuming that all model disturbances rely exclusively on the internal structure of diffusion behind the territorial system. It follows that the territorial unit in the second position will be easily identifiable: it only receives the information of the previous (top) unit, then, if that information disturbance is controlled (through the causal path) it is possible to identify it as the lowest remaining residuals variance spatio-territorial unit (conditional to the effects of previous spatio-territorial unit). That second territorial unit processes exogenous shocks and transmits them through the hierarchy, leading to the same identification strategy – the third position should be identified through minimal variance conditional to effects of previous spatial units on them, and so on. After all positions are identified from data, the estimated spatial diffusion hierarchical structure is recovered and there only remains the challenge to produce the estimations for these transmissions.

To illustrate and summarize the estimation principles proposed by Bhattacharjee (2017) and Basak, Bhattacharjee and Das (2018), see the following example:

- Considering a W matrix, where u, v and w are parameters of spatial interactions which describe the spatial hierarchic of information diffusion A -» B -» C, such as:

$$\mathbf{W} = \begin{matrix} . \\ \mathbf{A} \\ \mathbf{B} \\ \mathbf{C} \end{matrix} \begin{matrix} \begin{matrix} \mathbf{A} & \mathbf{B} & \mathbf{C} \end{matrix} \\ \begin{bmatrix} \mathbf{0} & \mathbf{0} & \mathbf{0} \\ \mathbf{u} & \mathbf{0} & \mathbf{0} \\ \mathbf{v} & \mathbf{w} & \mathbf{0} \end{bmatrix} \end{matrix} \qquad \text{Equation 7}$$

- Assuming $max\{|u|,|v|,|w|\} \ll 1$ to ensure estimation simplicity, $(I-W)^{-1}$ can be approximated up to first-order Taylor series expansion as $(I-W)^{-1} \approx (I+W)$. Then, under all these conditions spatial auto-covariance of price model disturbances can be defined as:

$$\boldsymbol{\Omega} \approx \boldsymbol{\sigma}^2 \begin{bmatrix} \mathbf{1} & \boldsymbol{u} & \boldsymbol{v} \\ \boldsymbol{u} & \mathbf{1}+\boldsymbol{u}^2 & \boldsymbol{uv}+\boldsymbol{w} \\ \boldsymbol{v} & \boldsymbol{uv}+\boldsymbol{w} & \mathbf{1}+\boldsymbol{v}^2\,\boldsymbol{w}^2 \end{bmatrix} \qquad \text{Equation 8}$$

- Analysing this covariance structure, note that the leading element *i* of the ordering can be identified as the element corresponding to the smallest variance. Similarly, the following order element can be identified by an analysis of a partial auto-covariance matrix: with *i* out of previous matrix, we obtain:

$$\boldsymbol{\Omega}^{-i} \approx \boldsymbol{\sigma}^2 \begin{bmatrix} \mathbf{1} & \boldsymbol{w} \\ \boldsymbol{w} & \mathbf{1}+\boldsymbol{w}^2 \end{bmatrix} \qquad \text{Equation 9}$$

- Hence, the second element of the order corresponds to the smallest partial variance. This sequential identification principle easily extends to a larger number of units. This suggests an easy recursive process which leads to the identification of the true hierarchical order behind the spatio-territorial system.

### 4.2.2.2 Estimating spatio-territorial interactions

Once the ordering of the territorial units is identified, the choice of zero elements to ensure the asymmetrical structure of W is easy: Kelejian and Prucha (1998) or Lee (2004) have shown that the elements of W are easily obtained following a two stage procedure:

the model residuals of a standard econometric model, obtained in the 1st stage are used to obtain estimations for W elements as the parameters of the 2nd stage, through a standard set of regression models between residuals.

The second stage OLS model procedure relies on the general challenge of estimating parameters for a structural triangular system (Lahiri & Schmidt, 1978). A system of sequential Z equations (one for each territorial unit j), will be specified with the residuals of territorial unit j in position p, as a dependent variable from the (matched) residuals on the territorial units of positions above on the hierarchy – each set of (matched) residuals for each territorial unit are the independent variables. The models are specified to follow each row of the W lower triangular structure defined by the territorial ordering/hierarchy and the recovered parameters of that models are $\widehat{w}$ estimators of the W matrix.

Thus, for each vector of $i$ residuals of the territorial unit $n_j$ at a specific row position $P$, it is estimated the following model:

$$\boldsymbol{\mu}_{p\,n_p} = \boldsymbol{\alpha} + \sum_{k=1}^{P-1} \boldsymbol{\beta}_{p\,k}\, \boldsymbol{\mu}_{p\,n_k} + \boldsymbol{\varepsilon} \qquad \text{Equation 10}$$

Where $\beta_{p\,k}$ estimated parameter is considered the estimator of the element of the spatial interaction matrix W ($W_{p\,k}$) – element that describes the relation between the spatial unit at the *p* position of the hierarchy set of P spatial units and the following k set of territorial units. The estimation follows the previously hierarchy identification, such as it is estimated a model for each $P \in \{1, \dots, Z\}$ and its following p on the hierarchy, for which is considered the cases $n_p \in \{1, \dots, N_p\}$ correspondents to each p, stored on the match residuals dataset.

# 5. APLICATIONS OF THE ANALYTICAL APPROACH

As was shown in previous chapters, the search for quantitative explanations in geography and economy has contributed to a progressive partial abandonment of Euclidean geometry as a geometric explanation tool. In the territorial planning context and, particularly, in the main argument of this work, it is considered that after many years of searching for the "geometry" and "dimensionality" that better explains spatio-territoriality, a slight change in this research endeavour is needed. The new framework proposed here is more concerned with improving the (indirect) observation of territoriality, returning to the classical role of geographic space and its Euclidian geometry as a tool to describe the behaviour of spatial objects, than its fundamental geometric properties.

The development of non-Euclidean geometries by mathematics (such as the elliptic and the hyperbolic geometries), has led to multiple applications on real world phenomena. One major example was the change of classical (Newtonian) physics' fundamental theories with modern theories proposed by Einstein, which resulted in the adoption of a new geometrical reference frame. Moreover, the need to explicitly consider the role of time in modern physics, implies a new understand of the dimensionality of real phenomena. In fact, other contemporary and complementary physical theories have been embracing different geometric and dimensional frameworks. Therefore, this chapter is concerned with two major applied exercises.

In section 5.1 a simulation exercise on an abstract territorial system with 9 territorial units is presented. It intends to show that it is possible to identify, through the framework presented in section 4.2 of the previous chapter, the geographic patterns of spatio-territoriality interactions, explicitly considering that the dimensionality and geometry are unknown, but where interactions follow a hierarchical structure. As shown by the empirical frameworks that supports this new estimation strategy, a general minimal condition is required for the identification of spatio-territorial interactions. Moreover, as argued in chapter 2 – and specifically in section 2.3 – the hierarchical organization is a well-documented property of spatio-territoriality that is usually identified even in the exercises with strong and restricted geometric and dimensional assumptions.

Section 5.2 applies the identification strategy to a real world case. Building on previous empirical efforts, the exercise will be focused on Aveiro-Ílhavo territorial system. As this area has been the focus of various research projects in recent years, this choice provides a set of tools (raw and processed data, identification of territorial units, theoretical insights) that are used in order to focus the present elements only on the estimation of Aveiro-Ilhavo units' geographic interaction patterns.

## 5.1. SPATIAL INTERACTIONS ON AN ABSTRACT TERRITORIAL SYSTEM: A SIMULATION STUDY

As suggested earlier, the main estimation strategy relies on two fundamental ideas: first of all, that a set of territorial units has been accurately identified in the geographical space; secondly, that the spatio-territoriality properties are part of the individual's knowledge about reality, which he can explicitly or implicitly show through its behaviour. The first idea is usual in scientific inquiry, as a research project needs to establish some frontiers on its objects of study. Moreover, defining spatial units is a common practice in territorial planning and multiple choices can be made with reasonable reliability and accuracy. The second idea has a more fundamental impact here: it is based on the idea that there is a link between human behaviour (base on the knowledge of reality) and market interactions as a mechanism where the human behaviour and its associated knowledge emerges. The estimation of this general (average) market behaviour of individuals is the major inquiry of econometrics, that combines a set of assumptions within different modelling strategies to estimate the drivers of some economic phenomena – usually, the price of a commodity. These models recover, implicitly and explicitly, the individual's preferences and general knowledge of the traded commodity.

Following this general overview, the standard econometric modelling strategies provide simple techniques to uncover the average individual's behaviour and, in this way, provide analysts with insights on that behaviour. Spatial econometrics in turn, recognises the major role of spatio-territoriality for individual's market behaviour and, specifically, on a model's reliability and accuracy to capture the economic drivers. The spatial interaction matrix W was proposed as a model component that makes it possible to fix the influence of the spatio-territorial relations between different territorial units, which are codified in the behaviour of market agents.

Despite the role of W for the estimation of economic drivers, the interest of economic modelling on a deep understanding of spatio-territorial properties is limited. However, this debate is very important for territorial planning, and the focus on modelling "residuals" is viewed as a major source of useful information about spatio-territoriality. Therefore, the method proposed previously relies on this general picture and tries to recover the codified information of spatio-territoriality through the residuals of a standard spatial econometrics estimation model.

Two major conceptual assumptions are followed to ensure it is possible to estimate the properties of the unknown matrix (W) that describes spatio-territoriality through geographic interactions parameters. First, it is assumed that W's structure is concerned with the internal interactions of an open territorial system that exposes all territorial units to a permanently hidden flow of spatial "information". That flow results in a spatial random model disturbance across territorial units plus a spatial interaction system that describes how that flow of exogenous shocks is captured and incorporated as endogenous information (that drives model estimations). In econometrics, these concepts, should lead to an assumption of residuals (spatial) homoscedasticity and implies that all (spatial) idiosyncrasies (properties) of territorial units are well-specified. Given this, the remaining disturbance has structural (spatial) properties that, if they exist, can be identified through minimal assumptions.

The major idea behind this section is to build a monte-Carlo simulation exercise. In this approach, the statistical random variables (Y, X) are previously obtained from well-known distributions and their properties. Following the model of eq. #, note that the dependent variable (Y) is built by the composition of the drivers (independent variables - X), its parameters and disturbances. X and $\varepsilon$ are generated through random number generation mechanism based on normal distributions with predefined parameters. Moreover, the parameters of the spatial interaction $W$ component are designed *a priori* to follow a design of spatio-territoriality interaction structure that is compatible with the minimal conditions required by the estimation framework described in chapter 4.

After the setup of all variables, parameters and predefined spatio-territorial design, the model estimation strategy is applied to this well-known dataset properties. The estimation strategy is performed through a predefined number of interactions (1000) where, in each interaction, the estimation strategy is reproduced using a slightly different data sample, obtained by a bootstrap sampling mechanism (stratified by each spatial unit). The statistical properties of the outcomes (parameters) are analysed in order to see the accuracy of these estimations.

The following sections show the choices that were made for the specification of the territorial system and its spatial interaction structure, plus specification for the standard model components.

## 5.2.1. SIMULATION PARAMETER SPECIFICATION

### The hierarchical order of territorial units in a territorial system

The major property of spatio-territoriality that will be evaluated on this simulation is the hierarchical structure of spatio-territoriality. Then, a becomes necessary to define the hierarchical ordering of an abstract interaction structure. It can be defined randomly. However, following this strategy, it is possible to choose an extremely complex structure that will be challenging to analyse and inaccurate with real world patterns. Therefore, a better strategy is to put some informative general insights, namely the idea that despite the assumption of unknown geometry and dimensionality, in general the empirical studies show that some geographic relations remains observable – as shown by Marques (2012). In fact, it is possible to restrict the specification design to a problem where the geographical hierarchical identification is uncertain because at each position of the hierarchy it is necessary to choose a unique direction on geographic space that is not provided by the dimensionality of the geographic space. Despite this, the geographical space shows the possible alternatives – as the topological relations for example. The problem is that a hierarchy implies to choose only one of those geographical neighbourhoods.

Remembering that, at an abstract level, this problem can be described as the challenge to show a hierarchical structure that is defined on a *n*-dimensional space constrained by the fact that observations can only be possible on the geographic space. Then, it is interesting that the conceptual idea can be viewed as analogue with an older mathematical challenge: how to describe an object, defined in a space of *n* dimensions, using an object defined by a smaller number of dimensions – the definition of space filling curves as described by (Bader, 2013). Giusep Peano presented one of the pioneering works that embrace this kind of challenged in mathematics. This mathematician tries to demonstrate that it is possible to connect all the points of a square unitary polygon, using a single line and, then, represent that polygon by a specific design of that curve that links all points contained in the polygon. Following an iterative and recursive approach (a strategy that breaks the traditional postulate deduction approach to define geometric properties), the Peano curve was found. In mathematics, this shows the possibility to transform an object of *n* dimension into an object of dimension n+1 dimensions – in this case, a curve that can be used to describe a unity square polygon. At the base of this idea was the search for a (mathematical) correspondence between (known) elements of different (known) dimensions.

The research described before has been developed in what nowadays is defined as the branch of fractal geometries in mathematics. These geometrical methods are based on the emergent properties of iterative sequential algorithmic rules to describe relations between simpler, lower dimensional objects, that result in higher dimensional complex objects. Moreover, a reverse analytical process is possible too (encountering fundamental, lower dimensional, objects that are the basis of a complex geometric object).

As a summary, the main contributions of Peano's works and the fractal geometry in general can be defined, with great simplification, by the idea that a set of geometrical phenomena can be obtained by recursive iterative processes. These ideas have general proximity with the object of inquiry here: it tries to analyse a phenomenon that is assumed to occur in an unknown (higher number of) dimension, through an observational tool assumed to be of a smaller dimensionality (the geographic space). Of course, the analogy is not perfect for various reasons that are not relevant to be analysed here. But note that the fractal geometry concepts have been explored in geographic problems. For example, it is well known the estimation problem of the length (perimeter) of boundaries for complex irregular geographic units. Other, more recent, applications are the efforts to understand the irregular shapes (and its dynamics) of urban forms – the shapes of pieces of land occupied with constructions.

For this work, it is interesting to highlight that the Peano curve, in particular, can provide an interesting insight to choose a hierarchical ordering of the territorial units in the abstract territorial system that we need to specify. Note that, to choose the specification of the sequential/hierarchical orders of spatio-territorial interactions in geographic space, the Peano curve provides the following specification (see figure X): it gives us an ordering, that follows a geographical linkage pattern, towards the connection of the centroids of 9 small squares that comprise the specification of territorial units in an abstract territorial system.

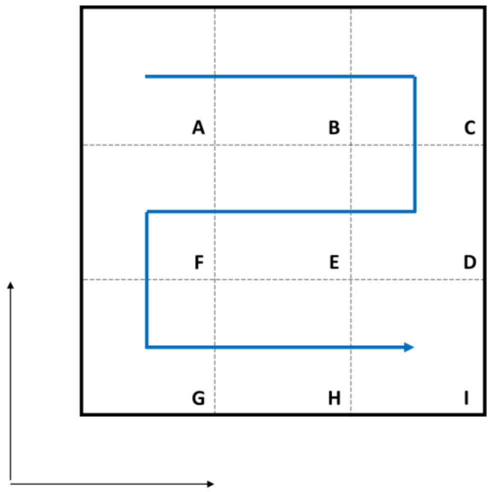



**Figure 5.1** The designed hierarchical ordering of spatial interaction through an abstract territorial system with 9 territorial units;

This designed can be viewed as inspired by the sequence of the first iteration Peano curve design

As noted before, the idea of an ordering should not be assumed as the unique fundamental property that defines interactions between territorial units. In fact, that property is very general, non-geometrical in nature, and corresponds only to a minimal assumption – such as the symmetry purposed by Arnab Bhattacharjee et al. (2013). In fact, the hierarchy establishes specific properties that can be associated with a set of territorial units – for example, that territorial units have a differentiate capacity to process and transmit exogenous shocks.

As shown in section 2.3, the different capacity of each territorial unit to process and transmit information has been pointed out in the literature. For example: models of polarized economic development; the properties that generate aggregation forces in new economic geography; the properties of command and control in the space of flows; and, even, the differentiated character of contemporary urban designs. Moreover, it is assumed, implicitly, in mostly territorial planning actions that transforming territoriality implies actions that can be viewed as attempts to transform territorial units process and transmit information capacities. The location of a transport interface, the rebuilding of urban shapes, the differentiated provision of housing, are only a small set of examples that can be pointed out as transformations prescribed by territorial planning that, more or less conscientious, results in changes of territorial units' functions – and, by this, its integration in the territorial system.

Following these general insights, it is possible to imagine that a local territorial system is a structure that is open to (crossed by) the field of forces – from physical forces to social forces. Through the specific properties (and specialized functions) of territorial units, a general coordination/collective structure manages the absorption of that information – the hierarchical property described before – but it should be expected that an efficient and reliable mechanism that guarantees the spatio-territoriality system function, should ensure multiple connections – even if conditioned by that hierarchical property. That additional structure specification will be defined in the following subsection.

## Guidelines on the spatio-territorial interaction parameters

Following the previous choice of a possible hierarchical order that connects all territorial units, it is necessary to design the geographic specification of the interaction parameters that describe a pattern of multiple links.

As said before, the idea is that the interaction mechanism in the unknown geometrical and dimensional space has a specific pattern, observable in the geographic space (representation of earth's surface). An easy specification strategy is to use only the sequential order defined before but, as is obvious, a unique territorial link does not seem reasonable with real world interactions. For example, the work of Marques (2012) shows that multiple connections of territorial units are obvious and many of them are not only geographic. Moreover, the standard literature on spatial econometrics in general assumes neighbourhood interactions are multiple.

Then, two major insights to specify W spatial interaction parameters are followed:

i. Try to mix traditional geographical interaction patterns, conditional to a previously defined order, with a more complex structure of interactions – for example, i) allowing interactions with units in lower positions of the hierarchy and ii) differentiating the strength of interactions following a structure that is not only driven by geographic space relations;
ii. Incorporate insights from the spatial interaction structure of ripple effects analogies in UK housing markets; the ideas is that interactions can assume different signals, what allows for different idiosyncrasies of territorial units to, both, respond to the exogenous disturbances and processing the endogenous interaction messages.

Applying these insights resulted in the specification of an interaction structure of territorial units that follows the Figure 5.1. Then, for each territorial unit at a given position of the hierarchy (marked in brown), the green tonalities show positive interactions, with the stronger coloured territorial units meaning stronger interactions. The orange tonalities are used to show the different negative interaction intensities. Given this, the abstract spatio-territorial interactions can be described by the following ideas:

- The interactions' strength closely follows standard geographic topological relations, but conditional to the geographical shape and disposal of the territorial units through the previously defined hierarchy.

  As shown in figure X, for example, the interaction of B is stronger to the territorial unit C. C is one of the first order neighbourhoods in the geographic topological configuration. Note that this configuration follows a standard choice of W from spatial econometric approaches, as described in section 4.1.1.
- The interactions signal is chosen such as, at each position the hierarchy, it positions the origin of the Cartesian reference frame on that location and the signals of interactions are defined as usual in that reference.

  An exception to this general rule are the interactions between the sets of three territorial units: C -» D and D -» I and F -» G. The idea is to give space for some additional complexity that reveals possible intermediate scales agglomeration structures. A situation that is common in territorial systems, such as the Urban – Suburban – Rural meso structures.
- The simulation is calibrated following insights on real data. As in Arnab Bhattacharjee et al. (2013), the parameters' specifications are based on the analysis of *per capita* state domestic product data, reported by Barro et al. (1992).

  Arnab Bhattacharjee et al. (2013) presents an exploratory analysis, through a panel data setting, which found evidence of heterogeneity in the rate of β-convergence across 9 US census regions – consistent with the presence of a spatial interaction structure which describes that convergence mechanism.

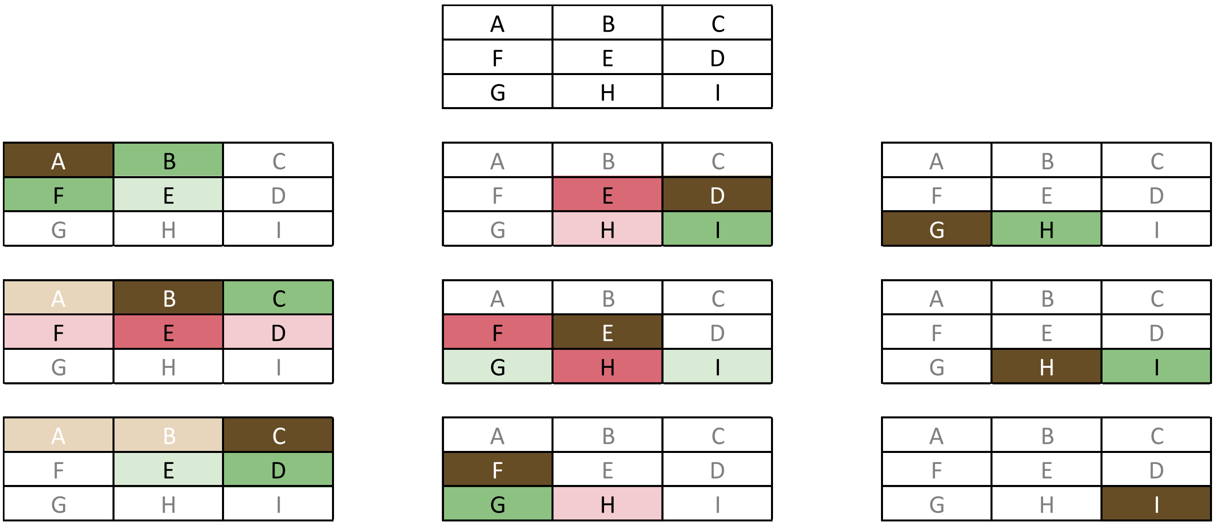



**Figure 5.2** The territorial hierarchical interaction structure: spatial patterns of a diffusion mechanism.

**Table 5.1** Designed spatial interaction matrix on the spatial error model specification

| $W_{\mu_j}$ | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C | 0 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D | 0 | -0.15 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 |
| E | 0.15 | -0.3 | 0.15 | -0.3 | 0 | 0 | 0 | 0 | 0 |
| F | 0.3 | -0.15 | 0 | 0 | -0.3 | 0 | 0 | 0 | 0 |
| G | 0 | 0 | 0 | 0 | 0.15 | 0.3 | 0 | 0 | 0 |
| H | 0 | 0 | 0 | -0.15 | -0.3 | -0.15 | 0.3 | 0 | 0 |
| I | 0 | 0 | 0 | 0.3 | 0.15 | 0 | 0 | 0.3 | 0 |

## General setup

In Arnab Bhattacharjee et al.'s (2013) study, the Monte-Carlo simulation assumes that the interaction mechanism can be well modelled by a symmetric spatial interaction structure, which reasonable follows a geographic first order contiguity. As described previously, here the simulation is calibrated with a spatial autocorrelation (interaction structure) through a spatial weights matrix which follows a hierarchical structure of interaction: a leading territorial unit diffuses information towards the territorial structure. Moreover, note that here the process will be assumed cross-sectional (instead of time dependent, as in the referenced work). The outcome of each territorial unit is generated according to the following Data Generation Process:

$$\boldsymbol{y_{ij}} = \boldsymbol{\alpha_i} + \boldsymbol{\beta_i x_{ij}} + \boldsymbol{\mu_{ij}} \qquad \text{Equation 11}$$

$$i = 1, \dots, 9\ (TUs)$$

$$j = 1, \dots, S\ (the\ j\ observations\ of\ each\ TUs\ sample\ with\ size\ S)$$

The vector of errors to each observation $\mu_j$ follows a spatial autoregressive process $\mu_j = W_{\mu_j} + \varepsilon_j$ . The independent variables describing the idiosyncratic characteristics of each of the 9 territorial units (fix heterogeneity) are generated following a normal distribution with specific territorial unit means, such that: $x_{ij} \sim N(\bar{x}_i\,,\ 0.15^2)$. The means, as well as the chosen values for the intercept and slope TUs specific are provided in Table 5.2 and, as said before, are inspired on (Barro & Sala-i-Martin, 1992).

Note that the chosen spatial weights matrix satisfies the spatial granularity condition and the idiosyncratic error $\varepsilon_{ij}$ is identical and independently distributed following a normal distribution, such that $N(0\ ,\ 3.0e^{-9})$.

The data generation process (DGP) generates territorial unit sample sizes of S=150 and S=500, in order to analyse the estimation properties of the proposed methodology through expected real world sample sizes.

**Table 5.2** Territorial Units model parameters

| Territorial units | $\alpha_i$ | $\beta_i$ | $\bar{x}_i$ |
|---|---|---|---|
| A | 0.047 | -0.011 | 2.25 |
| B | 0.047 | -0.011 | 2.25 |
| C | 0.073 | -0.024 | 2.00 |
| D | 0.073 | -0.024 | 2.00 |
| E | 0.047 | -0.011 | 2.00 |
| F | 0.073 | -0.024 | 2.25 |
| G | 0.073 | -0.024 | 2.00 |
| H | 0.047 | -0.011 | 2.25 |
| I | 0.047 | -0.011 | 2.25 |

## 5.1.2. SIMULATION RESULTS

### *Ordering*

After the development of the necessary code[21], the results obtained for identifying the ordering showed that: for the model with 500 samples for each territorial unit, this approach could correctly identify the (true) ordering in 8,4 percent of the bootstrap replications. Moreover, the difference between the first (true) most identified order and the second most identified order is more than 6 points (and 6% higher) – that is not a great difference but it makes the distinction in the results clear.

Comparing this result to the 150 samples simulation, it represents an improvement of 20% towards a better robustness of the proposed methodology. However, it is important to note that the 150 simulations have a weak performance: the orders most times established are less than 0,5% of all replications. Additionally, despite the true order remains the most chosen, the difference between that order and the next one is only 0,1 points, which is very low.

**Table 5.3** Hierarchical ordering identification frequencies, for a simulation with TU sample size equal to 150 (4 highest frequencies)

| Territorial Units samples size = 150 | | | | | |
|---|---|---|---|---|---|
| 3 Best | % | 6 Best | % | All Best | % |
| A B C | 5.7 | A B C D E F | 0.8 | A B C D E F G H I | 0.4 |
| A C B | 2.8 | B C D E A F | 0.6 | A B E F G H C D I | 0.3 |
| A B E | 2.7 | D A C B E F | 0.5 | B A C D F G E H I | 0.3 |
| B A C | 2.4 | A B C D F E | 0.4 | B C D E A F G H I | 0.3 |

**Table 5.4** Hierarchical ordering identification frequencies, for a simulation with TU sample size equal to 500 (4 highest frequencies)

| Territorial Units samples size = 500 | | | | | |
|---|---|---|---|---|---|
| 3 Best | % | 6 Best | % | All Best | % |
| A B C | 28.9 | A B C D E F | 11.4 | A B C D E F G H I | 8.4 |
| A B E | 4.2 | A B C D E H | 1.9 | A B C D E F G I H | 1.1 |
| B A C | 3.6 | A B C D E I | 1.5 | A B C D E G F H I | 1.1 |
| A B F | 3.2 | A B C E D F | 1.4 | B A C D E F G H I | 1.1 |

However, the analysis restricted to the identification of the order for the first three and the first six territorial units, shows a much better performance. Despite the 150

[21] All the analysis were developed under the R language code (version 2.5 and above) and using the RStudio as a development environment. https://www.r-project.org/

samples simulation is less robust than the 500 samples simulation, in both cases the territorial positions are very well identified. This can be explained by two phenomena: first, the transmission of the shocks through the system, does not only follow the direct link established from the ordering path – the territorial units interact with other geographic neighbours too – which increases the disturbances and makes them difficult to distinguish from the stochastic components; second, the balance between the magnitude of shock reception and shock emission (for lower level territorial units on the hierarchy) can be another source of difficulty when they do not match well the path of ordering – for example, in our example, on the 5ª position of the hierarchy, the interaction E -» F and E -» F is equal.

### *Interactions*

The 1000 Monte Carlo replications, of the estimated spatial weights matrix for 150 and 500 (spatial) cross-sectional samples, provide the basis to the non-parametric statistical inference. The results are summarized in table X, using the average bias and root mean square error (RMSE) as the key measures of estimate reliability.

Naturally, by methodological construction, the estimates obtained here are conditional to the estimated ordering from the previous estimation stage, i.e. if the estimated ordering is incorrect the estimated spatial weights will be heavily biased.

The statistical properties of this estimation process show a reasonable performance, despite the first stage identification efficiency. One more time, the sample size seems to be the most crucial condition for the results. Besides, the general regression coefficients (intercepts and slopes) are reasonable robust to sample size issues and potential misspecification of spatial interactions through the error modelling approach followed here.

Still, spatial weights are heavily affected: while the bias of the estimates is reasonable low, there is a higher downward on RMSE on the downward of the sample size. This naturally stems from the increasing estimations based on incorrectly identified orderings. As is showed in brackets, as sample size increases, the number of non-zero elements in true non-zero positions increases substantially, underlining the identification of ordering issues as the most important cause of spatial weights estimation efficiency.

The results show that care is required when applying these methods to real-world data as it seems mostly sensible to the robustness of the ordering identification.

**Table 5.5** Monte Carlo simulation results – Part 1

Inferences for model general parameters (α, β) and global W parameters.
Bias(RMSE) [% non zero] | Samples size of 150 and 500 records | 1000 bootstrap replications.

| Size of TU samples | α: spatial fixed effects | β: spatial hetero. slopes | W: upper triangle (36 zeroes) | W: lower triangle (36) |
|---|---|---|---|---|
| **150** | 7.74e-4 (0.0017) | -0.0757 (0.0064) | 0.0125 (0.0145) | -0.010 (0.0190) |
| **500** | 7.74e-4 (0.0017) | -7.57e-2 (0.0063) | 0.0080 (0.0082) | -0.0071 (0.018) |
| **150 ($\widehat{W}$ non-zero elements)** | – | – | – | 0.0026 (0.0095) [66.6%] |
| **500 ($\widehat{W}$ non-zero elements)** | – | – | – | 0.0011 (0.0031) [79.6%] |

**Table 5.6** Monte Carlo simulation results Part 2

Inference for W parameter estimation.
Bias(RMSE) [% non zero] | Samples size of 150 and 500 records | 1000 bootstrap replications.

| Size of TU samples | W: lower triangle, different values (0.30, 0.15, 0.00, -0.15, and -0.30; 36 entries) | | | | |
|---|---|---|---|---|---|
| | $W_{ij}$ = 0.3 (8) | $W_{ij}$ = 0.15 (4) | $W_{ij}$ = 0.0 (16) | $W_{ij}$ =-0.15 (4) | $W_{ij}$ =-0.3 (4) |
| **150** | -0.1056 (0.0377) | -0.0549 (0.0149) | 0.0221 (0.0165) | 0.0543 (0.0148) | 0.1093 (0.0385) |
| **500** | -0.0723 0.0235 | -0.0318 (0.0078) | 0.0144 (0.0095) | 0.0320 (0.0079) | 0.0725 (0.0240) |
| **150 ($\widehat{W}$ non-zero elements)** | 0.0060 (0.0082) [64.0%] | -0.0043 (0.0109) [65.0%] | – | 0.0037 (0.0108) [65.3%] | -0.0019 (0.0087) [63.4%] |
| **500 ($\widehat{W}$ non-zero elements)** | 8.63e-4 (0.0025) [76.0%] | 5.59e-4 0.0039 [79.0%] | – | 3.49e-6 (0.0040) [78.6%] | -0.0011 (0.0030) [75.9%] |

As general insights, it is possible to say that the results show that the sample sizes are a major driver of robustness, mostly to ensure a correct identification of the order. Moreover, the magnitude of the spatial weights seems to be relevant in itself: the higher the magnitude, the more difficult the identification process can be, which can be associated with high levels of variability across the interactions in the territorial system, making them more difficult to be distinguished from stochastic patterns.

Despite the reasonable results of the simulation exercise, it should be taken into account that real world applications are more challenging, as the two major elements that affect robustness tend to be present.

# 5.2. ANALYSIS OF THE AVEIRO-ÍLHAVO TERRITORIAL SYSTEM

## 5.2.1. DATA SOURCES, DATA FEATURES AND DATA PRE-PROCESSING

The database used for this empirical work is based on Janela Digital S.A. real estate listing service. CASA SAPO is one of the oldest real estate advertising service, accumulating, from 2000 to 2010, about 5 million records across Portugal. Web audience audits show that in that period it remained the leading housing listing website in Portugal.

It is obvious that CASA SAPO data is a unique opportunity to study housing market in that period, as it did not have any other source with that volume and variety of available data, in digital format. However, it is well shown in KDD and data mining literature (Fayyad et al., 1996; Feyyad, 1996; Liao et al., 2012; Tan et al., 2006), that this kind of data sources has a lot of scarce and potential erroneous information as its production is not driven by the research questions and usual scientific approaches to data collection. In fact, the field of data sciences that has develop in the last years has been focused on ways to process that data to match requisites, different from its original se. A housing market data sample, for research purposes, has been produced, for Aveiro-Ílhavo municipalities, with all KDD processing process and general statistical description of the data used provided by Batista (2010), Batista et al. (2017), Castro et al. (2013) and Marques (2012).

Knowledge Discovery in Database methodologies ensures, among others, a set of general purpose algorithms and statistical models to deal with the usual pitfalls to transform data to match requisites of other uses rather than the original one. As usual, some data characteristics are intrinsic to the context of production and remain in the final dataset. The CASA SAPO derived housing market data can be associated with the following characteristics that conditions the analysis of the outcomes:

- Available market price attributes are not effective transaction prices but listing/asking prices. In the used dataset, the last price inserted in the database is assumed as the transaction price, without any correction (some authors point for a real discount of 5-10% and possible variation through housing types, spatial locations and other variables);
- The 'date of exit' does not mean that the house was really sold, but that the property was removed from the database; however, this is used as the transaction date in this dataset;
- There are many duplicate records which should be caused by two distinct phenomena: i) houses that were traded with very similar attributes – e.g.: two flats, in the same building; ii) because there is no legal requirements for realtors exclusivity, sellers can make selling deals with various realtors, resulting in duplicate listings for the same house; in the dataset duplicates are allowed;

- Non-exclusivity between brokers in the selling process leads to significant levels of missing information about houses (e.g.: the exact location of each house); in order to make the dataset usable for spatial analysis, the final dataset used here did not have locational missing data as all records without any information about it are excluded.

Despite the (clean) dataset encompassing data records from 2001, only the data from the period between 2005 to 2010 is used for this modelling effort. This option is justified by the choice of a cross section analytical frame – as is argued before, the scheme that best matches the spatio-territoriality analysis focus and the long cycles of housing stock market transactions. Moreover, a period of 5 years seems to best ensure a steady equilibrium state on the housing market dynamics, necessary to guarantee time effects are reasonable fixed[22]. Moreover, this specific period is compatible with the census operations designs. Performed at 10 years intervals, the last two census were made in 2001 and 2011, then the 2005 – 2010 period is more compatible with the integration of census data. This is particularly important to fix spatio-territorial heterogeneity, as the availability of 2011 census data is crucial to include the socio-economic and housing stock dimensions in the spatial features that should be used to define the set of (homogenous) territorial units.

Following the previous considerations, the housing market dataset for the Aveiro-Ílhavo territorial system has 7288 records, from 2005 to 2010. The available basic georeferenced information are the 50 neighbourhoods produced by the *Drivers of housing demand* research project (Castro et al., 2013).

## Data features

As shown before, housing market value is assumed as the dependent variable (Y) on the econometric model of housing prices. To ensures the correct specification and improve the accuracy of the model, the following set of additional specifications are assumed:

- As the model uses a proxy variable for housing market prices, an additional independent variable is included, the (logarithm of) number of days "on market"/number of days that listing was active on the platform;
- As argued previously, the model specification on a cross-section setting should fix possible time effects related with the time desynchronization of data collection. Then, a set of time (yearly) dummy variable to control for aggregate cyclical and political time-related factors (time fixed effects) is included;

[22] An overview of major macroeconomic drivers on Portuguese housing market prices for this time period can be obtained on (Lourenço & Rodrigues, 2014) (Lourenço & Rodrigues, 2017)

- Even more, as the study comprises the modelling of a territorial system's housing market, the presence of spatial heterogeneity effects are very relevant. Moreover, as argued before, to study spatial interactions it is a *sin quoi non* condition to ensure that territorial units are previously defined. Here, it is additionally assumed that the identification of broad territorial units absorbs all sources of spatial heterogeneity, including market spatial segmentations (spatial submarkets). Therefore, fix spatial effects are ensured through a set of dummy variables for each territorial unit and, furthermore, as a set of slope dummy variables, which describe the expected spatial heterogeneity concerned with housing size[23].

The dataset provides a set of 8 structural variables related with the size of housing, the type of housing and is level of preservation– all of them are binary variables, except for the size. Then (1) to ensure the requisite of reasonable levels of independence between variables (to avoid multicollinariety and better accuracy of parameter estimations as described by Wooldridge, 2008), (2) to match the spatial econometric analytical insights purposed by Pesaran (2006) (which argues in favour of the factor model to better produce spatial inferences on unobserved common factors) and (3) to produce summarized information that ensures efficiency on data aggregation, the structural housing attributes are transformed, through a principal component analysis with orthogonal varimax rotation, on a set of 5 new variables – as shown in Table 5.7 and Table 5.8.

**Table 5.7** Total Variance Explained from Factor Analysis for structural house attributes (Aveiro – Ilhavo housing market)

| Component | Initial Eigenvalues | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|
| | Total | % of Var | Cum. % | Total | % of Var | Cum. % |
| 1 | 2,701 | 33,769 | 33,769 | 2,674 | 33,420 | 33,420 |
| 2 | 1,392 | 17,403 | 51,171 | 1,346 | 16,824 | 50,244 |
| 3 | 1,293 | 16,164 | 67,335 | 1,308 | 16,353 | 66,597 |
| 4 | 1,248 | 15,605 | 82,940 | 1,302 | 16,273 | 82,870 |
| 5 | 1,037 | 12,966 | 95,906 | 1,043 | 13,036 | 95,906 |
| 6 | ,328 | 4,094 | 100,000 | | | |
| 7 | 5,9E-14 | 7,3E-13 | 100,000 | | | |
| 8 | -3,9E-20 | -4,9E-19 | 100,000 | | | |

Extraction Method: Principal Component Analysis.

[23] The option to add additional spatial slope dummy variables for area / dimension of houses is sustained by previous works on this data set, such as (Castro, Marques, & Batista, 2011) (Arnab Bhattacharjee et al., 2016) it is the only structural attribute of houses that have a consistent evidence of price heterogeneity across space: house dimension is directly related with land plot and the urban economic research fields have been demonstrated the direct relation between high land price and high land occupation densities. Furthermore, the remaining and possible spatial heterogeneity can be incorporated on the dummy zone.

**Table 5.8** Rotated Component Matrix from Factor Analysis for structural house attributes (Aveiro – Ilhavo housing market)

| | Component | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Flat | -,975 | | | | |
| Single family dwelling | ,975 | | | | |
| Area | ,876 | | | | |
| Preservation - In construction/Projected | | ,959 | | | |
| Preservation - New | | -,616 | -,546 | -,540 | |
| Preservation - Used, to 10 years old | | | ,975 | | |
| Preservation - Used, 10 to 25 years old | | | | ,974 | |
| Preservation - Used, more than 25 years old | | | | | ,998 |

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Rotation converged in 11 iterations.

## 5.2.2. AVEIRO-ILHAVO: TERRITORIAL UNITS, GEOGRAPHIC BOUNDARIES AND DATA INSIGHTS

### Overview

The study area includes two municipalities, Aveiro and Ílhavo, which can be considered as a single territorial system as argued by Carvalho (2013). The municipality of Aveiro has a total area of 200 km² and a total population of 78 454; the municipality of Ílhavo has an area of 75km$^2$ and 38 317 inhabitants (data from 2011 Census). If the area of the lagoon, located inside the geographic boundaries of that territories, is removed, the population density is around 600 inhabitants per km$^2$ – a typical value for a Portuguese medium-sizec territorial system at the municipality scale.

Aveiro-Ílhavo is located 50 km from Porto, considered the second most relevant Portuguese municipality and the central pole of the second most populated Portuguese region – the metropolitan area of Porto (MAP). Note that Aveiro rail station is the final stop on the southern rail axis of the Porto region suburban transport system, which suggests that Porto is an important attraction pole for Aveiro's inhabitants and integrates Aveiro-Ílhavo territorial system as the frontier of that wider region – despite in administrative terms MAP not including Aveiro-Ílhavo, which, in fact, are the head of Baixo Vouga region – a third / regional level of administration organization and statistical divisions.

Aveiro-Ílhavo is crossed by major national transport infrastructures, namely the two most important national highways, the major national railroad (all national train routes, through this rail axis, have a stop in Aveiro rail station) and the fourth major Seaport, which gives to this territorial system a direct integration in the national mobility system.

Furthermore, this context makes it easy to assume Aveiro-Ílhavo as a regional attraction pole, which effects its close territorial neighbours.

## Territorial units

*What territorial units to consider?*

The territorial units (TU) here considered are obtained from the aggregation of the set of 50 basic territorial units (small neighbourhoods) and its geographic delimitations, developed by the *Drivers of housing demand research project* (see Figure 5.6) (Castro et al., 2013). This set of basic territorial units has a level of geographic desegregation that:

i) Makes it impossible to ensure the full set of modelling requisites to apply the proposed framework; as shown in the previous section (simulation study), the number of cases available in the sample for each territorial unit is crucial for a correct identification and inference performance; for samples with 150 records, identification can be problematic;

ii) Can have an undesirable territoriality complexity given the unknown dimensionality and geometry of the phenomena; a large number of territorial units that are observable plus a restricted set of socio-economic variables, introduce a level of uncertainty to this methodological framework that surpasses its general purpose;

iii) Violates the usual compromise between detail and generalization, adopted by territorial planning and public administration practices; administrative spatial divisions (as we can see in Figure 5.**3**and Figure 5.**4**) or even the territorial planning zoning plan, usually define a reduced number of units.

To define the desired number of territorial units, two major criteria are considered, namely:

i. A qualitative analysis of the spatial units proposed by different studies;
ii. The usual geographic administrative units considered – namely, the number and delimitation of parishes (old and new) or additional divisions (statistical units and statistical morpho-typological classifications).

Following these criteria it is decided to establish a target of 12 territorial units, combining the multiple requisites of modelling and the balance with constrains or interpretation complexity.

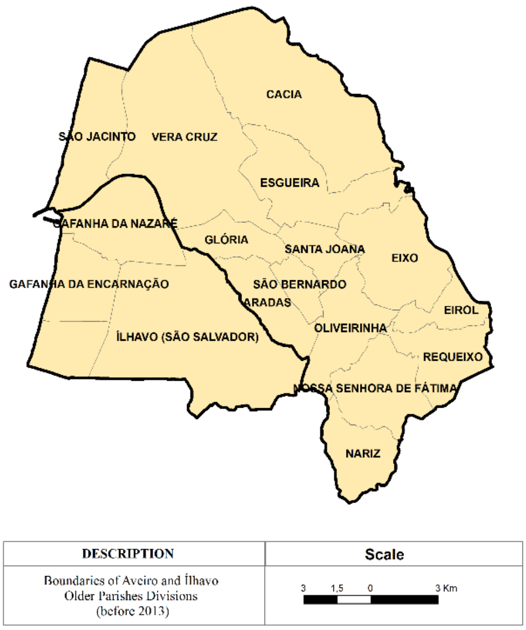



**Figure 5.3** Older [18] administrative boundaries (parishes)

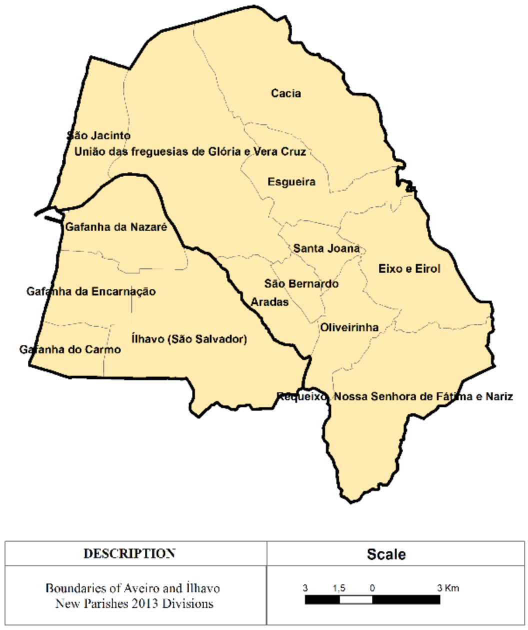



**Figure 5.4** Newly [14] administrative boundaries (parishes)

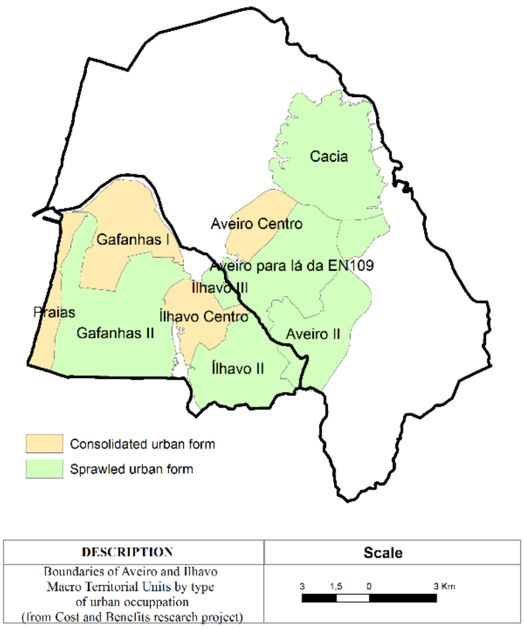



**Figure 5.5** (Macro) Territorial units based on urban form dimensions

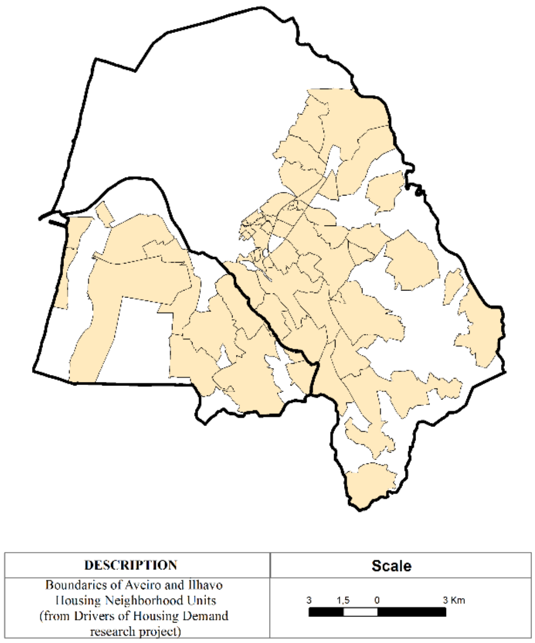



**Figure 5.6** Basic Territorial Units of Aveiro – Ílhavo (Small Neighborhoods)

*How to obtain a predefined set of territorial units?*

One the number of territorial units is defined, the challenge is to identify their geographical delimitations. As argued before, this is a basic condition to perform the analysis of spatio-territoriality interaction structures.

Choosing the number of territorial units can, to some extent, be an arbitrarily process, as all analysis are conditioned, by definition, to that scale of analysis. However, the is not true for identifying its geographic boundaries, as the different alternatives have important geometrical and statistical implications. Territoriality is built through a partially known set of mechanisms which, as argued before, is known as n-dimensional and only partially observed (as geographic units, that project the boundaries of territorial units on the geographic space)[24].

As is usual in spatial analysis, the construction of geographic units is guided by a mix of statistical analysis of available data – to summarize the maximum information about the latent dimensionality of territoriality – with additional geographic constrains – such as the criterium that aggregation should follow, sequential, topological relations. Moreover, a combination of previous approaches with the spatial submarkets of housing market prices) framework, as defined by Adair et al. (1996), Bourassa et al. (1999) and Watkins (2001). Finally, it is assumed that a geographic division should contain a minimum of 150 sampling data records, associated with each final geographic unit.

Following this general orientation the identification of spatial units (geographic boundaries of territorial units) goes as follow:

*Stage 1 – Recover latent dimensions of territoriality*

Assuming as a starting point the basic 50 (georeferenced) neighbourhoods (figure X), a dataset is collected with i) census data, with socio-economic features for individuals and families, housing features and buildings features; ii) land cover classification data provided by the urban atlas program of the European Environment Agency[25]. The variables available in this dataset, when available at lower geographic levels (desegregated) are summarized in order to define its (average) values at the geographic delimitations of the 50 (georeferenced) basic territorial units. Moreover, as the number of collected variables is very high (more than 50) first reduced dimensionality technique is applied. Following a

[24] Despite, (statistical) measured attributes are usually considered the dimensions of a phenomena, in fact it more correct to consider it as proxies to that unknown dimensionality. In statistical analysis, that difference between the collection of statistical variables and latent dimensions that can be obtained from them are mostly considered through Principal Component Analysis (geometric interpretation) or Factor Analysis (correlational interpretation).

[25] https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-urban-atlas

factor analysis, 12 latent factors (major dimensions) are obtained, reducing the complexity of the original information.

In other to consider the spatial submarket dimensions of territoriality, the CASA SAPO housing market dataset is processed to summarize market features at the geographical scale of the 50 basic geographic units. To do it, the following processes are applied:

1. First, a standard hedonic price model (global) is specified to ensure estimation of housing features hedonic values, in each basic territorial unit, plus the estimation of hedonic value of each basic spatial unit (added as additional independent, dummy, spatial variables). In other words, a model with 5 x 49 (the previous latent factors, described in **Table 5.7** and **Table 5.8**, averaged by each one of the 50 basic territorial units) + 49 covariates is estimated[26]. Secondly, summary statistics of houses, by each basic geographic unit are obtained (averages of latent factors described before).

   These analysis produces a new set of variables, describing each one of the 50 basic territorial units housing market features, namely: 5 variables to describe the housing in market features (averages) and 6 variables that point to the specific basic spatial units hedonic prices.
2. As in previous datasets, the set of 11 variables that describes the basic territorial units are reanalysed through a factor analysis model in order to obtain the 4 latent factors (reduced dimensions) that describe the spatial market information of the basic territorial units.

At the end of this phase, two datasets of spatio-territorial information are obtained, with a set of latent factors (12 + 4) that comprise the indirect observable dimensions that describe the 50 basic territorial units through the geographic space.

It is important to remember that dimensionality and geometry of territoriality is assumed to be unknown. Therefore, the observable information (described as latent dimensions) should be interpretable as a partial observation of the full phenomena. Moreover, these partial dimensions are conditional to a geographic space itself and the defined discontinuities (geographic units) – that have a high level of uncertainty caused by that unknown dimensionality and geometry.

*Stage 2 – Aggregation algorithm*

From the previous dataset, the phase 2 is concerned with the aggregation that identifies the best geographical boundaries to ensure the desired 12 (final) territorial units.

[26] In order to ensure the required degrees of freedom of standard (OLS) regression models, only 49 of 50 basic territorial units can be specified on the estimation process. The results are reported in relative terms to that leave-out basic territorial units

The aggregation algorithm is based on standard clustering analyses, such as an aggregation performed through the analysis of a distance matrix between the set of variables – in this case, the 16 latent factors obtained previously. However, here, the traditional cluster analysis algorithm (in this case the Ward's method with Euclidian distance was used) are reprogramed in order to match two additional constrains:

i) at each iteration, aggregation occurs only through a set of first order geographic queen topological neighbourhoods;
ii) the aggregation is performed (in each iteration) sequentially, starting with the clusters that are far away from the minimal requisite of territorial units' records (150).

*Stage 3 – Final solution and summarised information*

The final solution is obtained when all initial 50 basic territorial units have been aggregated through 12 territorial units (TU) and none of that final set have a lower number of records than 150. The result is presented in the Figure 5.7.

At this stage, to understand the most important drivers (homogeneity features) of each TU, the set of 16 latent factor from the initial data can be summarized (averaged) to describe each territorial unit. However, since the geographic aggregation process reduced significantly the geographic richness of that patterns, it will be desirable to reduce the information needed to describe the final TU itself. To do it, a new layer of data reduction analysis is performed taken the initial basic territorial units and its previous latent factors (16). Following that, (4) latent factors are obtained and are summarized (averages) - as showed in Table 5.9. The definition of its names – Urban Fabric Density, the (Population) Qualifications, the (Population) Demographic structure and the Housing submarket features – are only adopted for interpretation purposes.

Finally, an additional feature for better interpretation purposes is defined: a macro-structure that follows insights of the "Classification of urban areas" defined by the Portuguese statistical authority[27], with small adaptations to the case study: the changes on these classes' names and considering "beaches" as an additional category.

[27] https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_cont_inst&INST=6251013&xlang=en

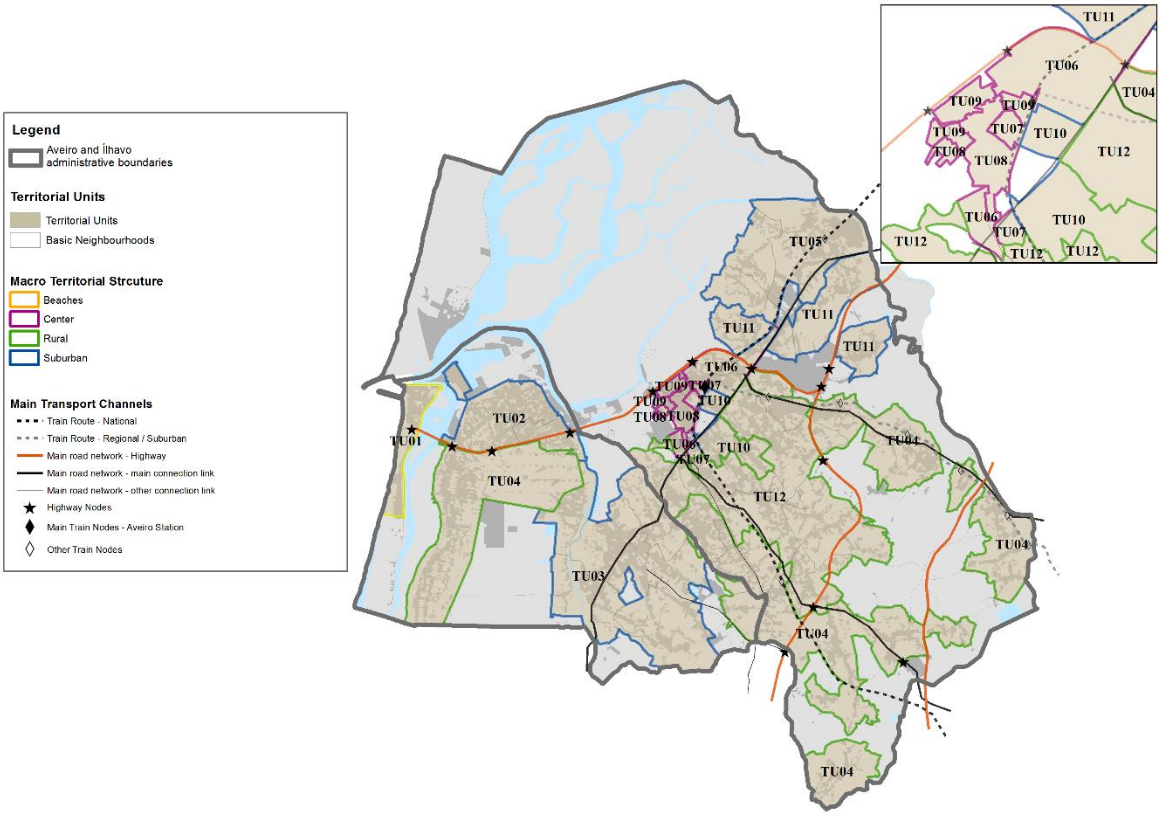



**Figure 5.7** The Aveiro-Ilhavo territorial system

**Table 5.9** Overview of the average scores from the final 4 latent factors on each territorial unit.

| | | | Urban Fabric Density | Qualifications | Demographic structure | Housing submarket features |
|---|---|---|---|---|---|---|
| Centre | Popular Aveiro Centre | TU09 | -0.61 | -0.99 | 0.44 | 0.65 |
| | Aveiro Modern City Centre | TU06 | -1.38 | 0.70 | -0.55 | -0.54 |
| | Aveiro Administrative Centre | TU08 | -1.67 | -0.86 | 0.99 | 0.40 |
| | Contemporary centrality | TU07 | -0.01 | -2.49 | -1.90 | -1.24 |
| Suburban | Ílhavo | TU03 | 0.35 | -0.12 | 0.27 | 0.46 |
| | Gafanha | TU02 | 0.24 | 0.75 | 0.27 | 2.00 |
| | Industrial Centre | TU05 | 0.80 | 1.05 | -0.11 | 0.42 |
| | Modern suburban | TU10 | 0.22 | -1.28 | -0.25 | -0.10 |
| Rural | Rural northeast | TU11 | 0.84 | -0.20 | 1.71 | -1.48 |
| | Rural - Urban interfaces | TU04 | 0.77 | 0.86 | -0.33 | -0.26 |
| | Rural core area | TU12 | 0.50 | -0.17 | 0.16 | 0.41 |
| Beaches | Beaches | TU01 | -0.53 | 0.27 | -0.55 | -0.46 |
| Qualitative interpretation of positive values | | | Lower urban density | The housing market of used dwellings and the less qualified population | The older population and the highest value of house dimension | The most valuable older dwellings and highest value neighbourhoods |
| Qualitative interpretation of negative values | | | Highest urban density | The housing market of new dwellings and the high qualified population | The younger population and less value of used dwellings | The most valuable newly dwellings |

This final scores are obtained from a factor analysis performed on selected principal components (eigenvalues > 1)

## Profiles for Aveiro - Ílhavo territorial units

As argued before, spatio-territoriality is defined by a set of n-dimensions. The previous set of observable and measurable attributes can be classified as proxies for describing part of the unknown multidimensionality.

An important feature can be identified from the Aveiro-Ílhavo's 12 territorial units: they follow, closely, the historical 18 parishes – the lowest level of the territorial administrative system – defined in the XIX century. Note that the changes are mostly explained by an aggregation of rural areas and the disaggregation of the town centre of Aveiro and its nearby suburbs. This is an expected change, as the history of territorial dynamics in the XX century was shaped by the abandonment of rural traditional life-styles (population dedicated to traditional agriculture, living in small, low density neighbourhoods) towards a modern life style, where the principal economic activity of the population occur in industrial and services economic sectors, and the preference for high densities neighbourhoods faced a substantial increase.

The study area is characterized by the dominance of individual dwellings with one/two floors (~86% of the buildings in all urban system), occupied for usual residence and whose residents are mostly owner-occupiers (~72%). A more detailed analysis, regarding the housing features reveals: a) the existence of a greater number of dwellings per family explained by a dominance of second-home residences for holidays (since the municipalities include seaside resorts), with ~35% of houses. In general, Aveiro - Ílhavo is characterized by the presence of ground floor dwellings, although some parts of the urban system (such as Aveiro and Ílhavo's town centres) have a high percentage of buildings with 2 or more floors (these follow the national trend for medium sized town centres). Throughout the last decades the Census data reveals that house construction has increased in Aveiro-Ílhavo, what explains why ~15% of the buildings are recent buildings with less than 10 years.

It is possible to produce a short-profile of each territorial unit by combining the insights provided by the previous geographic identification process of territorial units' boundaries with an additional qualitative analysis of Aveiro-Ílhavo's territoriality, provided by different sources. From this analysis multiple dimensional features are summarized and proved to play an important role for understanding this case study. The sources of additional information, considered to perform spatio-territorial profiles, are:

a) The distributions associated to other housing characteristics, comparing the distributions on the market (the data sample used here) and the housing stock (using 2011 census data) –presented in annexes Table A-2, Table A-3 and Table A-4
b) Additional key features – showed in the following Table 5.10 – important to give further interpretations on the estimation results.
c) The general pictures provided on the research projects: Drivers of housing demand and Costs and Benefits of scattered occupation – both using Aveiro-Ílhavo's urban system as a detailed case study.
d) Specific insights on historical features and the distribution of a widely set of points of interest, provided by (Almeida, 2011; Batista, 2010; Tork, Tomé, Moreira, & Batista, 2011) works.

**Table 5.10** Additional key features of the Territorial Units of Aveiro – Ílhavo territorial system

| | | | % of families (to the territorial system total) | Familiar housing units by families (in each TU) | % of vacancy houses in each TU | % of rent houses in each TU |
|---|---|---|---|---|---|---|
| Center | Popular Aveiro Centre | TU09 | 5% | 2,8 | 32% | 37% |
| | Aveiro Modern City | TU06 | 12% | 3,2 | 16% | 32% |
| | Administrative Centrality | TU08 | 5% | 2,8 | 24% | 38% |
| | Contemporary Centrality | TU07 | 2% | 3,0 | 35% | 34% |
| Suburban | Ílhavo | TU03 | 13% | 6,6 | 23% | 15% |
| | Gafanha | TU02 | 11% | 6,5 | 12% | 16% |
| | Industrial Centre | TU05 | 6% | 9,1 | 12% | 11% |
| | Modern City | TU10 | 4% | 5,4 | 15% | 19% |
| Rural | Rural northeast | TU11 | 4% | 9,0 | 13% | 11% |
| | Rural Core | TU04 | 20% | 8,4 | 13% | 12% |
| | Urban – rural interface | TU12 | 5% | 2,8 | 32% | 37% |
| Beaches | Beaches | TU01 | 12% | 3,2 | 16% | 32% |

*City Centre*

The macro-structure that comprises the core of the territorial system has the highest density of land occupation. Nowadays, it remains the location of the most important services and public facilities, even though only 24% of the families live in Aveiro – Ílhavo. Moreover, its inhabitants have qualifications above-average with a clear agglomeration of socio-economic groups following the age and preservation of the territorial units, with the newly contemporary housing stock mostly occupied by high social and economic households. The territorial units considered through this macro-structure are:

- *Popular Aveiro Centre* (TU09) this is one of the oldest and historical units, often associated with the popular cultural manifestations place. Nowadays, its urban shape is a mixture between traditional and ancient neighbourhoods with boulevards (inspired on the modernist urban design), to which is added a set of buildings classified through the architectural artistic current of "arte nova". It has a wide range of inhabitant types, but the census data suggests a more qualified population increase at the same time the traditional lower skilled inhabitants (fisherman's, salt production workers, etc.), with strong historical association to the traditional economic activities, are disappearing. An interesting point is the general high market value (particularly higher in specific internal neighbourhoods). The census data also reveals some building's degradation and abandonment; furthermore, this data showed possible the overlapping between the housing market itself and the real estate market in general. Despite this overlap, there are changes regarding the economic profile of the territorial unit, as a significant part of housing buildings are increasingly reconverted as assets for commercial and services activities – such as touristic buildings and other types of uses – what explains this apparent contradiction between the market value of the territorial unit and the vacant units.
- *Aveiro Modern City* (TU06) this place surrounds the historical and popular town described before. Its occupation pattern arose from the big expansion process of the urban core – as a result of the fast urbanization process in the early XX century. Due to its proximity to the most important national railway line, it was occupied, in a first phase, by small industrial areas (tile industry, small metalworking, salt industry, logistics, etc.) that were reconverted along the century in new housing neighbourhoods (a process that remains until nowadays). The extensive wave of transformation has been resulting on a great mixture of urban design characteristics (modern and classic urban designs, modern and old buildings, etc.). This territorial unit includes a very small but historically important place – Esgueira – an ancient (XVI /XVII centuries) town, that was previously to the XIX and XX centuries competing with Aveiro's historical core but that had been reduced to a small village, on the orbit of Aveiro centre in last centuries; despite some remaining historical

references, it was absorbed by the expansion of the Aveiro core centre and follows its major transformation processes. The long transformation process, with impact on land occupation, resulted on a mixture between different small socio-economic neighbourhoods, with places that range from the lower to the middle and upper classes.

- *Aveiro Administrative Centre* (TU08) it comprises the oldest and newly historical political centre – it was the place of Aveiro "Castel" and today is the symbolic place of the city municipality, regional authority and city council. Moreover, in the recent 40 years, the University of Aveiro campus occupied a vast land plot on its close surroundings boosting an expansion of that Aveiro's administrative urban core towards that geographical direction. The new neighbourhoods of Bairro do Liceu, Bairro Gulbenkian and others, are clearly linked with the expansion and occupation of an growing range of public buildings and services. A mixture between university students (mainly considered as temporary inhabitants by the census data), ageing population (it is the oldest population of the territorial system), and middle and, mostly, upper class community (higher qualifications and higher income socioeconomic profiles) reside on this territorial unit.
- *Contemporary Centralities* (TU07) this spatial unit combines two major areas that are geographically separated by open fields, but which are relatively connected and have been developed at same time, with similar programs. The areas were built mainly in the last 15 years (the population more than triplicated between 2011 and 2011) from abandoned extractive and agricultural landfills, where big contemporary urban design projects have been developed from scratch. In addition to the major extensions of open / green public areas surrounding housing blocks, the area is served by major commercial activities targeting high profile consumers (including the two-medium size and more "fashion" shopping malls – Glicínias Plaza and Forum Aveiro), as well by important mass culture and entertainment services (cinemas). The census data suggest that this is an area occupied by the younger and upper-class population of Aveiro-Ílhavo. The housing market is characterized by new houses, most of which the size is above the average of existent housing stock.

*Suburban*

The suburban macrostructure comprises a group of spatial units which are not far away from the urban core and comprise the major share of the territorial system population (around 2/3). Moreover, suburban territorial units are located on the centroids of both the territorial system geographically extended and the roads networks. Its housing stock is relatively new, where most of them were developed in the last 40 years. Despite that, the proportion dwellings available in the housing market are not considered to as new or recently built. This eventually suggests that residential mobility rates are higher than in other macro-structures. The landscape is dominated by a combination of modern neighbourhoods (with blocks of flats), classical ones (clusters of detached houses, mainly around older small villages that pre-exist before the suburbanization process) and the major industrial infrastructure – the major industrial area and the port area. Normally, suburban areas appear as territorial units whose population match to middle and lower classes, probably looking for more affordable housing and valuing the proximity to the employment centralities (in order to lower mobility costs). In addition, some other industrial facilities are disseminated within the housing plots.

- *Ílhavo* (TU03) is a spatial unit close to the Aveiro City Centre, which comprises the administrative centre (Ílhavo municipality) and most of its jurisdiction area[28]. It comprises the (small) city of Ílhavo itself (with a population density above-average, but with a small geographic extend) plus additional scattered agglomerations (rural type landscapes). Most of its inhabitants commute every day to access work, services or, as well, leisure and entertainment located outside the territorial unity. Despite the older, historical and small urban core of Ílhavo's city, in general, it is a very low density territorial unit, where the big detached houses dominate the landscape. The historical process is associated to the success of migrant population (on Brasil, in the XIX century, through rubber extraction; and in the XX century with fishery industry – mostly codfish). Thus, it results on a mixture of small middle and upper class descendants from traditional sailors, fishermen and other industries related. It comprises both middle and lower population classes that takes advantage of its suburban character – in terms of housing prices and characteristics of houses for example. Here, housing market is defined by lower prices and is located relatively close to some industrial poles.
- *Gafanha* (TU02) is a territorial unit dominated by the location of port facilities, all linked to industrial activities. Gafanha is a relatively dense territorial unit (above the territorial system's average) where the urban landscape is marked by both residential and industrial areas. It combines older and consolidated settlements,

[28] Note that, Aveiro and Ílhavo municipalities have a clear difference on jurisdiction area and population (Aveiro is more than 60% of the territorial system area and population in general), plus Aveiro municipalities is the center of regional administration services – Baixo-Vouga region

with detached houses spread throughout the surrounding rural landscape and major housing blocks around the major central streets.

- *Industrial centre* (TU05) is a spatial area dominated by great contradictions as it is a place of the most important industrial plants but, at the same time, there is also agricultural land use and small villages with a predominant rural life style. The inhabitants are divided between those who get some income from agricultural activities on their own small land parcel and the ones which are working either in manufacturing or in low skill service and industrial jobs. Many households accumulate income from both types of economic activities and most inhabitants are part of the lower or lower middle classes.
- *Modern suburban* (TU10) is a dense spatial unit, with a wide range of middle class family types. It combines areas of isolated unfamiliar dwellings with modern blocks of flats, with a mixture between high-density and low-density areas. It is close to important commercial shopping areas, more focused on mass consumption (big retailers) for middle and lower income classes. It takes advantage of major transport / road nodes, what provides good automobile accessibility across the different employment nodes but with enough distance to mitigate the negative effects (pollution, noise, etc.) of its location (as TU05 or TU02). The high demand for its amenities results on a continuous flow of new inhabitants and a relatively high average housing value (when compared with the previous suburban territorial units).

*Rural*

- ***Rural northeast*** (TU11) is a landscape dominated by big unfamiliar dwellings (one/two floors), which have been attracting the upper middle and upper classes in the last 15 years. It combines its preference for commuting by car with the availability of big (parcel areas) dwellings.
- ***Rural core*** (TU12) is a dominant rural spatial unit, with a wide agricultural and forest landscape. However, it includes some old and consolidated rural villages, with some higher-density areas. The diversity of environmental amenities attracts different kind of inhabitants, especially older age groups or families, which tend to prefer quiet and safe neighbourhoods; an important community of small farmers can be identified.
- ***Rural-Urban interface*** (TU04) is a small spatial unit, which has some peculiarities – it is located near Ílhavo's city Centre and has a central position in the context of the urban system's high capacity road network, providing fast connections by car to all parts of the urban system as well as out of it.

*Beaches*

The beaches are a territorial unit related to the most important leisure activity – which have, in general, high economic relevance. It is organized in two settlements occupied by high housing blocks. Besides one of the major land occupation densities, it has an average population density, as an significant part of the houses are second homes or are occupied during tourist market activities. As it is connected by high capacity transport links (a highway), it has attracted a great number of upper class inhabitants in recent years, concerned with the leisure amenities. Moreover, the housing market is characterized by the availability (above-average) of new and used (with no more than 10 years) houses. Most of its housing stock is relatively new too.

## 5.2.3 AVEIRO-ÍLHAVO TERRITORIAL SYSTEM INTERACTION STRUCTURE

*The territorial system's housing market price model*

The first stage of the proposed framework relies on the Aveiro-Ílhavo housing market price model. This model has an acceptable explanatory power (R2 = 54%) given the estimation conditions – where, in addition to 5 structural attributes, all additional price variations were specified through the territorial units' variables (dummies). This general specification is necessary to ensure that the territorial effects are not diminished by the use of proxy variables that capture part of its effects. Moreover, as we are interested in territorial interaction effects, this care to ensure that all potential information of these interactions remains codified in the residuals is important – as the framework relies, on a second stage, specifically on that model component.

From the territorial system model's results, is possible to see a geographic pattern of the territorial units hidden in prices: the geographic hierarchy between the most dense and multifunctional land use territorial units (the "City Centre") – higher valued – to the less occupied and mono-functional places in the "Rural" macrostructure. This pattern explains a significant amount of spatial variability on housing attributes and its values; even more, it is in accordance with economic theory that the densest occupied spaces are, usually, the most valuable one (as densification can be explained by the competition for land). This is clear as the high value for the dimension of houses in more dense places reflects scarcity of space.

In detail, it is possible to distinguish that observed spatial patterns suggest additional dimensions to explain it. For example, the market value of houses in the territorial units Beaches (TU01) are the highest and, in turn, Gafanha (TU02) are the lowest. Possible explanations are found by acknowledging the unique character of the Beaches when compared with others territorial units: its amenity is impossible to reproduce and, naturally, as its prices suggest, rises the contribution of that territorial dimensions to define the market price of houses. In specific economic-market domains, the explanations are related with the high demand for houses in TU01, in order to benefit consumers with its unique territorial attributes, but eventually not only for households but as for investors, who might use them as secondary homes or for capitalising house properties in other economic sectors – such as rental houses for tourism.

Furthermore, some shortage of (higher) value of housing in Rural Northeast (TU11) can be identified. This can be related to its relative advantageous position in the territorial system, as the TU is surrounding the both, the densified and higher value areas and the most important industrial pole. This position, associated with the "advantages" of its rural character, can be interpreted as a special preference on market for a TU which claims the best of both worlds: being near the centre but in a rural setting.

This general picture of some interesting geographical patterns of the housing market shows how territorial dimensions plays an important role on general explanations. Moreover, it is clear that territoriality embraces not only a diverse dimensionality but an enriched geometry: this is visible as some dimensions are more important to distinguish different phenomena in some TU's than in others.

But, as this short description on the patterns obtained from the model shows, analysing the territorial units itself is relatively easy: with the help of descriptive methods, combined with some expert practice and tacit knowledge, it is possible to create different narratives, that can be confronted, in the planning process, in order to produce a general picture of each territorial unit of the system, providing a first shared knowledge to make planning decisions.

What remains to be known is how we can get some insights of the possible linkages between territorial units? If the territorial planning process should ensure a global picture of the system, mapping these linkages is as important as the previous insights.

**Table 5.11** Aveiro-Ilhavo urban system housing market hedonic price model

| | B | Std. Error | t | Sig. |
|---|---|---|---|---|
| (Constant) | 6,956 | 0,012 | 604,571 | 0,000 |
| Time on market (log) | 0,001 | 0,002 | 0,694 | 0,488 |
| Structural attribute – Preservation Constr.&New | 0,036 | 0,003 | 13,706 | 0,000 |
| Structural attribute – Preservation Used, to 10yrs | -0,019 | 0,003 | -7,456 | 0,000 |
| Structural attribute – Preservation Used, 10yrs to 25yrs | -0,068 | 0,003 | -26,692 | 0,000 |
| Structural attribute – Preservation Used, More than 25yrs | -0,045 | 0,003 | -17,576 | 0,000 |
| TU01 (spatial unit dummy) | 0,423 | 0,011 | 39,811 | 0,000 |
| TU02 (spatial unit dummy) | -0,108 | 0,018 | -6,017 | 0,000 |
| TU03 (spatial unit dummy) | -0,059 | 0,013 | -4,587 | 0,000 |
| TU04 (spatial unit dummy) | -0,106 | 0,010 | -11,078 | 0,000 |
| TU05 (spatial unit dummy) | -0,119 | 0,016 | -7,241 | 0,000 |
| TU06 (spatial unit dummy) | 0,073 | 0,014 | 5,415 | 0,000 |
| TU07 (spatial unit dummy) | 0,165 | 0,023 | 7,187 | 0,000 |
| TU08 (spatial unit dummy) | 0,156 | 0,021 | 7,345 | 0,000 |
| TU09 (spatial unit dummy) | 0,276 | 0,016 | 17,080 | 0,000 |
| TU10 (spatial unit dummy) | 0,129 | 0,009 | 14,067 | 0,000 |
| TU11 (spatial unit dummy) | 0,001 | 0,029 | 0,024 | 0,981 |
| Structural attribute – Living space (TU01) | -0,128 | 0,012 | -10,901 | 0,000 |
| Structural attribute – Living space (TU02) | -0,087 | 0,016 | -5,561 | 0,000 |
| Structural attribute – Living space (TU03) | -0,051 | 0,009 | -5,662 | 0,000 |
| Structural attribute – Living space (TU04) | -0,074 | 0,006 | -13,312 | 0,000 |
| Structural attribute – Living space (TU05) | -0,094 | 0,010 | -9,241 | 0,000 |
| Structural attribute – Living space (TU06) | -0,140 | 0,023 | -6,061 | 0,000 |
| Structural attribute – Living space (TU07) | -0,125 | 0,040 | -3,138 | 0,002 |
| Structural attribute – Living space (TU08) | -0,143 | 0,033 | -4,382 | 0,000 |
| Structural attribute – Living space (TU09) | -0,165 | 0,020 | -8,325 | 0,000 |
| Structural attribute – Living space (TU10) | -0,124 | 0,009 | -14,375 | 0,000 |
| Structural attribute – Living space (TU11) | -0,122 | 0,016 | -7,768 | 0,000 |
| Structural attribute – Living space (TU12) | -0,085 | 0,006 | -15,198 | 0,000 |
| Year dummy 2005to2007 | 0,014 | 0,007 | 2,021 | 0,043 |
| Year dummy 2008 | 0,004 | 0,007 | 0,568 | 0,570 |
| Year dummy 2009 | -0,017 | 0,007 | -2,356 | 0,019 |

*The spatio-territorial hierarchies*

As argued in the theoretical framework, the idea of hierarchic relations reshapes most of the modelling attempts, from geography, to economy and sociology. With a greater or smaller focus on territorial interactions, different phenomena are being used to explain that relational structure of territoriality.

For example, from the global econometric model presented before, an obvious hierarchy is established by the housing market's hidden value of each territorial unit. It is possible to argue that ordering is not positional on the value scale but that it is a proxy that captures (and evaluates) a set of possible interaction phenomena: when the TU01 or the TU09 are the two most valuable TU, it can be argued they have more intense relations with the other territorial units, in a way that is analogous to the gravitational ideas described in the theoretical chapters.

The question of the previous explanation is that it restricts the dimensionality of the problem and imposes some kind of geometrical reasoning – as can be inferred by the claim with the analogy of gravitation. Moreover, there are many alternative explanations that question the stronger assumptions, such as:

i. Econometric modelling drawbacks can lead to misleading identifications; for example, from a standard econometric modelling practice, it is obvious that the model faces a sort of variable omission bias (as the low explanation power suggests) resulting in model parameter estimations that are not the most efficient;
ii. The spatial econometrics literature itself is a major suggestion that value hierarchy is not a spatial linkage structure (at least it is not the only one);
iii. Finally, recognizing the unknown dimensionality of territoriality, an approach that requires so much dimensionality (and geometric) assumptions, should be made with caution:
    - The market is only a small part of the interaction potential and, in the housing market in particular, market provides very sparse revealed preferences, and in this way, its outcomes on hedonic values are naturally interpreted through that market conditions – nonetheless, this can be used as a general cautionary reason to the claims derived from market mechanisms;
    - Moreover, as the sociologists have been argued for a while – namely Lefebvre (1991) – the production of space (and the production of the relations on it) have other explanations, that are not based on market commodification; despite the increasing adoption of market mechanisms, it can be argued that most social interactions are not comodifiable.

In fact, as shown in Table 5.12 it is possible to define different orderings, focusing on specific assumptions, such as the relevance of each dimensions to explain the hierarchical order of a territorial system. One important assertion that drives this thesis is explicitly looking for an identification alternative, that relaxes the dimensionality and geometrical assumptions in an easy framework. The attempts to identify the hierarchical structure of territorial units from the analysis of the stochastic component on the econometric model setting seems to provide a more general overview, as it only requires minimal assumptions.

As it is possible to see on the last column of Table 5.12, the hierarchy identified through the first stage of this framework presents important differences from the other alternatives.

**Table 5.12** Different possible orderings of territorial units

| Order | Value of Territorial Unit | | Population Density Pop/Km2 | | Interaction hierarchy |
|---|---|---|---|---|---|
| **1** | TU01 | 42,3% | TU09 | 3053 | TU07 |
| **2** | TU09 | 27,6% | TU08 | 2409 | TU10 |
| **3** | TU07 | 16,5% | TU06 | 2043 | TU03 |
| **4** | TU08 | 15,6% | TU07 | 2015 | TU12 |
| **5** | TU10 | 12,9% | TU02 | 751 | TU09 |
| **6** | TU06 | 7,3% | TU10 | 741 | TU02 |
| **7** | TU11 | 0,1% | TU01 | 572 | TU06 |
| **8** | TU12 | 0,0% | TU12 | 344 | TU04 |
| **9** | TU03 | -5,9% | TU03 | 293 | TU01 |
| **10** | TU04 | -10,6% | TU05 | 226 | TU08 |
| **11** | TU02 | -10,8% | TU11 | 206 | TU05 |
| **12** | TU05 | -11,9% | TU04 | 196 | TU11 |

A global pattern that emerges from these outcomes is that the hierarchy follows a combination between geographical sequential positions with complex geometrical relations. If the three leading units have more or less geographical relations, an obvious example can be given by T03 --» T12. In fact, after the three leading TUs, most of the following linkages are not geographical. This shows how real territorial interaction structure can be complex and it reveals that the simulation study on the abstract territorial system is possible to be understood in a reasonably more geographical way than this example.

A deep analysis of the hierarchical identification shows the possible drawbacks in the simulation studies of the previous section. As shown, the presence of territorial units with a low number of records increases the uncertainty of the assessed order. The Table 5.15 and the partial analysis position by position presented in the annexes show that the first TU are well, and consistently, identified. However, when the first TU with a number of cases lower than 300 (TU09 and TU06) appears, the uncertainty increases significantly and the separation between different orders becomes difficult to distinguish. In annexes Figure A- and Figure A-2 additional tables can be found describing the highest frequency hierarchy identified at each positional identification step: this tables shows that after the 4th iteration two orders emerge as candidates with equal identification frequency rate. In the last iteration this equality remains and a criteria needs to be established to opt between them: to choose the order that remains more time in a leading position across all the iterations.

Despite these uncertainties, a close look on the final hierarchy and the process of identification itself leads to the following observations:

- the leading territorial units are identified consistently;
- despite some uncertainty, a set of TUs remains in the middle positions of the hierarchy;
- in last positions, most receptor TUs remains the same in different orderings.

In these general patterns (three sets of TUs), it is possible to highlight that the last positions can be differentiated by TU's usually assumed as more consolidated (regarding their socio-economic characteristics, land use, urban form, etc.) and with specific specializations (the administrative but older and historical centre, the beaches, etc.). On the other hand, the other two TUs on last positions are rural TUs where that rural landscape is more clearly associated with its attributes (for example, rural TU where there are many detached, big houses, with low densities, in comparison to the territorial system's average).

**Table 5.13** Ordering sequences

| Territorial Units ordering sequences | | | | | | | | | | | | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | TU_04 | TU_08 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_04 | TU_02 | TU_09 | TU_08 | TU_01 | TU_11 | TU_05 | 0.3 |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_08 | TU_04 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_06 | TU_04 | TU_08 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_07 | TU_10 | TU_12 | TU_02 | TU_09 | TU_03 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_10 | TU_07 | TU_03 | TU_12 | TU_02 | TU_09 | TU_08 | TU_06 | TU_04 | TU_01 | TU_05 | TU_11 | 0.3 |

Looking for theoretical explanations of the ordering retrieved from the data, under the minimal assumption of hierarchy, theoretical insights based on information diffusion phenomena can offer interesting interpretation guides.

First, the pioneering ideas of spatial diffusion suggest that the path of diffusion is mostly linked to the communication infrastructure. These insights are extended by the literature on the spatial differentiated poles (territorial units) of growth, where the interaction is mostly explained through the capacity of each territorial unit to receive information, process it and produce new (innovations) that spread across the system. Following both insights, the differentiated/ordered/hierarchical organization should be analysed as internal functions of territorial units to turn the flow of shocks into usable and valuable information for the system and its open communication channels with the other territorial units of the system.

More recently, the NEG models showed that some properties that support the interconnection structures (for example, transport costs, labour mobility) are the main origins of the specialization of different territorial units, with a clear order/hierarchical organization following the importance of that specialization function to maintain the system connected.

Finally, Castells argued that territorial systems are globally interconnected in a hierarchical way. Information and communication technologies created a more efficient super-structure to establish territorial interconnection between the different points of geographic space and that opens the possibility for another differentiation mechanism: some territorial units can be integrated on that super-structure, specializing on the creation and processing (reception and transmission) of information through that global network and are interfaces between that macro-structure and small structures (the local territorial systems).

This insights can be easily translated to our hierarchy. For example, the idea that top hierarchical territorial units should be located near centralities of the mobility networks, that assume functions of major importance (can be translated by its higher territorial value?) and that are better connected with supra local system nodes, are all specifications encountered in the characteristics of the top territorial units. TU07 is, moreover, an emergent contemporary territorial unit, that matches the conditions described by these approaches.

*Estimated interactions structure*

Two previous general notes should be taken into account:

1. Following insights from the simulation study, the parameter estimations presented here are obtained as averages of the vector built from estimations for each bootstrap sample. However, the zero elements are eliminated as they are clearly misidentified estimators. Note that in the previous exercise (the simulation study) all elements are used to identify the estimator parameter of W, and the framework robustness remains stable, suggesting that this option can be made with reasonable security; the reason is that it improves the accuracy of the parameter estimations.
2. An inference framework for the results presented here is not established. Following the conditional nature of estimators (to the ordering identified previously), a correct inference framework can be develop in further applications. Despite this, the standard parametrical inference is used, based on the assumption that each parameter has an underlined normal distribution.

As seen before, the identified hierarchical order presents a complex structure that assumes the geographic space as a mere observational device, rather than a framework to provide explanations for these results. If the ordering itself is of higher complexity in relation with previous abstract territorial system simulations, it is expected that the interaction matrix can be challenging to interpret.

The Table 5.14 shows the estimations for each element of W. The blue colour is used to distinguish the geographical contiguities interactions; orange is used to distinguish the non-significant (through the standard inference adopted) interactions but with high magnitudes of the estimator (>0,1). In general, the major considerations that can be highlighted from this results are:

- Concerned with the general patterns of interactions intensity, the values have a wide range, with a maximum of 0,442 and a tendency for higher magnitudes occurring on the leading territorial units.
- It is noted that across the path of the hierarchical ordering, the interactions magnitude did not present higher intensities. This shows that hierarchical positions tend to be explained by the accumulated effects of all interactions rather than guided by the path/ordering.
    - It is important to note this can be linked to the drawbacks of ordering, specially valid for the lower positions of the hierarchical order, where correct identification is difficult.
    - However, it should be noted that even leading territorial units (for example between TU07 --» TU10), the value of interactions are lower (in the example, not significant).

- Most of the interaction effects are positive. The interpretation of positive and negative signals on interactions can be pointed to ideas of cooperation and competition. By construction, the weak assumptions considered here are more consistently with the idea of a territorial system where cooperation (positive interactions) should dominate: the idea of a territorial system itself relies mostly on that. But this claim is more a researcher's perception that is reasonable consistent with the outcomes than a strong assumption.
    - Some competition between units can occur – here, only between the leading territorial unit and TU06 – and both TU are geographical neighbourhoods.
    - The signal of interactions can be used as an important insight for territorial planning interventions: negative interactions can be related with tensions in the territorial system that can be desirable for further analysis.
- As showed in the simulation exercise, higher interaction values can result in higher disturbances in the model specification. As showed on the table, the leading hierarchies tend to establish stronger connections, reinforcing the explanations for the difficulties encountered in hierarchical ordering presented before.

**Table 5.14** Estimated cross spatial interaction matrix for the asymmetric hierarchical interaction structure of the Aveiro – Ílhavo territorial system

| | TU07 | TU10 | TU03 | TU12 | TU09 | TU02 | TU06 | TU04 | TU01 | TU08 | TU05 | TU11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TU07_C** | | | | | | | | | | | | |
| **TU10_S** | 0,118 *** | | | | | | | | | | | |
| **TU03_S** | -0,080 | 0,120 | | | | | | | | | | |
| **TU12_R** | 0,013 | 0,141 *** | 0,245 *** | | | | | | | | | |
| **TU09_C** | 0,035 | 0,268 *** | 0,109 | 0,151 | | | | | | | | |
| **TU02_S** | 0,252 *** | 0,405 *** | 0,269 *** | 0,442 *** | 0,074 | | | | | | | |
| **TU06_C** | -0,078 *** | 0,064 * | -0,052 | 0,169 *** | 0,035 | 0,002 | | | | | | |
| **TU04_R** | 0,143 *** | 0,217 *** | -0,048 | 0,314 *** | 0,055 *** | 0,178 *** | 0,006 | | | | | |
| **TU01_B** | -0.052 | 0,097 * | 0,056 | 0,086 | 0,106 * | 0,162 *** | 0,157 *** | 0,211 *** | | | | |
| **TU08_C** | -0.022 | 0,066 | 0,056 | 0,156 ** | 0,186 ** | 0,110 ** | 0,023 | 0,160 ** | 0,039 | | | |
| **TU05_S** | 0.047 | 0,207 *** | 0,058 | 0,194 *** | 0,027 | 0,142 * | -0,026 | -0,068 | 0,211 *** | 0,122 ** | | |
| **TU11_R** | 0.118 | 0,269 *** | 0,000 | 0,182 *** | 0,062 | 0,146 | -0,049 | 0,023 | 0,135 | -0,110 | 0,109 | |

Notes: *** Significant at the 1% level, **significant at the 5% level, *significant at the 10% level.

As argued in this work, the geographic space remains an important observational tool that provides major insights on the complexity of spatio-territorial patterns. The Figure 5.8 shows the interaction structure mapped following a usual geographic space framework. It shows that interactions are especially stronger across a north/south central axis, with its centre on the suburban territorial unit TU10 rather than the City Centre. Moreover, combining with the table data, it is possible to highlight that central diffusion core – that are not totally represented as leading TU establishes both types of (strong) connections: non-geographically (such as between TU10 --» TU02) but within the same type of macro-structure (suburban), and geographically (such as TU10 --» TU12) besides they are from different macro-structures (suburban vs rural).

These geographic linkage patterns reinforce the idea that, in this case study, the hierarchical ordering does not imply stronger emission power to link territorial units. As argued before, explanations can be multiple and, for now can only be based on theoretical clues. Then, for example, the different diffusion power between TU07 (the leading territorial unit) and TU10 (the second), can be linked to different consolidation phases within the territorial system: T07 is a more recent territorial unit, with newer buildings and less pre-existing population and which is at an initial stage of building linkages.

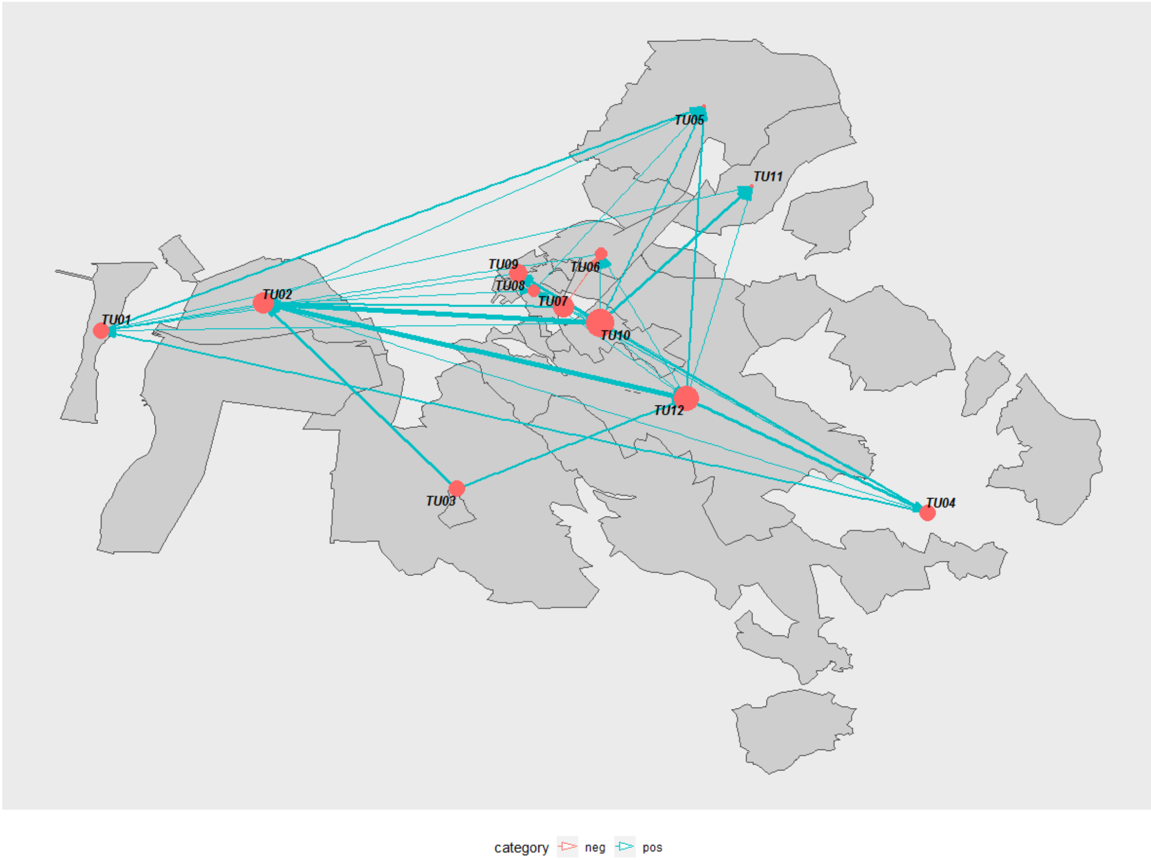



**Figure 5.8** Geographic interaction paths across the 12 territorial units

*Connection links are proportional to the intensity of interaction and indicate the direction of the flow*
*Territorial Units geographic polygons geometric centralities are proportional to its emission power*

Finally, the Table 5.15 shows complementary insights to the results presented before with an analysis grounded on the idea of the spatial interaction matrix as a kind of Input – Output table. Following that, for each territorial unit, the emissions and reception power is analyse through different criteria and a ratio is calculated to better understand what phenomena dominates.

Begin with the idea of the E/R ratio, its values reinforces that instead a pattern that should follow the hierarchical order, the greater E/R values are found on the territorial units on the middle positions of the hierarchy. That pattern is consistent across all the different strategies to measure E-R relations presented. That pattern is mostly defined by the values of TU06 and TU01, with a higher contrast when viewed within the hierarchy.

This major insight can be combined with the previous identified role of TU10 and TU12 (that are highlighted here too as consistently appearing with higher E/R ratio): despite the hierarchical order, the territorial units characteristics – mostly, its historical "functions" or "character" within the territorial system – can gives them an important role to guarantee the interconnection of the system. In other words, despite its lower positions on the hierarchy they can reinforces the strength of connections.

**Table 5.15** Insights about the emission – reception patterns of the hierarchical interactions identified before

| **Average (global) (E)Emission, (R)Reception power and its E/R ratio (without non-significant interactions)** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **TU07** | **TU10** | **TU03** | **TU12** | **TU09** | **TU02** | **TU06** | **TU04** | **TU01** | **TU08** | **TU05** | **TU11** |
| **Emission** | 0,108 | 0,209 | 0,257 | 0,243 | 0,116 | 0,148 | 0,157 | 0,185 | 0,173 | 0,122 | - | R |
| **Reception** | E | 0,118 | - | 0,193 | 0,268 | 0,342 | 0,051 | 0,181 | 0,146 | 0,153 | 0,175 | 0,195 |
| **E/R** | E | 1,8 | - | 1,3 | 0,4 | 0,4 | 3,0 | 1,0 | 1,2 | 0,8 | - | R |
| **Average (pondered by position on hierarchy) (E)Emission, (R)Reception power and E/R ratio (without non-significant interactions)** | | | | | | | | | | | | |
| | **TU07** | **TU10** | **TU03** | **TU12** | **TU09** | **TU02** | **TU06** | **TU04** | **TU01** | **TU08** | **TU05** | **TU11** |
| **Emission** | 0,010 | 0,021 | 0,029 | 0,133 | 0,017 | 0,025 | 0,031 | 0,046 | 0,058 | 0,061 | - | R |
| **Reception** | E | 0,118 | - | 0,064 | 0,067 | 0,068 | 0,009 | 0,026 | 0,018 | 0,019 | 0,501 | 0,018 |
| **E/R** | E | 0,2 | - | 2,1 | 0,2 | 0,4 | 3,7 | 1,8 | 3,2 | 3,1 | - | R |
| **Average (pondered by position on hierarchy) (E)Emission, (R)Reception and E/R ratio (with non-significant interactions)** | | | | | | | | | | | | |
| | **TU07** | **TU10** | **TU03** | **TU12** | **TU09** | **TU02** | **TU06** | **TU04** | **TU01** | **TU08** | **TU05** | **TU11** |
| **Emission** | 0,004 | 0,019 | 0,009 | 0,135 | 0,011 | 0,021 | 0,004 | 0,020 | 0,043 | 0,003 | 0,109 | R |
| **Reception** | E | 0,118 | 0,010 | 0,044 | 0,035 | 0,058 | 0,004 | 0,018 | 0,013 | 0,010 | 0,501 | 0,007 |
| **E/R** | E | 0,2 | 0,8 | 3,0 | 0,3 | 0,4 | 1,1 | 1,2 | 3,3 | 0,3 | 0,2 | R |
| **Total (E)Emission, (R)Reception power and its E/R ratio (without non-significant interactions)** | | | | | | | | | | | | |
| | **TU07** | **TU10** | **TU03** | **TU12** | **TU09** | **TU02** | **TU06** | **TU04** | **TU01** | **TU08** | **TU05** | **TU11** |
| **Emission** | 0,434 | 1,668 | 0,514 | 1,457 | 0,347 | 0,592 | 0,157 | 0,371 | 0,346 | 0,122 | - | R |
| **Reception** | E | 0,118 | - | 0,386 | 0,268 | 1,368 | 0,154 | 0,907 | 0,732 | 0,612 | 0,876 | 0,586 |
| **E/R** | E | 14,2 | - | 3,8 | 1,3 | 0,4 | 1,0 | 0,4 | 0,5 | 0,2 | - | R |
| **Number of (E)Emission, (R)Reception links and its E/R ratio (without non-significant interactions)** | | | | | | | | | | | | |
| | **TU07** | **TU10** | **TU03** | **TU12** | **TU09** | **TU02** | **TU06** | **TU04** | **TU01** | **TU08** | **TU05** | **TU11** |
| **Emission** | 4 | 8 | 2 | 6 | 3 | 4 | 1 | 2 | 2 | 1 | - | R |
| **Reception** | E | 1 | - | 2 | 1 | 4 | 3 | 5 | 5 | 4 | 5 | 3 |
| **E/R** | E | 8,0 | - | 3,0 | 3,0 | 1,0 | 0,3 | 0,4 | 0,4 | 0,3 | - | R |

# 6. FINAL REMARKS

This chapter aims to shed light on the major insights of this research concerning the understanding of the territoriality characteristics of planning practices, with implications for policy, and housing policy in particular.

For this purpose, this chapter is organized into three sections.

Section 6.1 presents a brief summary of the theoretical framework that justifies the need of explicitly assuming the unknown dimensionality and geometry in the research on territoriality. Moreover, it summarizes the major findings resulting from the analytical approach applied to the case study of the territorial system of Aveiro-Ílhavo, namely: the understanding of territoriality and the identification of the main limitations of the purposed analysis.

Section 6.2 points out the major challenges of the methodology to support planning and policy decision-making. In a brief overview, it is analysed the capacity of this analytical framework to answer important planning challenges such as understanding housing dynamics through its contemporaneous (free) market allocation mechanisms.

Section 6.3 presents the scientific advances achieved and the set of insights and guidelines for further research, with the aim of assisting territorial planning practitioners and policy-makers in overcoming the limitations when dealing with territoriality.

# 6.1. SUMMARY OF THE THESIS' MAJOR INSIGHTS

## 6.1.1. THE ROLE OF SPACE IN TERRITORIAL PLANNING PRACTICES

As argued by Morin (2008), contemporaneous societies face an increasing complexity that claims for multidisciplinary scientific approaches in knowledge production. There are visible challenges to apply this strategy on the efforts to understand territoriality, as it is been shaped by fast changes in multiple dimensions, such as:

- Improvements in the transport systems, leading to complex, multi-modal and increasingly accelerated mobility solutions.
- The increasingly efficiency of traditional communication at a distance – from postal (written), to telephone (oral) communication systems to its transformation as (classical) media services – guiding the combination of communication, information and entertainment through a central system of processing and transmission, such as newspapers, radios and TVs.
- Last, but not least, the recent transformations of new and "old" information and communication systems through a general convergence between communication and information and computation technologies. The internet is the most well-known result of that, besides other phenomena, such as the transformation of media through the World Wide Web or the increasing automation services, grounded on increasing big (digital) data sources.

These phenomena, among others, have been pointed as enablers of meaningful changes of social, economic and spatial structures of agglomeration and interaction (Couclelis, 1996; Couclelis, 2004).

As territorial systems change faster than the production of knowledge, there are several researchers focused on producing insights on the nature of those changes, despite the difficulty to ensure a wider, multidisciplinary focus in times of increasing complexity. The results have been that analytical approaches, to produce structured explanations (such as models, laws), are scarce and rely on strong theoretical assumptions. Notwithstanding these drawbacks, the efforts show that the mechanisms of formation and consolidation of territorial units – as groups of individuals, of economic activities or landscape units – as well as the mechanisms which enable linking those units need to be revisited.

From a practical perspective, even the territorial planning activity has been facing important transformations. On the one hand, the organisation of territorial planning practices – its institutional and functional context within the political and administrative framework – faced changes guided by the recognition of the transformations described above. On the other hand, the speed of scientific knowledge production and technological development led to changes in the notion of spatio-territoriality.

The development of new territorial planning tools that can increase the understanding of contemporary territoriality, in order to help territorial planning and public policy decision-making have been assumed as a major priority on applied planning research. However, the transformations described before have associated challenges concerned with the different assumptions regarding space – as a geometric and dimensional mathematical device – and territoriality, in general.

It is within this context that it is possible to state that the broad understanding of territorial planning is confronted with the absence of effective analytical instruments, even though recent modelling developments. The adoption of new tools, based on new ICT possibilities, has been pointed as a standard solution as. at a first analytical level, that tools can be straight answers to the challenges of the most recently planning practice – the participatory and community planning (C. N. Silva, 2010).

However, the set of new analytical tools that have been developed within planning researchers' community claims to improve the planning activity in a most wide range of practices: they include tools that go from geographic information systems, territorial simulation systems and communication platforms to enable the participation of planning stakeholders. For example, the use of computational methods, in a set of empirical modelling approaches defined as "geosimulations", began to dominate a significant part of the new analytical application to solve problems of territorial planning practices – which remains, in its outputs (the plan and its legal rules), reasonable and immutable.

Facing remarkable technical challenges, to produce a new set of tools, territorial planning has been attributing a secondary role to the debate on the notion of space-territory[29]. Territorial planning, and its focus on the cohesion of the territorial system, is usually concerned with understanding of the relations between territorial units. On this inquiry, a notion of space is adopted and the analytical tools are conditional to it.

As showed here, by accepting a notion of space shaped by an unknown dimensionality and geometry, quantitative approaches are still possible. Moreover, these efforts – in line to what is presented in this work – show that the interaction structures are more complex and richer than the usual assumptions, that better answer the challenges faced by territorial planning on the new spatio-territorial context described before.

As argued in this work, the minimal assumption of hierarchy can produce misleading partial understand of territoriality if it is combined with strong dimensional and geometric

[29] Nevertheless, it's important to highlight that this scarce "operational utility" concerns an analytical referential that allows to identify, in a general way, the mechanisms of territorial restructuring, namely the ones that are the object of this work – the interaction structure of a territorial system at a local scale. There are several areas of action of the territorial planning activity where the development and use of tools based in the potential of the new information and communication technologies has proved to have a remarkable utility. This goes from the computer-aided design to the geographic information systems, and is related with the development of a myriad of platforms to support the interaction of the territorial planning process. Some examples include platforms of communication between the elements of the team, often multidisciplinary; communication between technical teams and decision-makers (namely, political decision-makers); and the increasingly sophisticated mechanisms of involvement/ participation of the citizens in the territorial planning process.

assumptions. A major example showed was the usual adoption of the hierarchical (market) value ordering as a driver of spatial interactions (spill over effects): this leads to, for example, the allocation of more public investment on the higher order territorial units, expecting the diffusion of (positive) effects across the territorial system. As showed, that hierarchical order is one among several possibilities conditional to strong assumptions of spatio-territoriality. The insights presented in this work, with minimal dimensional and geometrical assumptions, suggests that the complexity behind the drivers of spatio-territorial interactions go beyond the simplicity of a market value ordering, for example.

### 6.1.2. THE PRESUMPTION OF AN UNKNOWN GEOMETRY AND DIMENSIONALITY ON ANALYTICAL EFFORTS

This thesis embraces the role of TFL of geography as a central research artefact in understanding territoriality, through modelling efforts. Tobler (2004) recognizes that its formulation is sufficiently vague and ambiguous, but if researchers are open to explicitly embrace the unknown nature of spatio-territoriality, the TFL provides a general framework that guides scientific inquiry. In fact, if TFL fails to explain the territorial units' interaction structure, using the geographic space (based on the Euclidian geometry) as a framework, it should be recognized that this leads to questioning the usual geometrical and dimensional analytical references, in geographic as well as economic modelling efforts.

In this work, despite the additional contributions to reinforce the notion of a spatio-territoriality, a major contribution was made through the assumption of the hierarchical interaction of the territorial system. This hierarchical structure was evidenced in the case-study of Aveiro-Ílhavo, which presented empirical results coherent with the conceptual theoretical framework. In fact, many previously developed works considering this territory, and namely the work of Marques (2012), support this conclusion and attest the complexity of the territorial patterns observed here.

In general, it is possible to show the feasibility of observations on a territorial interaction structure, embracing an unknown dimensionality and geometry. Econometrics, applied as a spatial analysis approach, supported by the geographic space as a visualization tool rather than as a guide for geometrical (and dimensional) assumptions, can constitute a new, valuable, tool to assist territorial planning – namely regarding the general diagnosis and understanding of territoriality.

It should be noted that spatial data itself has relevant idiosyncrasies that need additional efforts to be fixed. If, on the one hand, the increasing data availability is an advantage, most of this data is stored with purposes not related with the research questions for which it is used – this points to the need to embrace advanced techniques for pre-processing. In fact, this study was only possible by incorporating previous works, mainly in what concerns the data collection and pre-processing.

Moreover, this approach can give insights for a better specification of standard spatial econometric models, which have an extended use in planning practices, as well as for housing or land price estimations. In what concern the spatial econometrics specifications, note that these results suggest that an improved reliability of housing price estimations can, eventually, be obtained considering predictive models that specify interactions through hierarchical spatial interaction structures. It should be noted that , these models need to be studied in detail as their specifications face new econometrics challenges.

As described in the previous chapter, the first and most important challenge of the methodological approach developed here is to identify the correct hierarchical property of the interaction mechanism. This minimal assumption is challenging as it implies to correctly identify the hidden causal mechanism behind it, through the statistical properties of the estimators. In fact, as argued before, in this filed most recent literature has been developed on causal inference. The approach that is followed here frames these debates and takes into account the usual properties of econometric models. However, this application was developed with a focus on spatial analysis rather than on the estimation of all statistical parameters and robustness. In fact, note that, here, the estimation is mostly concerned with $\boldsymbol{\lambda W u}$ model component as a whole, rather than with the estimation of each $\boldsymbol{\lambda}$ and $\boldsymbol{W}$ parameters, as is usual in econometrics and statistical analysis.

A major open question is related to the empirical identification of the territorial interaction drivers. Most of the explanations advanced here to interpret the model results are based on theoretical insights, guided by my personal perceptions. That analysis, while being useful in this context, can limit the adoption of this framework for planning purposes: despite the general picture of territoriality presented here, choosing between territorial transformation programs implies to identify – even if only partially – the drivers that contribute to reinforce the interactions (or, in other words, the dimensions that can be used to characterize them).

Finally, the results show that spatio-territoriality features have an intrinsic complexity that is compatible with the unknown dimensionality and geometry assumed before. Notwithstanding the hierarchical assumption, this work attempt to shorten the gap between geographic, economic and territorial notions of space and embrace uncertainty. However, the challenges encountered point to the need of future research efforts.

### 6.1.3. TOWARDS E-TERRITORIALITY

This work did not focus on the identification and analysis of territorial units, whose geographical delimitation was made through one of the standard planning strategies: spatial geographic aggregation of neighbourhoods (cluster analysis), in order to obtain a pre-defined number of spatial units that are assumed as proxies of territorial units. However, that territorial units definition are relevant to the analysis as the results are conditional to that assumptions. The results for the empirical study of the Aveiro-Ílhavo territorial system, can be reasonably interpretable, following the theoretical insights and based on the territorial features, described in territorial units' profiles section. These interpretations are, naturally, limited. As argued on the begin of this work, new information and communication technologies, disseminated at an incredible rapid pace, have been pointed as the source of major territorial transformation. Those changes not only imply the adaptation of analytical tools to produce accurate empirical evidences, as they require that its claims should be grounded on new deductive and theoretical explanations.

As argued in the theoretical background, several authors advanced, in last years, with possible patterns that emerge from the ongoing restructuration of spatio-territoriality. In this context, the following observations, which are assumedly speculative, strengthen the conclusions of the identified hierarchical structure. Those interpretations should be read as prospective insights from scientific literature in the field and the point of departure for further research.

[A]

In future territorial systems, it should be expected that leading territorial units are the ones that are distinguished by their ubiquitous, geographic, social, and economic, connectivity, integrated in a larger (macro) geographical structure – the regional, national, international networks of information flows. This expectation reflects the ideas behind the central role of the major nodes of the digital communication and transportation networks, plus the insights provided by recent descriptive efforts (e.g. mapping, on geographic space). These will be the territorial unities that are expected to gather a more educated population, professionally related to command and control systems, working on the economic sectors that provide more added-value to its commodified objects (and which are, therefore, better paid), including the territorial units where they live and that they consume as another commodified product.

[B]

An intermediate position is assumed by the territories of mass consumption – although this contemporaneous mass consumption, via the global interconnection allowed by the new (and old) ICT, embraces a remarkable diversity of life styles. This diversity and its patterns of consumption, integrated in a supply chain of goods and services at the global scale, is evident in the diversity of new taxonomies that emerge in the popular culture (Coleman, 2010), from the groups clearly associated with the new ICT – geeks, gamers, youtubers (McArthur, 2008) - to macro taxonomies as the hipster life style (Maly & Varis, 2016). These social groups are not only characterised by the patterns of (mass) consumption, but also by accepting and reinforcing the commodification of cultural dimensions that usually did not reply to capitalist logics, moving them away from the conceptions of counterculture.

[C]

Finally, the basis of the territorial hierarchical structure, are both: i) the territorial units that harbour the conventional productive sectors along with their associated labour force; and ii) the territorial unities that host the declining productive activities, as well as, the individuals with most difficulties in integrating the new socioeconomic organisation – in other words, the territories where the population has lower incomes, lower level of education and are older.

The insights described previously reinforces that the drivers of territoriality have been transforming the properties that describes the territorial system units. More than changing the characteristics of the "new" agglomeration structures, the new territorial interactions structure supports what should be a major object of research, embracing a new notion: the e-Territorial System.

## 6.2. EMBRACE E-TERRITORIAL PLANNING PRACTICES WITH TRADITIONAL (UPDATED) TOOLS

The Portuguese territorial planning system faces a significant transformation process which challenges its capacity to support public policy making: its practices have been changing at a fast pace to achieve international standards and rapid, non-expected, territorial transformations have been taken place, without the development of analytical instruments able to deal comprehensively with them. In the opposite sense, the increasing perception of the role of spatio-territoriality to ensure quality of life and the importance of housing provision puts additional pressure on territorial planning practices in order to produce accurate and substantiated solutions. However, regardless of the countless news tools available to promote efficiency in territorial planning, much of them do not match the usual needs for the development of zoning plans, which remain central planning outcomes. Moreover, much of these approaches, instead of updating consolidated tools, are more concerned with replacing them. The work developed here tries to establish a compromise between territorial planning practices and tools and the necessary revision of the concepts that support them.

In particular, the notion of space embraced by territorial planning practices (and tools) should be further developed. The last statement was based on two major assumptions: i) even though not knowing the dimensionality and geometry of space, it is possible to identify a set of abstract properties that characterise territorial systems; and ii) those properties can be adopted as informative analytical assets in the implementation of an empirical approach, more suitable for identifying the structure of territorial interactions.

Even within the classical geographic space framework, geographic and economic empirical works accumulate evidence of territorial phenomena shaped by an unknown number of dimensions and unknown geometry. However, despite these conclusions, planning practice remains associated with the production of documentation that establishes the territorial development strategies through land use rules, specified through the geographic space – the prevalent zoning system. As a result, Euclidean space remains a geometric reference frame to the description and translation of the properties of the territorial system – both, the identification of the territorial units or the structure of territorial interactions.

The “plan” comprehend a set of amendments that explain changes in the housing value, in order to achieve the previous general objectives of land/housing policy. Therefore, it can be assumed that the analysis of these changes is the basis to evaluate the real value of a territorial plan. In addition, the plan often proposes a set of urban operations that require changes in the ownership of several parcels of land, imposing an analysis on their value both for purposes of compensation or for the proper distribution of the costs and benefits of territorial transformations.

This prevalent role of the geographic space through planning outcomes can explain the use of classical analytical tools as key instruments. The combination of the leading role of the market, as the allocation device supported by planning guidelines, with the need to maintain a consolidated and flexible analytical framework, contribute to the resilience of standard econometric models as a broad approach to territorial analysis.

The market (land) value (and, in particular, the housing value) is assumed as a key component in assessing contemporary territorial planning efficacy. It assumes that territoriality is embedded in the market agent's knowledge and the analysis of the market value should be considered as a valid proxy to uncover that information. The presumption of a notion of space, codified on individual's knowledge, is additionally supported by the literature that suggests a key role of housing in the perceptions building of [territorial] life quality as well as a major indicator of citizens' wealth. Given that housing allocation is increasingly ensured by free market mechanisms, econometrics, and spatial econometrics in particular, constitutes an effective framework to enlighten the debate on the notion of space, in particular, and territoriality, in general.

While considering the main questions that planning activity faces, this work sought to contribute to the debate about the key concepts of territoriality through the lens of its role on market mechanisms. Defining territorial units' boundaries is relatively close to territorial planning practices – the choices made often result from a balance between operational needs, political aspirations and social constructions – however understanding the territorial interactions structure remains an open question for planners.

This thesis shows that from spatial econometrics it is possible to design an empirical quantitative framework that identifies territorial interactions without strong assumptions on the geographic or non-geographical dimensions that drive it.

## 6.3. LIMITATIONS AND FUTURE WORK

As was expected from the beginning, relaxing the dimensionality and geometrical assumptions on spatial modelling efforts raises analytical challenges. Spatio-territoriality is complex and this is the reason why quantitative analytical efforts have adopted strategies based on a restricted number of dimensions and conditional to a predefined geometrical framework – in what can be defined as the classical strategy of divide-to-conquer.

On the contrary, the work presented here follows the well-known principle of "doggy-bag" ("never throw away your leftovers") that transcends the usual modelling practice of neutralizing the residuals. As Griffith & Paelinck (2011) argue, "informative residuals argues, 'pure spatial randomness' also could be interpreted as spatial complexity, and might encourage continued analysis rather than finishing it by discussing 'ideal' parameter properties" (p. 215).

As a result, this approach faces important limitations – some of which were identified in the previous chapters. Although recognizing that other limitations could be discussed, two of them where considered particularly relevant and interesting for future research and will, as such, be discussed in the following paragraphs.

The first point is concerned with reliability. Despite the reasonable simplicity of the approach proposed here, it is clear that the reliability of the results are very sensible to the balance between the complexity of the territorial structure and the minimal specifications adopted to describe it through the lens of geographic space – as the last remains the available observational tool. The correct balance is obviously difficult to achieve as the dimensionality and geometry of territoriality are unknown. It should, therefore, be an iterative process of trial and error.

The goal here was to go further on a line of research that tries to obtain insights on the structure of spatio-territoriality, modelling residuals of simpler econometric models. Focussing on the local (municipal) scale – as is important for territorial planning – the nature of spatial (georeferenced) data introduces great uncertainty in the estimation process itself, as the data is conditional to a "production" process based on the geographic reference frame. In other words, the origin of raw data itself and, mostly, the *a priori* definition of geographic units (or the methods used to do it), imply strong geographic assumptions. It is difficult to measure the influences on the results of further spatial interactions – such as the ones presented here.

The problem is amplified by the hierarchical nature of the diffusion process, since a unit can interact with all units above its position on the hierarchy in very unusual ways (e.g. at a distance). Moreover, the hierarchical diffusion of information is expected to be a (spatial) continuous transmission of shocks, which increases the disturbances across the path of transmission. At certain levels, it can be very difficult to distinguish them from the disturbances caused by the 'artificial' definition of analytical boundaries in the geographic space.

Despite these uncertainties, many different approaches can be tested in future research. One interesting possibility is a deep exploration of the aggregation techniques that are available today. For example, taking advantage of the increasing volumes of data and relaxing the Euclidian distance, that tends to be used in standard cluster algorithms, the self-organization maps (SOM) can provide more reliable insights about the boundaries of territorial units.

As described by Agarwal & Skupin (2008), SOM approach can be defined as a combination between the identification of latent dimensions on data (such as FA and PCA) and clustering/agglomeration analysis, where the topological relations between clusters are explicitly considered. However, note that its modelling principles are completely different from these statistical techniques and are based on machine learning approaches and artificial neural networks algorithms in particular. Beyond its conceptual contributions to the representation of the complexity of spatio-territoriality, its development, in a big data context, is also interesting as the literature suggests that standard statistical methods can face potential problems in this new context.

The second point is concerned with available data quality which also relates to relating the previously discussed limitations. In fact, even in quasi-ideal, laboratorial, experiments, data collection is a major issue. Empirical approaches in social sciences, in general, and in spatio-territorial modelling, in particular, face obvious and very significant challenges.

Despite these well-known problems, it is possible to argue that new communication and information technologies have been providing an increasing amount of (digital) data. However, important challenges remain in processing this data in order to make it useful for different purposes. In fact, as shown by this work, even bigger datasets than the existing ones in the recent past, face the recurrent problem of missing data. For example, part of the identification of a territorial hierarchy is challenged by a lack of data problems in specific territorial units – as the simulation shows, territorial units with 150 samples faced increasing identification problems.

A further research direction that can be explored is the use of data-mining techniques in order to fix some of these problems. In fact, the original dataset includes more data: most of it was removed in the cleaning process, which includes the simple removal of records with missing data. This suggests that the data mining process on the early stage of data collection and processing can be revisited. Moreover, additional and state-of-the art techniques can be tested. For example, for unbalanced datasets – similar to the problem faced here with the wide range of territorial unit sample sizes – the SMOTE technique

(Chawla, Bowyer, Hall, & Kegelmeyer, 2002) algorithms can be explored as a solution to minimize the weakness related with that data structure.

Finally, despite the multiple limitations of this research program, three major lines of development seem to be interesting to follow from here.

Firstly, it would be interesting to analyse the results from a declared preferences exercise. Despite the advantages of using housing market transactions as a proxy for a hidden spatio-territoriality, as it obliges individuals to increasing levels of rationality on their decisions, the long cycle of this product implies that at each step, only a very small part of population effectively participates on market transactions. An underlying assumption followed here is that individuals actions are driven, not only an individual presumption of the spatio-territoriality but, further, its collective/globaç sense. However, to ensure more reliable analyses the sample used on analysis should be calibrated as a population sample. Declared preferences, between other advantages, would gives us the chance to achieve this.

Secondly, it is obviously expected that a territorial planner, as well as all stakeholders involved in the planning process, will try to identify the possible drivers of interaction beyond theoretical conjectures. This is a further line of research which is interesting for real world applications.

Thirdly, efforts are needed to embed these methodological and analytical ideas in territorial planning practices. Combining a deep understanding of the territorial planning system, its approaches, tools, expected outcomes, is essential to match the insights of this work to the real needs of practitioners.

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# ANEXES[30]
# Additional tables and figures

**Table A-1** Additional simulation studies inference statistics (see chapter 5, section 5.1)

| Size of TU samples | W: lower triangle, different values (0.30, 0.15, 0.00, -0.15, and -0.30; 36 entries) | | | |
|---|---|---|---|---|
| | $W_{ij} > 0$ (12) | $W_{ij} < 0$ (8) | $\|W_{ij}\| = 0.3$ (12) | $\|W_{ij}\| = 0.15$ (8) |
| 150 | -0.0887 (0.0301) | 0.0818 (0.0267) | 0.0339 (0.0380) | -3.3e-4 (0.0149) |
| 500 | -0.0587 (0.0183) | 0.0522 (0.0160) | -0.0240 (0.0237) | 7.19e-5 (0.0079) |
| 150 ($\widehat{W}$ non-zero elements) | 0.0026 (0.0091) [64.3%] | 9.0e-4 (0.0097) [64.4%] | 0.0034 (0.0084) [63.8%] | -3.2e-4 0.0108 [65.1%] |
| 500 ($\widehat{W}$ non-zero elements) | 3.89e-4 (0.0030) [77.0%] | -5.64e-4 (0.0035) [77.2%] | 1.98e-4 (0.0027) [76.0%] | 2.78e-4 (0.0039) [78.8%] |

[30] Data and R code that supports this thesis is also available on this link: https://mega.nz/#F!gtIUiShL!vQ_HnyHzxQE1hpO1jiGCLQ

Additional information is provided by the author through the email: pauloricardolb@ua.pt

**Table A-2** Housing characteristics statistics - Preservation

| | | | % of territorial system | | New | | Used | |
|---|---|---|---|---|---|---|---|---|
| | | | Stock | Market (Sample) | Stock | Market (Sample) | Stock | Market (Sample) |
| Center | Popular Aveiro Centre | TU09 | 9% | 7% | 4% | 64% | 96% | 36% |
| | Aveiro Modern City Centre | TU06 | 23% | 33% | 5% | 46% | 95% | 54% |
| | Aveiro Administrative Centre | TU08 | 11% | 5% | 2% | 32% | 98% | 68% |
| | Contemporary centrality | TU07 | 4% | 7% | 41% | 92% | 59% | 8% |
| Suburban | Ílhavo | TU03 | 25% | 9% | 5% | 59% | 95% | 41% |
| | Gafanha | TU02 | 18% | 4% | 5% | 36% | 95% | 64% |
| | Industrial Centre | TU05 | 9% | 7% | 4% | 33% | 96% | 67% |
| | Modern suburban | TU10 | 7% | 20% | 12% | 67% | 88% | 33% |
| Rural | Rural northeast | TU11 | 6% | 5% | 5% | 67% | 95% | 33% |
| | Rural - Urban interfaces | TU04 | 34% | 21% | 7% | 40% | 93% | 60% |
| | Rural core area | TU12 | 27% | 31% | 6% | 60% | 94% | 40% |
| Beaches | Beaches | TU01 | 15% | 15% | 6% | 59% | 94% | 41% |

**Table A-3** Housing characteristics statistics – Type

| | | | Dwelling | | Apartment | |
|---|---|---|---|---|---|---|
| | | | Stock | Market (Sample) | Stock | Market (Sample) |
| Center | Popular Aveiro Centre | TU09 | 49% | 7% | 51% | 93% |
| | Aveiro Modern City Centre | TU06 | 21% | 1% | 79% | 99% |
| | Aveiro Administrative Centre | TU08 | 19% | 2% | 81% | 98% |
| | Contemporary centrality | TU07 | 8% | 1% | 92% | 99% |
| Suburban | Ílhavo | TU03 | 81% | 43% | 19% | 57% |
| | Gafanha | TU02 | 76% | 29% | 24% | 71% |
| | Industrial Centre | TU05 | 90% | 59% | 10% | 41% |
| | Modern suburban | TU10 | 58% | 11% | 42% | 89% |
| Rural | Rural northeast | TU11 | 95% | 87% | 5% | 13% |
| | Rural - Urban interfaces | TU04 | 92% | 45% | 8% | 55% |
| | Rural core area | TU12 | 78% | 21% | 22% | 79% |
| Beaches | Beaches | TU01 | 37% | 7% | 63% | 93% |

**Table A-4** Housing characteristics statistics - Size

| | | | <50 | | 50 - 100 | | 100 - 200 | | > 200 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Stock | Market (Sample) | Stock | Market (Sample) | Stock | Market (Sample) | Stock | Market (Sample) |
| Center | Popular Aveiro Centre | TU09 | 11% | 14% | 41% | 59% | 41% | 24% | 8% | 3% |
| | Aveiro Modern City Centre | TU06 | 6% | 2% | 51% | 41% | 40% | 56% | 3% | 2% |
| | Aveiro Administrative Centre | TU08 | 6% | 5% | 32% | 46% | 54% | 46% | 8% | 4% |
| | Contemporary centrality | TU07 | 12% | 2% | 37% | 42% | 45% | 45% | 6% | 11% |
| Suburban | Ílhavo | TU03 | 6% | 0% | 32% | 26% | 47% | 45% | 15% | 29% |
| | Gafanha | TU02 | 5% | 1% | 34% | 32% | 51% | 50% | 11% | 18% |
| | Industrial Centre | TU05 | 5% | 0% | 30% | 16% | 50% | 49% | 14% | 35% |
| | Modern suburban | TU10 | 3% | 0% | 29% | 32% | 52% | 57% | 16% | 11% |
| Rural | Rural northeast | TU11 | 5% | 0% | 28% | 7% | 48% | 30% | 19% | 63% |
| | Rural - Urban interfaces | TU04 | 5% | 1% | 29% | 29% | 50% | 40% | 16% | 31% |
| | Rural core area | TU12 | 5% | 0% | 32% | 35% | 49% | 48% | 15% | 16% |
| Beaches | Beaches | TU01 | 8% | 2% | 47% | 38% | 37% | 54% | 8% | 6% |

**Table A-5** Modelling dataset descriptive statistics - overview

| | Number of records | Price | Time on market | F1 - House size | F2 - Preservation new | F3 - Preservation Used with 10 to 25 yrs | F4 - Preservation Used to 10 yrs | F5 - Preservation Used more than 25 yrs |
|---|---|---|---|---|---|---|---|---|
| | n houses | €/m2 | n days | Factor scores μ=0 and σ=1 | Factor scores μ=0 and σ=1 | Factor scores μ=0 and σ=1 | Factor scores μ=0 and σ=1 | Factor scores μ=0 and σ=1 |
| | | μ σ | μ σ | μ σ | μ σ | μ σ | μ σ | μ σ |
| TU01_B Beaches | 666 | 1735+/-484 | 332+/-347 | -0.323+/-0.683 | -0.188+/-0.932 | -0.207+/-0.877 | -0.078 +/-1.020 | 0.167 +/-1.398 |
| TU02_S Gafanha | 157 | 963+/-306 | 194+/-196 | 0.207+/-1.089 | -0.086+/-0.834 | 0.497+/-1.177 | 0.079 +/-0.970 | -0.161 +/-0.057 |
| TU03_S Ílhavo | 397 | 1001+/-210 | 295+/-317 | 0.541+/-1.175 | -0.010+/-1.037 | -0.081+/-0.975 | -0.033 +/-0.964 | -0.058 +/-0.874 |
| TU04_R Rur. –Urb.interf. | 927 | 917+/-206 | 358+/-386 | 0.576+/-1.235 | -0.200+/-0.788 | 0.266+/-1.142 | 0.132 +/-1.028 | -0.064 +/-0.812 |
| TU05_S Indust.Centre | 309 | 882+/-239 | 329+/-384 | 0.942+/-1.159 | -0.006+/-0.853 | 0.758+/-1.182 | -0.085 +/-0.722 | 0.039 +/-1.083 |
| TU06_C Av.Moder.City | 1459 | 1222+/-272 | 311+/-345 | -0.463+/-0.282 | -0.212+/-0.812 | -0.014+/-0.990 | 0.183 +/-1.145 | 0.013 +/-1.014 |
| TU07_C Contemp.central | 306 | 1454+/-277 | 226+/-138 | -0.480+/-0.372 | 0.686+/-1.260 | -0.360+/-0.603 | -0.489 +/-0.351 | -0.137 +/-0.476 |
| TU08_C Admin.Av.Centre | 243 | 1267+/-344 | 300+/-380 | -0.480+/-0.458 | -0.108+/-0.767 | -0.107+/-0.775 | 0.347 +/-1.132 | 1.074 +/-2.385 |
| TU09_C Pop.Av.Centre | 295 | 1569+/-396 | 354+/-340 | -0.536+/-0.682 | 0.085+/-1.088 | -0.251+/-0.779 | -0.108 +/-0.992 | 0.153 +/-1.330 |
| TU10_S Modern suburb. | 900 | 1292+/-294 | 346+/-345 | -0.186+/-0.802 | 0.386+/-1.153 | -0.224+/-0.734 | 0.021 +/-1.006 | -0.104 +/-0.616 |
| TU11_R Rural northeast | 242 | 915+/-259 | 356+/-339 | 1.597+/-0.831 | 0.053+/-1.104 | -0.188+/-0.905 | -0.075 +/-0.903 | -0.067 +/-0.919 |
| TU12_R Rural core | 1387 | 1105+/-261 | 313+/-308 | 0.015+/-0.998 | 0.051+/-1.053 | 0.064+/-1.063 | -0.154 +/-0.880 | -0.136 +/-0.500 |

**Table A-6** Cross-submarket spatial error autocovariance and autocorrelation matrix (variances reported on the diagonal, autocorrelations below diagonal)

| | TU02 | TU11 | TU08 | TU09 | TU07 | TU05 | TU03 | TU01 | TU10 | TU04 | TU12 | TU06 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TU02** | 0.060 | | | | | | | | | | | |
| **TU11** | 0.022 | 0.067 | | | | | | | | | | |
| **TU08** | 0.012 | -0.007 | 0.049 | | | | | | | | | |
| **TU09** | 0.035 | 0.018 | 0.012 | 0.050 | | | | | | | | |
| **TU07** | 0.010 | 0.013 | 0.003 | 0.004 | 0.031 | | | | | | | |
| **TU05** | 0.025 | 0.018 | 0.012 | 0.005 | 0.004 | 0.061 | | | | | | |
| **TU03** | 0.016 | 0.007 | 0.007 | 0.005 | 0.001 | 0.015 | 0.037 | | | | | |
| **TU01** | 0.016 | 0.021 | 0.017 | 0.017 | 0.027 | 0.025 | 0.007 | 0.053 | | | | |
| **TU10** | 0.016 | 0.021 | 0.008 | 0.015 | 0.005 | 0.020 | 0.007 | 0.009 | 0.032 | | | |
| **TU04** | 0.019 | 0.019 | 0.015 | 0.014 | 0.008 | 0.012 | 0.007 | 0.013 | 0.002 | 0.050 | | |
| **TU12** | 0.019 | 0.018 | 0.012 | 0.011 | 0.008 | 0.018 | 0.009 | 0.012 | 0.004 | 0.017 | 0.038 | |
| **TU06** | 0.010 | 0.011 | 0.003 | 0.003 | -0.001 | 0.000 | -0.002 | 0.012 | 0.003 | 0.006 | 0.005 | 0.041 |

**Figure A-1** Hierarchical ordering (highest) frequencies at each sequential position (from 1 to 9)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| TU_10 | **35.8** | | | | | | | | |
| TU_03 | **2.1** | | | | | | | | |
| TU_12 | **0.5** | | | | | | | | |
| | **Order** | | **%** | | | | | | |
| TU_07 | TU_10 | TU_03 | **26.2** | | | | | | |
| TU_07 | TU_10 | TU_12 | **21.3** | | | | | | |
| TU_10 | TU_07 | TU_03 | **10.8** | | | | | | |
| TU_10 | TU_07 | TU_12 | **6.9** | | | | | | |
| | **Order** | | | **%** | | | | | |
| TU_07 | TU_10 | TU_03 | TU_12 | **17.9** | | | | | |
| TU_07 | TU_10 | TU_12 | TU_03 | **15.0** | | | | | |
| TU_10 | TU_07 | TU_03 | TU_12 | **7.4** | | | | | |
| TU_07 | TU_10 | TU_03 | TU_02 | **5.1** | | | | | |
| | | **Order** | | | **%** | | | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | **7.2** | | | | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_02 | **6.1** | | | | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_06 | **6.0** | | | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | **4.0** | | | | |
| | | **Order** | | | | **%** | | | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_02 | TU_09 | **4.1** | | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | **2.9** | | | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | **2.8** | | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_04 | **2.2** | | | |
| | | | **Order** | | | | **%** | | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_02 | TU_09 | TU_06 | **1.4** | | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | **1.2** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_02 | TU_09 | **1.1** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | **1.1** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_02 | TU_09 | TU_04 | **1.0** | | |
| | | | **Order** | | | | | **%** | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_04 | TU_06 | **0.8** | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | TU_04 | **0.7** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_02 | TU_09 | TU_04 | TU_06 | **0.7** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_06 | TU_04 | **0.7** | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_02 | TU_09 | TU_06 | TU_04 | **0.7** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_02 | TU_09 | TU_08 | **0.6** | |
| | | | | **Order** | | | | | **%** |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_08 | TU_04 | **0.6** |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_02 | TU_09 | TU_08 | TU_04 | **0.5** |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_04 | TU_02 | TU_09 | TU_08 | **0.5** |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_02 | TU_09 | TU_06 | TU_04 | TU_01 | **0.5** |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_04 | TU_06 | TU_08 | **0.4** |

**Figure A-2** Hierarchical ordering (highest) frequencies at each sequential position (from 10 to 12)

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Order** | | | | | | | | | | **%** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_04 | TU_02 | TU_09 | TU_08 | TU_01 | **0.5** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_02 | TU_09 | TU_08 | TU_04 | TU_01 | **0.4** | | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_04 | TU_06 | TU_08 | TU_01 | **0.3** | | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | TU_04 | TU_08 | TU_01 | **0.3** | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_02 | TU_09 | TU_04 | TU_06 | TU_01 | TU_08 | 0.3 | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_04 | TU_01 | TU_08 | 0.3 | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_08 | TU_04 | TU_01 | 0.3 | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_04 | TU_08 | TU_06 | TU_01 | 0.3 | | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_06 | TU_04 | TU_08 | TU_01 | 0.3 | | |
| TU_07 | TU_10 | TU_09 | TU_02 | TU_03 | TU_12 | TU_06 | TU_04 | TU_08 | TU_01 | 0.3 | | |
| TU_07 | TU_10 | TU_12 | TU_02 | TU_09 | TU_03 | TU_04 | TU_08 | TU_06 | TU_01 | 0.3 | | |
| TU_07 | TU_10 | TU_12 | TU_03 | TU_06 | TU_02 | TU_09 | TU_04 | TU_08 | TU_01 | 0.3 | | |
| TU_10 | TU_07 | TU_03 | TU_12 | TU_02 | TU_09 | TU_08 | TU_06 | TU_04 | TU_01 | 0.3 | | |
| TU_03 | TU_10 | TU_07 | TU_12 | TU_02 | TU_09 | TU_04 | TU_06 | TU_01 | TU_05 | 0.2 | | |
| **Order** | | | | | | | | | | | **%** | |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | TU_04 | TU_08 | TU_01 | TU_05 | **0.3** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_04 | TU_02 | TU_09 | TU_08 | TU_01 | TU_11 | **0.3** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_08 | TU_04 | TU_01 | TU_05 | **0.3** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | **0.3** | |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_06 | TU_04 | TU_08 | TU_01 | TU_05 | 0.3 | |
| TU_07 | TU_10 | TU_12 | TU_02 | TU_09 | TU_03 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | 0.3 | |
| TU_10 | TU_07 | TU_03 | TU_12 | TU_02 | TU_09 | TU_08 | TU_06 | TU_04 | TU_01 | TU_05 | 0.3 | |
| TU_03 | TU_10 | TU_07 | TU_12 | TU_02 | TU_09 | TU_04 | TU_06 | TU_01 | TU_05 | TU_08 | 0.2 | |
| **Order** | | | | | | | | | | | | **%** |
| TU_07 | TU_10 | TU_03 | TU_02 | TU_09 | TU_12 | TU_06 | TU_04 | TU_08 | TU_01 | TU_05 | TU_11 | **0.3** |
| TU_07 | TU_10 | TU_03 | TU_12 | **TU_06** | **TU_04** | TU_02 | **TU_09** | TU_08 | TU_01 | **TU_11** | **TU_05** | **0.3** |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_06 | TU_09 | TU_02 | TU_08 | TU_04 | TU_01 | TU_05 | TU_11 | **0.3** |
| TU_07 | TU_10 | TU_03 | TU_12 | TU_09 | TU_02 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | TU_11 | **0.3** |
| TU_07 | TU_10 | TU_03 | TU_12 | **TU_09** | TU_02 | **TU_06** | **TU_04** | TU_08 | TU_01 | **TU_05** | **TU_11** | 0.3 |
| TU_07 | TU_10 | TU_12 | TU_02 | TU_09 | TU_03 | TU_04 | TU_08 | TU_06 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_10 | TU_07 | TU_03 | TU_12 | TU_02 | TU_09 | TU_08 | TU_06 | TU_04 | TU_01 | TU_05 | TU_11 | 0.3 |
| TU_03 | TU_10 | TU_07 | TU_12 | TU_02 | TU_09 | TU_04 | TU_06 | TU_01 | TU_05 | TU_08 | TU_11 | 0.2 |