DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

TRANSPORT INFRASTRUCTURE AND REGIONAL GROWTH: CASE OF THE TURKISH REGIONS

by
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İZMİR

TRANSPORT INFRASTRUCTURE AND REGIONAL GROWTH: CASE OF THE TURKISH REGIONS

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We have read the thesis entitled **"TRANSPORT INFRASTRUCTURE AND REGIONAL GROWTH: CASE OF THE TURKISH REGIONS"** completed by **ZEYNEP ELBURZ** under supervision of **PROF.DR. K. MERT ÇUBUKÇU** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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TRANSPORT INFRASTRUCTURE AND REGIONAL GROWTH: CASE OF THE TURKISH REGIONS

ABSTRACT

The economic effects of transport infrastructure on economics have been attracting a great deal of attention both from policy makers and researchers since the pioneering works of Aschauer in the late 1980s. From the policy makers' point of view, the provision of infrastructure, which generates positive externalities and promotes the productivity of firms, is an important policy tool for promoting regional growth and reducing regional disparities. For this reason, Turkey has invested in transportation infrastructure to diminish the regional economic inequalities since the early 1960s. However, this serious change in the transport infrastructure stock has captured little attention in the literature.

To our knowledge, this study is the first attempt to measure the latest developments of transportation infrastructure in twenty-six NUTS 2 regions in Turkey with a spatial perspective. The aim of this study is to examine spatial effects of public transportation infrastructure investments on regional economic growth. We employ a Cobb-Douglas production function model, and estimate the model with spatial panel model. The novelty of this study lies on selecting the most appropriate spatial weight matrix for detecting the spatial effects more accurate. We create 11 different spatial weight matrices pertaining to each year for the period 2004-2014, which reflect the change over time, to capture the impacts of recently built-up roads or extension the existing ones on regional economic growth. The results show that infrastructure investment has significant and positive spillover effect on regional growth and employing multiple spatial weight matrices matters for obtaining the significant and accurate findings.

Keywords: Spatial weight matrix, spatial Durbin model, road infrastructure

ULAŞIM ALTYAPISI VE BÖLGESEL BÜYÜME: TÜRKİYE ÖRNEĞİ

ÖZ

Ulaşım altyapı yatırımlarının bölgelerdeki ekonomik etkisi uzun yıllardır hem politika hazırlayıcılarının hem de araştırmacıların ilgisini çekmektedir. Özellikle Aschauer'in (1989, 1990) ilham verici çalışmalarının ardından, ulaşım altyapı yatırımları ile bölgesel ekonomik performans arasında pozitif bir ilişkinin olduğuna dair genel bir kanı oluşmuştur. Politika hazırlayıcılarının perspektifinden bakıldığında ulaşım altyapı yatırımlarının bölgesel büyümeyi hızlandıran ve bölgesel farklılıkları azaltan önemli bir politika aracı olduğu görülmektedir. Bu sebeple, Türkiye 1960 sonrasında az gelişmiş bölgelere, farklılığı azaltmak adına ulaşım yatırımlarını arttırmıştır. Türkiye'de ulaşım yatırımlarındaki bu ciddi artış literatürde henüz yeterince yer bulamamıştır.

Bu çalışma NUTS 2 bölgelerinde ulaşım yatırımlarının bölgesel ekonomi üzerindeki etkisini mekânsal boyutuyla ölçecek ilk çalışma olacaktır. Bu çalışmada genişletilmiş Cobb-Douglas üretim fonksiyonu Türkiye NUTS 2 bölgelerine ulaşım altyapı yatırımlarının katkısını ölçmek adına kullanılacaktır. Bu çalışmada diğer çalışmalardan farklı olarak mekânsal etkileri daha doğru ve etkin şekilde ele alabilmek adına farklı mekânsal ağırlık matrisleri kullanılmıştır. Bu bağlamda 2004-2014 yılları gerçek mesafeye dayanan 11 farklı ağırlık matrisi oluşturulmuştur. Sonuçlar ulaşım altyapısı yatırımlarının olumlu ve anlamlı yayılma etkilerinin olduğunu ve farklı mekânsal ağırlık matrisi kullanımının geçerliliğini göstermektedir.

Anahtar Kelimeler: Mekânsal ağırlık matrisi, mekânsal Durbin modeli, karayolu altyapısı

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CHAPTER ONE
INTRODUCTION

Regional economic growth and development theories have witnessed a rapid increase in the last decades since the foundations of modern economic growth theory (Barca et al., 2012; Capello and Nijkamp, 2011). Neoclassical growth theory, the most influential model in modern growth theory (Dawkins, 2003), explains sources of output growth with three factors - capital stock, labor force and technology (Armstrong and Taylor, 2000). The neoclassical growth theory claims that regional economic disparities vanish in the long-run based on spatial mobility of these production factors assumption (Capello and Nijkamp, 2009). Based on Solow (1956) model, the theory assumes that the level of technology which is the only factor that determines a region's growth rate in long-run is exogenous. Barro and Sala-i-Martin (2004) criticize this unrealistic assumption and label the model as "a model of growth that explains everything but long-run growth" (Barro and Sala-i-Martin, 2004, p.18). By taking into account of the shortcoming of neoclassical approach, endogenous growth theory attempts to modify assumptions of the neoclassical growth model (Dawkins, 2003). The endogenous growth theory, developed by Romer (1986) and Lucas (1988), takes technological progress as endogenous by emphasizing the importance of human capital. Contrary to neoclassical approach, the endogenous growth theory presumes increasing marginal productivity of production factors. However, depending on how technological change is made endogenous, the theory allows both convergence and divergence in the long-run (van Dijk et al., 2009). Subsequently, Krugman's (1991) New Economic Geography demonstrates the spatial dimension of regional growth with "core-periphery" model for economic activity clusters (Dawkins, 2003). New economic geography basically attempts to "explain the formation of a large variety of economic agglomeration (or concentration) in geographical space" (Fujita and Krugman, 2004, p. 140). New economic geography models are based on cumulative causation models and the agglomeration process of firms and labor in a developed region because of economies of scale advantages, may cause divergence. Instead of taking transport cost as zero in the traditional trade theories, new economic geography includes transport cost as a substantial element for that influences location choices (Ascani et al., 2012). According to the new economic geography, improved transport and communication infrastructure between core and peripheral regions may foster agglomeration process and thus deepens regional disparities (Minerva and Ottaviano, 2009) however, decreased transport costs may also cause convergence (van Dijk et al., 2009). Therefore, while endogenous growth theory encourages policy makers on the impacts of policy measures, new economic geography is pessimistic about the effects of policies (van Dijk et al., 2009). As an important policy instrument, the role of infrastructure has been emphasized along two dimensions: the effect of infrastructure on economic growth and the effect of infrastructure on income inequality (Calderon and Serven, 2004). In this study, we focus on the relationship between infrastructure and regional economic growth.

The role of public investment in the economic growth process has been mostly investigated in the development economics in the 1950s (Button, 1998) and since the end of the 1970s, public investment has been considered as a major regional policy instrument with its complementary effects on private investment (Martinez-Lopez, 2006). Neoclassical economics consider public investment as the generator of economic growth and source of regional convergence (Rodriguez-Pose et al., 2012). Endogenous Growth Theory reexamines the effects of public capital and sees public spending as an important long-term growth factor (Barro, 1990). Along with the theoretical view, the inspiring study of Aschauer (1989) has caused public investment to reattract great attention (Gonzalez-Paramo and Martinez, 2003; Rodriguez-Pose et al., 2012). Public investments which are any capital outlay of a government (United Nations [UN], 2009) can be divided into three categories: (1) investment in infrastructure, (2) investment in human capital, and (3) investment in technical progress. All categories are closely related with economic growth (Lloyd, 1999). Although the effects of investment in infrastructure on regional development have been investigated with different aspects in urban economics, business, regional science and geography literature (Bergman and Sun, 1996), the definition and classification of infrastructure have lack of consensus.

Rostow (1960) and Hirschman (1958) use the notion of social overhead capital as a synonym of infrastructure. According to Hirschman's Unbalanced Growth Theory (1958, p.83), infrastructure is "the basic service which without the primary, secondary and tertiary economic activities cannot function", while Rostow (1960) views social overhead capital as a pre-condition for take-off stage. Jochimsen (as cited in Torrisi 2009) defines infrastructure as "the sum of material, institutional and personal facilities". Gramlich (1994, p.1177) states that "the definition infrastructure that makes the most sense from an economics standpoint consists of large capital intensive natural monopolies such as highways, other transport facilities, water and sewer lines, and communications systems". Banister and Berechman (2003, p. 35) define infrastructure as "the durable capital of the city, region and the country and its location is fixed". Kapshe et al. (2003, p. 291) delineate infrastructure as "the system of linkages that facilitate and enable the flow of goods and services which includes road, railways, electric power systems etc.". Weisdorf (2007, p.17) defines infrastructure as "the essential facilities and services that the economic productivity depends on" which includes the movement of goods, people, water and energy. Fulmer (2009, p.30) describes infrastructure as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions".

As well as definitions, there many classifications for infrastructure in the economic literature. Aschauer (1989) considers transport (roads, airports) and networks (sewers, electrical facilities) as the core infrastructure and others as non-core infrastructure. On the other hand, Biehl (1991) divides infrastructure into two groups as network (roads, electrical facilities) and nucleus (schools and hospitals). More recently, Sturm et al. (1995) classify infrastructure investments into two groups because of analytical reasons. The first group is called basic infrastructure, and includes main railways, roads, ports, drainage. The second group is called complementary infrastructure, and includes urban tramways, gas electricity, and water supply. Weisdorf (2007) categorizes infrastructure into four groups. Transportation assets include roads, railroads, airports, ports; communication assets include radio and television broadcast towers, cable systems; regulated assets include electricity transmission lines, gas and oil pipelines, sewerage systems and finally social assets include schools, hospitals, and courthouses.

The classification of infrastructure in empirical studies depends on not only the theoretical background but also data availability (Torrisi, 2009). The lack of a universal definition and classification of infrastructure create complexity on measuring infrastructure endowment considering also availability of infrastructure data. Infrastructure endowment can be measured in monetary and physical terms both which have advantages and disadvantages for empirical studies. Golden and Picci (2005) point to the shortcoming of using monetary measures of public works by underlying the differences between value and cost of public infrastructures due to mismanagement, waste, and corruption.

Taking into account the different aspect of infrastructure that has been underlined in the literature, the basic characteristics of infrastructure can be summarized as follows (Kapshe et al., 2003; Kay, 1993; World Bank, 1994):

- Infrastructure cannot be imported from other places,
- Infrastructure facility has built in a minimum size thus it is indivisible,
- Infrastructure has benefits for all society,
- Infrastructure is generally public provided because of high first investments,
- Infrastructure has long gestation period,
- Infrastructure is developed in a network structure,
- Infrastructure has elements of natural monopolies,
- Infrastructure capital cost is larger than running cost,
- Infrastructure reduces the production cost,
- Infrastructure has high sunk cost
- Infrastructure is essential for all kind of production but infrastructure alone is not productive.
- Infrastructure is considered as pre-condition of development.

Based on neo-classical economics which consider infrastructure as an input to production along with labor and private capital, any improvements of infrastructure result in higher productivity (Rietveld and Nijkamp, 1992). In the long-run, the contribution of an infrastructure provision on regional economy varies based on infrastructure type. Transportation and communication infrastructure for example has primary role on integrating a region with the rest of the network (Gomez-Antonio and Garijo, 2012) and has been at the origin of the economic development (Vreeker and Nijkamp, 2005).

The debate on the economic effects of transport infrastructure investments has been attracting a great deal of attention both from policy makers and researchers. In the mainstream economic literature, transport infrastructure has been claimed as an important determinant of economic growth due to its effects on reducing transport cost and increasing accessibility. From the policy makers' point of view, the provision of infrastructure is an important policy tool for promoting regional growth and reducing regional disparities. For this reason, Turkey has invested in transportation infrastructure to reduce the regional economic inequalities since the 1960s (Karadağ et al. 2004). However, this serious change in the transport infrastructure stock that costs approximately 65 billion dollars last decade has captured little attention in the literature.

To our knowledge, this study is the first attempt to measure the latest developments of transportation infrastructure in twenty-six NUTS 2 regions in Turkey with a spatial concern. The aim of this study is to examine spatial effects of transportation infrastructure investments on regional economic growth by using spatial econometric models. The originality of this paper can be listed as follows.

First, unlike most of the studies in the literature using a simple contiguity spatial weight matrix for the spatial econometric models, we create a spatial weight matrix for each year from 2004 to 2014. Taking into account the huge investments on road infrastructure in Turkey since 2003, we believe that relying on a spatial weight matrix would not capture the difference on the distance between the regions and thus would not control the neighborhood criteria. So we measure the real time distance between 26 NUTS 2 regions in Turkey for each year and create 11 different spatial weight matrices. In this way, we fill in the literature a gap about describing the spatial relation which changes over time due to changes in the road infrastructure network.

Second, this study is the first attempt to measure the latest developments of transportation infrastructure in Turkey from a spatial perspective. Previous studies that investigate the impacts of transport infrastructure on regional economy in Turkey have largely ignored the spatial spillovers and focus on only standard econometric models.

Third, we use the most recent regional data from TurkStat that contains regional Gross Domestic Product (GDP) data until 2014. As it is reviewed in the Chapter 2, previous Turkish case studies mostly use old provincial data from 2000 or regional Gross Value Added (GVA) data.

We believe investigating the recent improvements in road infrastructure with a spatial perspective in an emerging economy as Turkey is necessary to generate more effective and practical regional policies.

The structure of this study is as follows. In Chapter 2, the previous studies that investigate transport infrastructure and regional growth relation with spatial and non-spatial aspects are reviewed. Also Turkish case studies in the literature review section are focused on. In Chapter 3, Turkish transport infrastructure investments and future goals for extending the existing road network are looked into. Chapter 4 then introduces the data and the sources of the variables and presents the spatial weight matrices that used in this study. Chapter 5 describes the empirical model apply to analyze the spatial effect of transport infrastructure on regional economy. The results of the spatial econometric models are reported in Chapter 6. Finally, Chapter 7 contains the main conclusion with several policy recommendations that ensue from the estimated results from the previous chapter.

CHAPTER TWO
LITERATURE REVIEW

The long-run effects of transport infrastructure on regional development are various, complex and difficult to analyze. Basically, it is accepted that improvement of transport infrastructure causes reduction of transport cost/travel times and increase in accessibility. This situation leads to redistribution of economic groups and also an increase in transportation volumes (Reitveld and Nijkamp, 1992). Provision of transport infrastructure also leads to a raise in private investments, stimulation of trade and thus creation of jobs in the regions (Deng, 2013). These are why transport infrastructure is portrayed as an element for reaching regional development goals such as reducing income inequalities and fostering trade in the continental approach. Since relying on market to achieve these goals is not efficient, there is a need for government intervention on the transportation sector. This situation makes transport the policy to be more integrated with regional economic development policies considering the fact that policy makers use transportation infrastructure as major policy instrument for both developing and advanced economies. For example, European Union Regional Development Fund invests mostly on transportation infrastructure to promote economic growth and to reduce regional disparities. The main reason underlying this approach is the view that transportation promotes mobility, mobility promotes trade, and trade promotes economic growth (Vickerman, 2002; Button, 2005).

However, it should be noted that an improvement of a link in a transportation network may not have positive impacts for all regions in the network. Some regions may lose their markets because of increasing competition with low transportation costs (Reitveld and Nijkamp, 1992). As Puga (2002) states, transport infrastructure has two lanes going both ways, which makes mobility easier and cheaper for all developed and lagging regions. Increased mobility may have negative effects on lagging regions due to out-migration of capital and labor by the helping of increased transport infrastructure stock. Thus increasing the stock of infrastructure may harm regional economic growth rather than raising productivity.

Lall (1999) claims that the effects of infrastructure depend on many factors such as level of development, initial infrastructure endowments, and spillover effects. Gomez-Antonio and Garijo (2012) add diversity of productive structures and institutional and political factors to Lall (1999)'s study to classify the reasons behind the uncertain effects of infrastructure on regional economy. In the development economics, different effects of infrastructure on regions with different levels of development have already been questioned by Hansen (1965). While Hirschman (1958) hypothesizes to promote social overhead capacity (public infrastructure investments) in developing urbanized regions, Hansen (1965) argues that in the early stages of development, economic overhead capital (transportation and networks) should be allocating in intermediate regions to maximize the effectiveness of public infrastructure. Reitveld and Nijkamp (1992) also state that developing countries with low infrastructure stock would have higher transport infrastructure impact than in developed countries due to decreasing marginal productivities.

The general notion on the effects of transportation infrastructure is that transportation infrastructure is a precondition for regional development when other complement resources are present and the region has already potential for new development, but it is alone not sufficient to reach regional development goals (Rephann, 1993; World Bank, 1994; Rietveld and Nijkamp, 1992).

2.1 Empirical Studies

According to Lakshmanan (2011), the first study that investigates the effects of public infrastructure on regional economic growth is Mera (1973)'s study. Mera (1973) reports a positive impact of transport and communication infrastructure on manufacturing and service sectors for Japanese regions from 1954 to 1963. But it is Aschauer (1989)'s study that attracts great attention from both academics and policy-makers for the relation between public infrastructure and economic growth. Based on supply driven neo-classical economics approaches, Aschauer (1989)'s study considers infrastructure as an important factor in the production function to explain the productivity slowdown of the 1970's and 1980's. Aschauer (1989) focusses on the period from 1949 to 1985 by using public capital stock and productivity data with Cobb-Douglas production function model. He distinguishes public non-military capital type into five categories. According to his results, core infrastructure which includes highways, mass transit, airports, electrical and gas facilities, water, sewer is the biggest explicator of productivity with an elasticity of 0.24 compared to other public capital types. He interprets this significant and high result as an evidence of the importance of the public capital to explain productivity decline in the 1970's and 1980's in the USA. He concludes that the public infrastructure contributes productivity rise and economic growth. Aschauer's view has been supported by Munnell (1990a). Munnell (1990a) builds her study upon Aschauer's insight to explain the slowdown in productivity growth in the USA using public capital with a similar methodology. Munnell (1990a) finds that 1% increase in public capital may raise productivity by 0.31% to 0.39%. Munnell (1990b) also analyzes the relationship between productivity and public capital at the subnational level from 1970 to 1986. The Cobb-Douglas production function model results confirm the strong relation with a lower elasticity (0.15) at the state level. Even though Aschauer (1989)'s study can be considered as a milestone in the empirical literature on the effects of public infrastructure, Aschauer's highly significant and positive view is far from being the norm (Rodriguez-Pose et al, 2012).

Aschauer (1989)'s study and his very high elasticity results which labelled as "Aschauer effect" have been criticized and objected by many researchers. The major criticism is about the causality issue between output and infrastructure. Eisner (1991) underlines a serious question for the state output and public capital by questioning which one is the cause and which one is the effect. Hulten and Schwab (1993) also point out the direction of causality problem by indicating that causality does not run only from public infrastructure to output but it may run in both directions. Tatom (1993) deprecates the USA economic program which views increased spending on infrastructure is an urgent national priority based on the inspiring works of Aschauer (1989) and Munnell (1990a). Tatom (1993) claims that these studies have spurious regressions problems and adopting simply first-differenced data can eliminate the problem. According to the results, public capital effects are not statistically different from zero. Tatom (1993) also investigates the causality using Granger Causality test and finds same direction of influence as Eisner (1991).

Second criticism is about the ignorance of the nonstationary of the data which can cause spurious correlation between public capital and output. Aaron (1990) and Hulten and Schwab (1991) state that the time series data from previous studies suffer from nonstationary. They suggest removing drift trend from the data to examine the true relationship between the variables by employing first differencing. Their results indicate no systematic relation between public capital and productivity for the USA case. However, Munnell (1992) displays the problem of first differences which hinders to estimate the long-term relationship between input and output. Another criticism comes from Tatom (1991) about Aschauer (1989)'s model specification. Tatom (1991) argues that Aschauer's high elasticity findings are the results of misspecification of production function. He suggests including energy prices which has negative effects on productivity to the production function model. However, this approach also receives critiques for mixing production and cost functions (Gramlich, 1994).

The 1990's was the golden years for the infrastructure investment studies following the seminal work of Aschauer (1989). Evans and Karras (1994) use Cobb-Douglas production function to estimate the elasticity of highway capital stock with panel data (see Table 2.1). After controlling region and time effects by fixed effects model, they find no evidence that highway capital is productive. They conclude that the US as a whole does not suffer from under provision of public capital, but may suffer from overprovision. Holtz-Eakin and Schwartz (1994) investigate 48 states from US between 1971 and 1986 with panel data, and reach negligible effects of infrastructure on annual productivity growth. Baltagi and Pinnoi (1995) also examine the relationship between public infrastructure and economic performance in 48 contiguous states over the period 1970-1986 with panel data. They reach similar results with Munnell (1990b) when region specific effects are ignored with a simple Ordinary Least Squares (OLS) model. On the other hand, when they employ Instrumental Variable (IV) model, highways and streets effects are statistically insignificant. Garcia-Mila et al. (1996) perform state-level production function using public capital as in input for the time period between 1970-1983. After controlling random and fixed state effects, measurement error, and endogeneity problems, panel data model results reveal no significant effect of highway capital investments on state output.

Basically, studies that focus on the effects of public infrastructure at the regional level tend to reach insignificant impacts by taking into account the previous critics in the early studies. Pereira and Andraz (2013) discuss the underlying reason for the different findings between the empirical studies and suggest that spillover effect is a possible explanation for this, since infrastructure impacts are confined to specific regions only (Moreno and Lopez-Bazo, 2007). Holtz-Eakin and Schwartz (1995) address spillover effect issue by measuring the indirect effect of highway capital stock on neighboring states with panel data from 1969 to 1986. They find that highway capital stock has no statistically significant spillover effect on productivity for the USA case. Kelejian and Robinson (1997) consider spatial interaction by using spatial lags of dependent and independent variables to assess the infrastructure effect on 48 states from 1972 to 1985. They perform several estimation models and conclude that estimation results are very sensitive to model specification, and neighbor infrastructure is not significant when spatial correlation is considered. Boarnet (1998) claims that point infrastructure produces local benefits, while network infrastructure produces spillover effects. Thus, the effects of public capital need be clarified. He tests for the existence of negative output spillovers for 58 counties in California from 1969 to 1988 by using same street and highway capital stock data with Holtz-Eakin and Schwartz (1995). The results suggest that street and highway capital of Californian counties negatively affect neighboring counties' output.

Table 2.1 Empirical studies

Authors	Year	Data Type	Time Period	Estimation	Scope	Country	Transportation Meas.	Spillover Effect	Results
Aschauer	1990	pooled data	1960-1985	OLS WLS 2SLS	48 states	USA	existing road mileage	-	Positive
Munnell	1990	pooled data	1970-1986	OLS	48 states	USA	highway	-	Positive
Evans and Karras	1994	panel data	1970-1986	FE	48 states	USA	highway capital stock	-	Insignificant
Holtz-Eakin and Schwartz	1995	panel data	1969-1986	ML	48 states	USA	highway capital stock	spillover effect	Insignificant spillover effects
Baltagi and Pinnoi	1995	panel data	1970-1986	OLS, FE	48 states	USA	highway and street ways	-	Insignificant
Garcia-Milla et al.	1996	panel data	1970-1983	FE	48 states	USA	highway investment capital	-	Insignificant
Kelejian and Robinson	1997	panel data	1972-1985	OLS 2SLS GMM	48 states	USA	highway public capital	spillover effect	Sensitive to econometric problems
Percoco	2004	panel data	1970-1994	ML 2SLS	20 regions	Italy	roads, rail, maritime, communication	spillover effect	Positive
Cantos et al.	2005	panel data	1965-1995	FE, IV	17 regions	Spain	road railway port airport capital stock	spillover effect	Positive
Berechman et al.	2006	time-series	1990-2000	OLS	48 state, 18 county, 389 municipality	USA	highway capital stock	spillover effect	Positive
Ozbay et al.	2007	time-series	1990-2010	OLS	18 counties	USA	highway capital stock	spillover effect	negative spillover effect
Kuştepeli and Akgüngör	2010	cross section	2000	OLS	26 regions	Turkey	rural asphalt road, proportion of asphalt road	-	Positive
Jiwattanakulpaisam et al.	2012	panel data	1984-2005	GMM-SYS	48 states	USA	roadway lane mile	-	Positive

The studies that investigate spillover effects at European countries reach positive evidence mostly. Percoco (2004), for instance, focuses on Italian regions for the period 1970-1994 to analyze the impact of public capital on productivity using a Cobb-Douglas production function. He adds one-year lag of public capital stock to overcome endogeneity and public capital stock in neighboring regions to account for spillover effects to the model. The results indicate that public capital has a positive effect on regional productivity, while railways and maritime infrastructure have higher effects than road infrastructure.

Similarly, Cantos et al. (2005) find positive and significant spillover effects for transportation infrastructure for Spanish regions by using one-year lagged infrastructure as an instrumental variable. Berechman et al. (2006) use three different geographical levels-state, county and municipality- to understand different spillover effects based on geographical study areas. According to the results from highway capital stock data from 48 states, 18 counties and 386 municipalities in the USA, the impact of public infrastructure declines as the geographical level gets smaller due to spillover effects.

2.2 Empirical Studies with Spatial Interaction

Studies mostly concentrated on the spatial effects of transport infrastructure by using spatial econometric models as well as causality and non-stationary issues which have been highly criticized in the literature since the 1990s. Cohen (2010) argues that ignoring spatial effects may cause omitted variable bias, which creates inaccurate estimations of infrastructure effects (see Table 2.2). He uses the US states highway capital stock data for 1996 to investigate the broader benefits, which refers to indirect benefits that may result from spatial interaction of transportation infrastructure. The results based on spatial lag model with contiguity weight matrix show a positive effect of transport infrastructure on the output. Jiwattanakulpaisarn et al. (2011) suggest using dynamic production function approach with an additional variable to capture spatial spillover effects from highway capital stock to outputs of neighboring states. They use five different spatial weight matrices based on contiguity and distance, since the literature does not point out the correct spatial weight matrix for all studies. Their findings reveal positive spillover effects of highway improvements to the neighbors. It is also underlined that employing distance decay matrix helps to reach higher output elasticities compared to the other four spatial weight matrices.

For the case of EU regions, Del Bo and Florio (2012) apply Moran's I statistics test to regional Gross Domestic Product (GDP) as a spatial diagnostic test. The results indicate that there is a spatial autocorrelation and thus the OLS estimates that ignore spatial effects, can be misleading and biased. They prefer to use spatial Durbin model (SDM) with respect to likelihood ratio (LR) tests results with row-standardized contiguity matrix (W) based on inverse of geographical distance. The findings demonstrate that while motorways have positive direct and insignificant indirect effects, other roads have negative direct and positive indirect effects on regional GDP. Del Bo and Florio (2012) underline the presence of investment complementary across European regions regarding the spatial econometric analysis results.

Xueliang (2013) takes China as example to examine the role of transport infrastructure to promote regional economic growth using a panel data for 29 Chinese provinces and regions. The model which contains spatial spillover effects of transport infrastructure is estimated with the fixed effects spatial lag model with four different spatial weight matrices (W). These four spatial weight matrices are created on the basis of binary contiguity, population density, GDP per capita, and transport network. The positive and significant results show that improvement of transport infrastructure fosters regional economic growth however; ignoring spatial spillover effects in the model causes overestimation o the role of transport infrastructure. Even though the spatial spillover effects of highway mileage in neighboring regions are mostly positive, taking into account the model with spatial weight matrix based on population density reveals negative spatial spillovers. Xueliang (2013) relates this finding with high mobility and one-way movement of population and suggests local governments to improve their investment environment for not losing human capital and labor in their regions. Arbues et al. (2015) contribute the literature by estimating a spatial Durbin model for 47 Spanish provinces by controlling for endogeneity issue and spatial spillovers. Spatial lags of disaggregated transport infrastructure, dependent variable and other explanatory variables are added in Cobb-Douglas production function model, and the model is estimated with maximum likelihood (ML) and generalized method of moments (GMM). Arbues et al. (2015) build two spatial weight matrices based on binary contiguity and physical contiguity matrix and row-standardize them. They find evidence of highly significant and positive direct and indirect effects of road capital stock on regional output. The results indicate that improvement of road infrastructure in Spanish provinces would create a productivity rise in neighboring provinces up to 5.5%.

Table 2.2 Empirical studies with spatial models

Authors	Year	Data Type	Time Period	Estimation	Scope	Country	Transportation Meas.	Spatial Weight	Results
Boarnet	1998	pooled data	1969-1988	GLS Spatial Lag Model	58 countries	USA	street and highway capital stock	contiguity matrix	Both positive and negative spillover effects
Cohen	2010	cross section	1996	Spatial Lag OLS, 2SLS	48 states	USA	highway capital stock	contiguity matrix demographic variables	Positive
Jiwattanakulpaisam et al.	2011	panel data	1984-1997	OLS, FE, BG, FGLS, GMM, 2SLS	48 states	USA	Existing road lane miles	binary contiguity and inversed distance matrix	Positive
Del Bo and Florio	2012	cross-section	2006	OLS, 2SLS, SDM	262 regions	EU	length of motorways and regular roads	contiguity based on inverse distance	Positive
Tong et al.	2013	panel data	1981-2004	SDM	44 states	USA	road disbursement, rail miles	contiguity matrix	Positive
Xueliang	2013	panel data	1993-2009 2000-2009	FE SLM	29 province, region	China	km of highways	binary contiguity	Positive
Chen and Haynes	2015	panel data	1991-2009	SAR SEM SDM	32 MSA	USA	highway and railway stock	contiguity matrix	Positive
Arbues et al.	2015	panel data	1986-2006	SDM ML IV GMM	47 provinces	Spain	road capital stock	contiguity matrix	Positive
Li et al.	2017	panel data	2005-2014	SARFE Spatial torbit model	31 provinces	china	highway network km/km2	binary matrix	Positive
Dehghan Shabani and Safaie	2018	panel data	2001-2011	SDM FE	28 provinces	Iran	road length per capita	inverse distance	Positive

More recently, Dehghan Shabani and Safaie (2018) investigate 28 Iranian provinces from 2001 to 2011 to measure direct and spillover (indirect) effects of road transport infrastructure on economic growth with spatial Durbin model (SDM) and maximum likelihood (ML) estimation method. They create spatial weight matrix based on inverse Euclidean distance to capture spillover effects more properly than simple binary contiguity weight matrix. The estimation results give clear evidence of positive direct, indirect and total effects of main road length per capita on regional GDP per capita. Regarding the results, Dehghan Shabani and Safaie (2018) recommend policy-makers to increase cross-regional transport networks mostly.

2.3 Empirical Studies for Turkish Case

Transportation infrastructure investments have been used as an important policy instrument for policy-makers in Turkey since 1960's. However, the number of studies that focuses on the effects of transportation infrastructure on regional economic growth is limited. Kuştepeli and Akgüngör (2010) investigate this phenomenon by using cross section data from 2000 with 26 NUTS 2 regions in Turkey. With very limited number of observations, they employ Cobb-Douglas production function approach. The results demonstrate that asphalt roads in rural areas and asphalt road ratio in total roads variables significant and positive in the model. An increase in the asphalt road variables may increase the value added of the manufacturing industry in Turkey.

Önder et al. (2010) analyze the dynamic effects of transportation capital stock on regional economic convergence at NUTS 2 level in Turkey for the time period 1980 to 2001. They use per capita transportation capital stock calculated with perpetual inventory method (PIM) for least squares dummy variables (LSDV) and generalized method of moments (GMM) techniques. They report evidence of negative impact of transportation capital stock on regional convergence and relate these results with uneven distribution of transport investments on developed and less developed regions. They suggest allocating more transport infrastructure on less developed regions in order to reduce regional disparities between western and eastern regions.

Celbiş et al. (2015) analyze infrastructure and export performances of NUTs regions for the years 2002 through to 2010. According to the results, land infrastructure which contains road, highway and railroad stocks, plays an important role in regional exports. Recently, Elburz et al. (2017) study the role of transport infrastructure stock in the Turkish regions with different estimation methods. They use OLS, fixed-effects, 2SLS and Hausman-Taylor IV estimations with region and time effects from 2004 to 2011. The results confirm that the road and highway infrastructure have significant and positive effects on Turkish regional Gross Value Added (GVA).

Based on the review of the transport infrastructure effects literature, it can be said that the results are quite heterogeneous and one of the main reasons for this is the about the measurement of the spatial spillover effects of transport infrastructure. The studies that measure spatial effects of transport infrastructure on regional economy in the economic literature rely on simple spatial weight matrices without any arguments on how to define neighboring regions. As it is underlined in the introduction section, the originality of this study lays in the definition the neighborhoods for spatial weight matrix to have accurate spatial spillover effects by using spatial econometric models.

CHAPTER THREE
TURKISH TRANSPORT INFRASTRUCTURE

Public infrastructure investment has been seen a substantial policy tool for promoting regional growth and reducing regional disparities in both developed and developing countries as well as in Turkey. Since the 1960s, Turkey has invested in infrastructure -mainly transport infrastructure- to reach development goals as indicated in Development Plans (Karadağ et al., 2004).

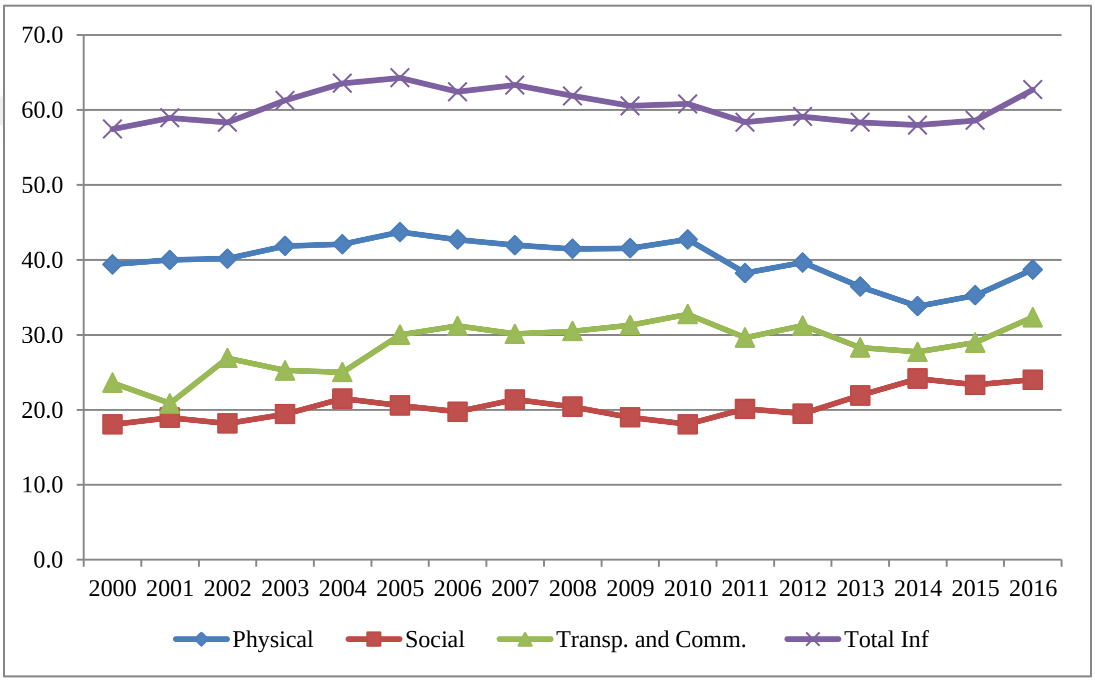

Figure 3.1 Shares of public infrastructure investments in public investments (%) (Source: Ministry of Development)

Figure 3.1 shows the shares of public infrastructure investments types based on the categories in the literature in public investments from 2000 to 2016. Total infrastructure is composed of physical (transportation/communication and energy) and social infrastructure (health and education) and it has an average of 61% share in public investments during 2000 and 2016. It can be seen that the share of social infrastructure in public investments is growing (average of 21%), while physical infrastructure's share (average of 40%) is decreasing in the same time period. One possible explanation for this decline is the dramatic fall in energy investments due to policy of privatization of energy sector (Serdaroğlu, 2016). For the case of transportation and communication infrastructure investments, there is an up-going trend of shares in public investments. Approximately 30% of public investment is allocated to transportation and communication infrastructure every year. The share of it in public investment has reached 32.7% in 2010 with the highest share since 2000. According to latest Development Plan, this ratio is expected to rise to 34% for the period of 2014-2018 (Ministry of Development, 2013).

In Turkey, fostering transport infrastructure -especially road infrastructure- has been considered a priority for achieving economic development. Since the 1950s, road transport is the dominant transport type in Turkey which leads to substantial improvement process of road infrastructure by neglecting railway and maritime infrastructure (Ministry of Transport and Communication, 2011). According to the statistics of Ministry of Transport and Communication, governments have expended approximately 65 billion dollars for road infrastructure between 2004 and 2014. The highest road infrastructure investment has been made in 2011 with 8.8 billion dollars and has a percentage of 1.06% in GDP in the same year (Table 3.1 and Figure 3.2).

Table 3.1 Road infrastructure investment expenditures (2004-2014) (Source: Ministry of Transport and Communication)

	Investment (Billion $)	Percentage of GDP (%)
2004	2.30	0.46
2005	3.15	0.52
2006	3.80	0.60
2007	4.14	0.53
2008	6.30	0.74
2009	5.93	0.87
2010	8.52	1.05
2011	8.88	1.06
2012	7.54	0.91
2013	7.62	0.90
2014	7.24	0.89

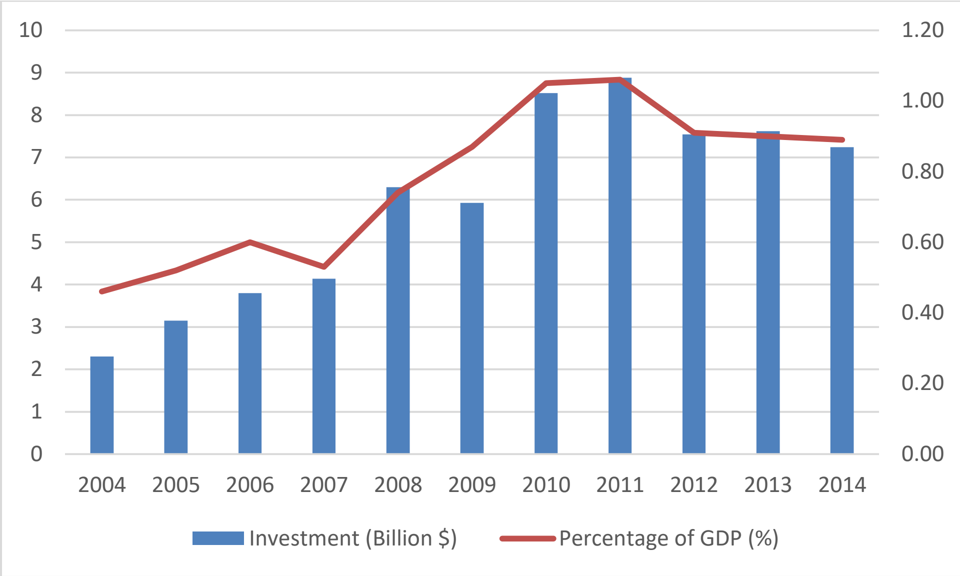

Figure 3.2 Road infrastructure investment expenditures (Source: Ministry of Transport and Communication)

Turkish road infrastructure contains three categories: highways, provincial roads and state roads. Between 2004 and 2017, 17378 km provincial/ state roads and 869 km motorways have been built (Figure 3.3). In 2016, the total road infrastructure in Turkey reach 66,970 km and almost half of the network consists of provincial roads (49.8%) as indicated in Table 3.3. Recent Turkish road infrastructure network can be seen in Figure 3.4.

Table 3.2 Road network in Turkey (2016) (Source: Ministry of Transport and Communication)

	Km	%
Highways	2,489	3.7
Provincial Roads	33,355	49.8
State Roads	31,126	46.5
Total	66,970	100

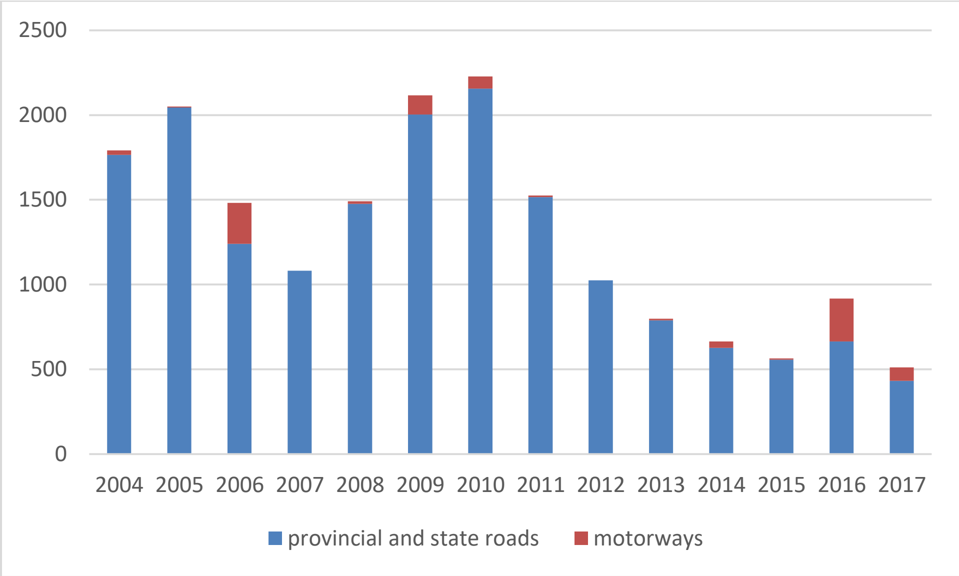

Figure 3.3 Completed road infrastructure lengths (km) (Source: Ministry of Transport and Communication)

As a result of the governmental policy on investing mainly on road infrastructure since the 1950s, road transport has the lion share of both passenger and freight transport. Table 3.3 shows that road infrastructure has 89.2% of passenger transport (passenger-km) while air transport has only 9.01% in 2015. The case of freight transport (ton-km) is similar with passenger transport, almost 90 percent of freight transport uses road infrastructure.

Table 3.3 Share of passenger and freight transport (2015) (%) (Source: Ministry of Transport and Communication)

	Passenger (%)	Freight (%)
Highways	89.2	89.8
Airlines	9.01	-
Railways	1.01	3.9
Sea Routes	0.6	6.3
Total	100	100

Based on 2023 prospects, population of Turkey is expected to be more than 85 million while total passenger is estimated to reach 500 billion in all modes of transportation. For highways, 378 billion passengers are predicted and that is why road transport development is essential for Turkey (Ministry of Transport and Communication, 2011). The first National Regional Development Strategy which has been prepared by the Ministry of Development (2015) also points out the importance of transport infrastructure as a prominent regional development goal by to increasing accessibility. By taking into account this goal, the General Directorate of Highways (KGM) has launched a highway construction program for building new highways to connect metropolitan cities with trade centers (see Figure 3.5 and Figure 3.6). General Directorate of Highways is planning to reach 8227 km. highway network by constructing 5738 km new highways by the end of 2035 (Table 3.4).

Table 3.4 Highway network goals of the Ministry of Transport and Communication

Highways	Km
Highways in operation	2489
2023 goal (under construction)	631
2023 goal (first group)	1893
2023-2035 goal (second group)	3214
Total	8227

Both current distribution and future prospects of road infrastructure in Turkey is uneven. Based on the road length (km) and surface area (km2) data of NUTS 2 regions in 2014, it can be seen that TR10 (İstanbul), TR31 (İzmir), TR42 (Kocaeli), TR81 (Zonguldak) and TR90 (Trabzon) regions have the highest road length per square (see Figure 3.7). However, if one takes into account population instead of surface area of the regions, well-developed regions such as TR10 (İstanbul), TR51 (Ankara), TR31 (İzmir) have the lowest road length per capita (see Figure 3.8).

Figure 3.4 Road network in Turkey (2016) (Source: Ministry of Transport and Communication)

Figure 3.5 Motorway network in Turkey (2016) (Source: Ministry of Transport and Communication)

Figure 3.6 Targets of motorway network in Turkey for 2023 (Source: Ministry of Transport and Communication)

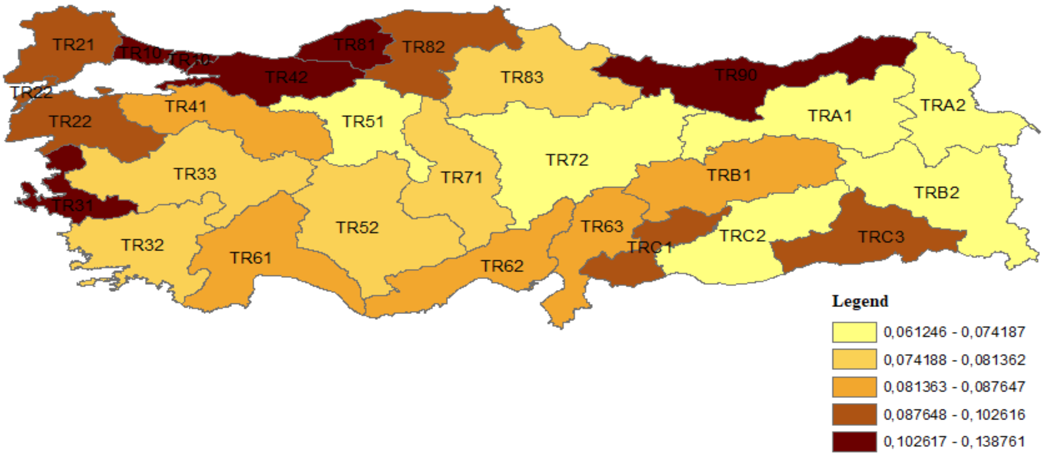

Figure 3.7 Road length per square (quantile classification)

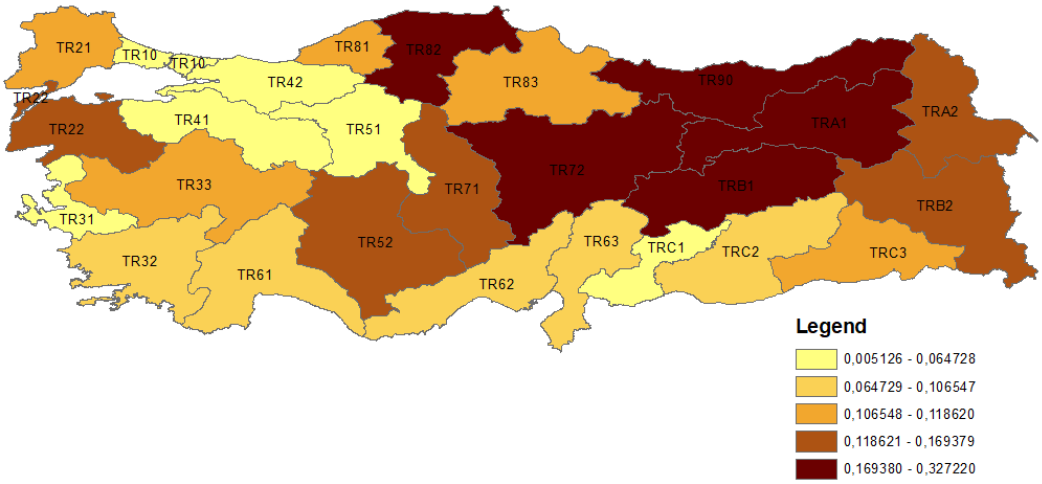

Figure 3.8 Road length per capita (quantile classification)

CHAPTER FOUR
DATA

One of the main reasons for the limited number of studies on the effects of transportation infrastructure on Turkish regions is the problematic process of finding the appropriate data at the subnational level. Along with the EU accession process, TurkStat released regional data based on NUTS 2 level instead of provincial data starting from 2004 which diminished the number of observation. Another limitation on the data is about the time period. Gross Domestic Product (GDP) data is only available for the time period between 2004 and 2014 which is launched by TurkStat at the end of 2016. Therefore, we use macroeconomic panel data at 26 NUTS 2 regions from 2004 to 2014. Using panel data increases the degrees of freedom while reduces collinearity among dependent variables (Hsiao, 2003). The benefits of using panel data is expresses at Hsiao (1985) especially at regional data which many regional characteristics cannot recognized in cross-section data (Hong et al, 2011). Using regional data also allows us to consider spatiality issue more deeply. It is also important to convert data into a standard format, so we use per capita level for regional output and private capital data to reduce the influence demographic variations as indicated in Chen and Haynes (2015).

4.1 Definitions of the Variables

We use an augmented Cobb-Douglas production function to measure the role of transport infrastructure on regional economic performance with regional GDP per capita as regional output. GDP deflator which is obtained from Central Bank of the Republic of Turkey is applied to eliminate the inflation impact. Since private capital stock data is unavailable in Turkey, we use industrial electricity consumption per capita as a proxy for private capital stock as proposed in Moody (1974). Following Barro (1990), we add human capital variable to the model which is the proportion of the university graduated to the total population. Finally, we augmented the production function by adding transportation infrastructure variable (Table 4.1).

Table 4.1 Definitions of the variables

Variables	**Year Coverage**	**Description**	**Data Source**
Y (GDP per capita)	2004-2014	Gross Domestic Product per capita	TurkStat
K (Private Capital)	2004-2014	Industrial electricity consumption per capita	TurkStat
H (Human Capital)	2004-2014	University graduates divided by total population	TurkStat
T (Transport Infrastructure)	2004-2014	Divided roads and motorway infrastructure (km) divided by population	TurkStat and OECD

We measure transport infrastructure stock by adopting physical measurement instead of monetary measures as indicated in Bröcker and Rietveld (2009) and Vickerman (2007). They claim that monetary measure is less accurate than physical measurement of transport infrastructure stock. Different transport infrastructure investment may have similar monetary values even though the effects on output may be various (Melo et al., 2013). Deng (2013) also states that physical measurement leads significant and positive results more often than monetary measure by investigating recent studies.

Table 4.2 Descriptive statistics of the variables

Variables	**Units**	**Observation**	**Std. Dev.**	**Min**	**Max**
Y (GDP per capita)	Per person	286	0.5202	8.0271	10.5964
K (Private Capital)	Per person	286	1.0747	-3.5035	1.51189
H (Human Capital)	Number of person	286	0.70693	-2.6562	1.78182
T (Transport Infrastructure)	Km/number of person	286	0.7876	-10.002	-5.6410

Many researchers remark the fact that economic contributions of transport infrastructure vary based on the type of infrastructure (e.g. Rodriguez-Pose et al., 2012; Gomez-Antonio and Garijo, 2012; Bronzini and Piselli, 2010; Deng, 2013). We inspire the results of Elburz et al. (2017) which shows the substantial impact of road infrastructure on regional economic growth in Turkey. By taking into account

Turkish governments massive investments on road infrastructure since 2003 and Elburz et al. (2017) study results, we prefer to focus on only road infrastructure in this study instead of including all type of transport infrastructure (point and network infrastructure). We employ length (km) of total highway and divided roads which are standardized with total population of a region (see Table 4.2). Since regional population data is not available between the years 2000 and 2007 at TurkStat, we use the estimated regional population data by OECD regional statistics between 2004 and 2007. It is also important to underline the fact that the effects of transport infrastructure do not emerge immediately. Thus using data for transport infrastructure and regional output for the same year may not reveal the real effects. That is why we consider lagged transport infrastructure variables in our model.

We apply unit root test for panel data for all variables to check stationarity problem as underlined in the related literature greatly already (Table 4.3). The Levin-Lin-Chu unit root test results confirm that all variables are statistically significantly stationary during 2004-2014. It is also possible to check temporal distribution of means of the variables as shown in Figure 4.1 which support the unit root test results for panel data.

Table 4.3 Unit root test results for panel data (2004-2014)

Levin-Lin-Chu unit root test	Y (GDP)	H (Human Capital)	K (Private Capital)	T (Transport Infrastructure)
	-5.154***	-10.143***	-7.806***	-11.052***

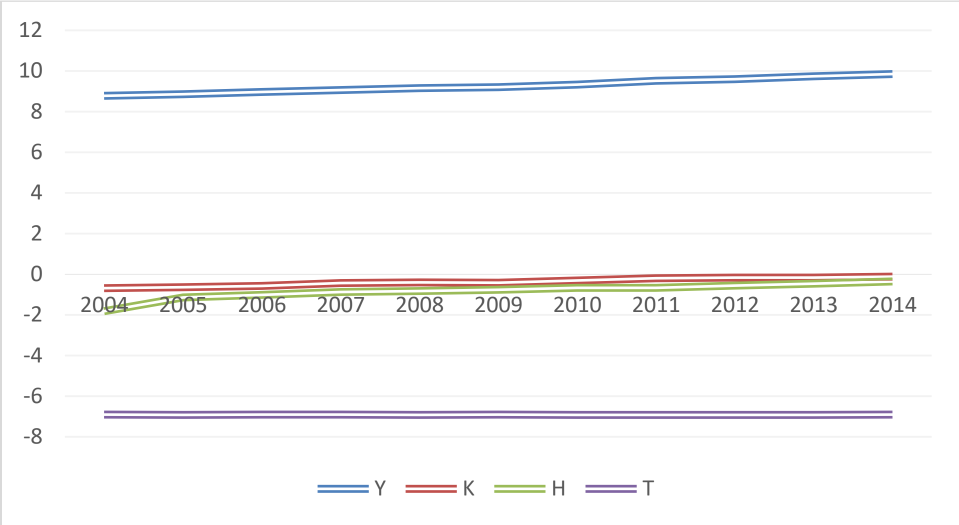

Figure 4.1 Temporal variations of the variable means (All variables were measured in logarithmic term)

4.2 Spatial Weight Matrix

Before applying spatial econometric analyses, the spatial weight matrix (W) is to be set. Spatial weight matrix is the simplest measure of spatial influence (Bavaud, 1998) and entirely depends on the neighborhood definition in the model (Anselin, 2001). Neumayer and Plümper (2016, p.2) defines spatial weight matrix (W) as “a connectivity matrix which determines which and to what degree observation spatially depend on each other” while Getis and Aldstadt (2004) designate spatial weight matrix (W) as a key element in a spatial regression.

There are several ways to construct a spatial weight matrix to formalize the role of space (Anselin, 1989). Mostly, spatial weight matrices are based on geographical arrangements or contiguity. LeSage and Pace (2009) criticize contiguity or nearest neighbors with distance function based spatial weight matrices for being intuitive and suggest more elegant ways to generate spatial weight matrix (see Figure 4.2, Figure 4.3 and Figure 4.4). In parallel with this, Anselin (2001) states that contiguity or distance based spatial weight matrices that have only zero or one elements are too general and alternatives can be considered as well such as inverse distance squared (Anselin, 1999).

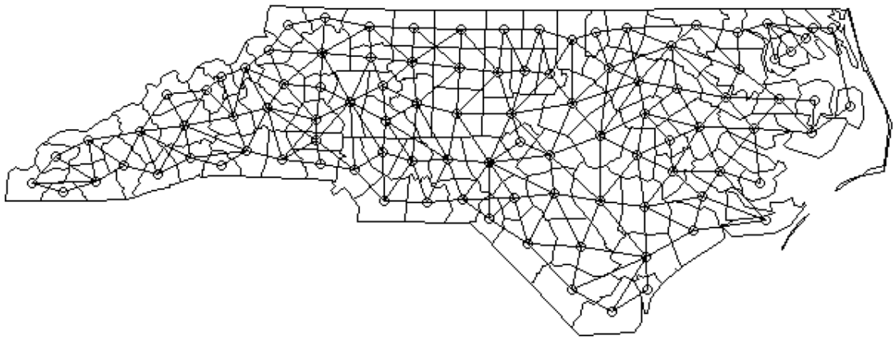

Figure 4.2. Neighbor relations based on queen-contiguity (adopted from Root, 2011)

Figure 4.3. Neighbor relations based on k-nearest regions (adopted from Root, 2011)

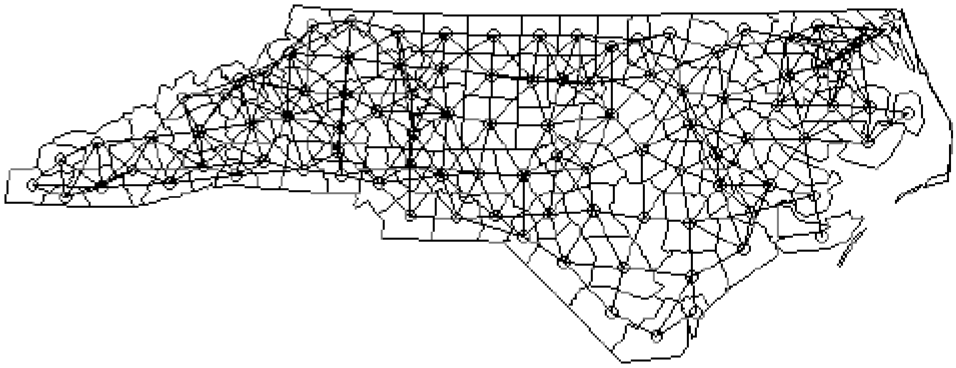

Figure 4.4. Neighbor relations based on distance with threshold (adopted from Root, 2011)

Even though a misspecified spatial weight matrix may cause inconsistent and misleading results, there is no “true” or “universal” spatial weight that fits all cases

(Bavaud, 1998; Anselin, 1988). Finding the most appropriate spatial weight matrix for a model and data is up to researcher's decision which is completely subjective.

In this study, we follow a different path from the previous studies which prefer to rely on contiguity matrices which are simple and easy to interpret (see Table 2.2) to generate spatial weight matrix. Relying on distance decay methods, we create a spatial weight matrix for each year from 2004 to 2014 (see Appendix). These spatial weight matrices reflect the change over time, to capture the impacts of recently built-up road infrastructure or extension the existing ones on regional economic growth.

Approximately 30% of the total public investment has been transferred to transportation investments since 2004 and it is clear that there is a change in the transport infrastructure stock in terms of length of the state highways, provincial roads and motorways in Turkey between 2004 and 2014 (Figure 3.3 and Table 3.2). As expected, building new road network and/or extension of the existing ones and or improving the quality of existing road network (e.g. dual carriageways) cause a reduction of the travel times between regions. Based on this fact, we believe a simple contiguity weight matrix would not reflect the real changes in Turkish transportation infrastructure and thus would not measure the spatial influence properly. Therefore, we use network analysis to calculate the distances in minutes between the regions based on 3 different road categories with different speed limits each (see Table 4.4, Figure 4.5 and Figure 4.6).

Table 4.4 Speed limits of roads

Type of road	Speed limit (km/h)
Motorways	120
State highways	110
Provincial road	90

First, we start with adjusting road network data obtained from the General Directorate of Highways to WGS 1984 Web Mercator (Auxiliary Sphere) projected coordinate system. Then we measure the quickest route from each origin region to destination region and produce distance matrix by using OD cost matrix analysis extension of network analysis (Environmental Systems Research Institute, 2018).

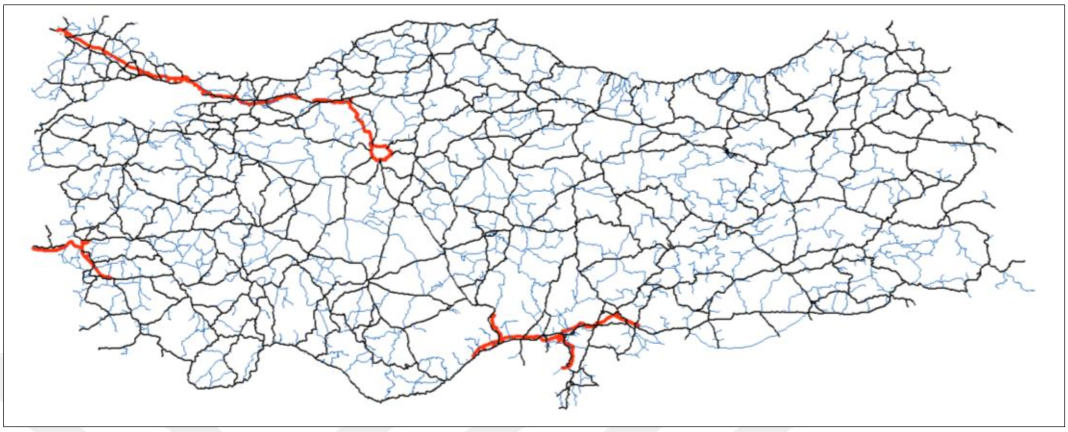

Figure 4.5 State highways (black), provincial (blue) roads and motorways (red) in 2004

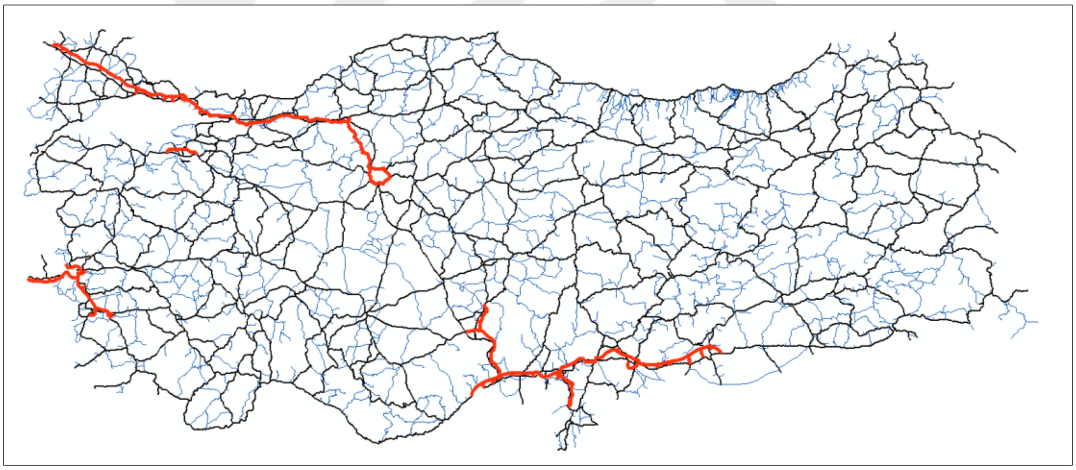

Figure 4.6 State highways (black), provincial (blue) roads and motorways (red) in 2014

After obtaining the annual changes in the real distance between regions, we generate inverse distance spatial weight matrices ($1/d^2$) for 26 NUTS 2 regions for each year between 2004 and 2014. The inverse distance spatial weight can be formulated as:

$$W_{ij} = \left(\frac{1}{d_{ij}^2}\right) \tag{4.1}$$

where W_{ij} reflects spatial interaction between region i and region j, and d_{ij} denotes real distance (in minutes) between i and j. Finally, we transform the spatial weight matrices with row-standardization to produce a row-stochastic weight matrix (LeSage, 2004) which can be shown as:

$$W_{ij}^{s} = \frac{W_{ij}}{\Sigma_j W_{ij}}, \qquad \Sigma_j W_{ij}^{s} = 1\,, \quad W_{ij} = 0,\ if\ \ i = j \tag{4.2}$$

At the end of this process we get 11 different *nxn* (26x26) size (4.3) non-negative symmetric spatial weight matrices (W) with zeros on the diagonals (see Appendix for all spatial weight matrices).

$$\begin{bmatrix} w_{1\,1} & \cdots & w_{1\,26} \\ \vdots & \ddots & \vdots \\ w_{26\,1} & \cdots & w_{26\,26} \end{bmatrix} \tag{4.3}$$

We use these eleven spatial weight matrices for each year from 2004 to 2014 in the spatial panel econometric models which will be discussed in the next chapter.

CHAPTER FIVE
METHODOLOGY

This study aims to investigate the spatial effects of transportation infrastructure investments on regional economic growth by using spatial panel econometric models. First, we briefly introduce the basic econometric model and its augmentation by adding new variables. After, we present the used spatial econometric model in this research which based on basic model.

5.1 Econometric Model

In this study, we use an augmented Cobb-Douglas production function by following the literature to investigate the relation between transport infrastructure stock and regional development in 26 Turkish NUTS 2 regions. Rietveld (1989) argues that Cobb-Douglas production function is a commonly used form of production function. In this approach, infrastructure has an important role along with other production factors such as labor and private capital. This means when public sector fails to provide sufficient infrastructure, the productivity of production factors decreases. The basic Cobb-Douglas production function can be expressed as:

$$Y = K^{a} L^{1-a} \tag{5.1}$$

where *Y*, *K*, and *L* denote output, private capital, and labor force respectively, while *a* denotes the returns to the factor input which is constant to scale in this equation. Since we use a production function per capita, the Equation (5.1) is divided by *L*. After adding human capital and transportation infrastructure stock variables to get the augmented production function form, we can rewrite the equation as:

$$YP_{it} = KP_{it}^{\alpha} \; H_{it}^{\beta} \; T_{it}^{\gamma} \tag{5.2}$$

$$\alpha + \beta + \gamma = 1 \tag{5.3}$$

where *YP*, *KP*, *L*, *H*, *T*, *i*, and *t* denote output per capita, private capital per capita, human capital, transport infrastructure stock, region and time respectively, while α, β, and γ denote constants. The Cobb-Douglas production function in Equation 5.2 has constant returns to scale, which is shown in Equation 5.3. By taking the log of both sides of the Equation 5.2 to interpret the coefficients as elasticities, the model is defined as:

$$LnYP_{it} = \alpha LnKP_{it} + \beta LnH_{it} + \gamma LnT_{it} + \varepsilon_{it} \qquad i = 1, 2 \ldots N; \; t = 2, 3 \ldots T \qquad (5.4)$$

As indicated in literature review section, infrastructure has gestation period and it may not affect regional economic output simultaneously. A current and past value of transport infrastructure stock is needed since transport infrastructure can influence regional output with time lags. Thus, based on this basic model (5.4), we first form a complete model which contains multiple lagged variables of transport infrastructure stock which can be expressed as:

$$LnYP_{it} = \alpha LnKP_{it} + \beta LnH_{it} + \gamma LnT_{it} + \delta LnT_{it-1} + \theta LnT_{it-2} + \vartheta LnT_{it-3} + \varepsilon_{it} \qquad (5.5)$$

where T_{it-1} is one year lagged transport infrastructure stock, T_{it-2} is two year lagged transport infrastructure stock and T_{it-3} is three year lagged transport infrastructure stock variable.

The second model includes only one transport infrastructure stock variable which has the highest correlation value with dependent variable according to correlation matrix results in Table 5.1. So the second model can be shown as:

$$LnYP_{it} = \alpha LnKP_{it} + \beta LnH_{it} + \gamma LnT_{it-3} + \varepsilon_{it} \qquad (5.6)$$

We assume that the second model do not suffer from reverse causality problem since we use lagged transport infrastructure variables as indicated in the literature mainly. Obviously, lagged transport variable may have an effect on current output but vice versa is not possible.

Table 5.1 Correlation matrix results

	T	T-1	T-2	T-3
Y	-0.0234	-0.0730	-0.1227	-0.1553

Jiwattanakulpaisarn et al. (2011) strongly claim that using a static framework such as the Cobb-Douglas production function ignores the dynamic feedback effects among infrastructure and economic growth. However, since panel unit root test shows that all data series are stationary (Table 4.1), dynamic models are not necessary (Tong et al., 2013; Levin et al., 2002).

Baltagi (2016) states that spatial models deal with spatial autocorrelation, while panel data models control heterogeneity across units. Thus spatial panel models can handle both heterogeneity and spatial correlation (Anselin, 1988; Baltagi 2008). By taking into account this advantage as indicated by Baltagi (2016), we apply spatial panel models in this study.

5.2 Spatial Econometric Models

Following the recent approach in the literature to investigate spillover effects of transport infrastructure, spatial econometric models are used in this study. Anselin (1988, p.7) describes spatial econometrics as “the collection of techniques concerning the peculiarities caused by space in the statistical analysis of models on regional sciences”. Anselin (1999, p. 3) clarifies this definition by adding a statement “spatial econometrics deals with methodological concerns that follow from the explicit consideration of spatial effects, such as spatial autocorrelation and spatial heterogeneity”.

According to Anselin (1988), there are two types of spatial effects; spatial dependence (or spatial autocorrelation) and spatial heterogeneity. Spatial dependence which has mostly been investigated in the field of regional science is involved with Tobler's (1979, p.379) first law of geography, "everything is related to everything, but near things are more related than distant things". In the existence of spatial dependence, standard econometric techniques often fail, thus spatial econometrics models are needed (Anselin, 1999). On the other hand, spatial heterogeneity is about the instability of parameters over space and spatial heterogeneity problems can be solved by standard econometric techniques (Anselin, 1988).

Spatial dependence (spatial autocorrelation) can be modelled in two ways. First specification is referred as the Spatial Lag Model (SAR) and includes Wy, a spatially lagged dependent variable. Second specification is referred as the Spatial Error Model (SEM) and contains $W\varepsilon$ a spatially lagged error term (Anselin and Bera, 1998). More generally, Anselin (1988) labelled the model that contains both spatially lagged dependent variable and spatially lagged independent variables as Spatial Durbin Model (Elhorst, 2010). Thus the spatial Durbin model (SDM) includes both the Spatial Error Model (SEM) and the Spatial Lag Model (SAR) (LeSage and Pace, 2009). Elhorst (2010) explicates two strengths of spatial Durbin model which may be seen a landmark in the field of spatial econometrics. Spatial Durbin model generates unbiased coefficients and produces both local and global spillover effects (Elhorst, 2010).

Selecting the appropriate specification model is quite a problematic process for researchers. Elhorst (2010) summarizes linear spatial econometric models (Figure 5.1) and claims that starting with the most general model is the best way to analyze spatial effects. Similarly, LeSage and Pace (2009) consider the spatial Durbin model as a best point to begin. The adjusted Lagrange multiplier (LM) test which is recommended by Anselin et al. (1996) is used to decide which model is appropriate to the data. Elhorst (2010) suggests to estimate spatial Durbin model if the results of the LM-test and the robust-LM test reject both spatial lag and spatial error models.

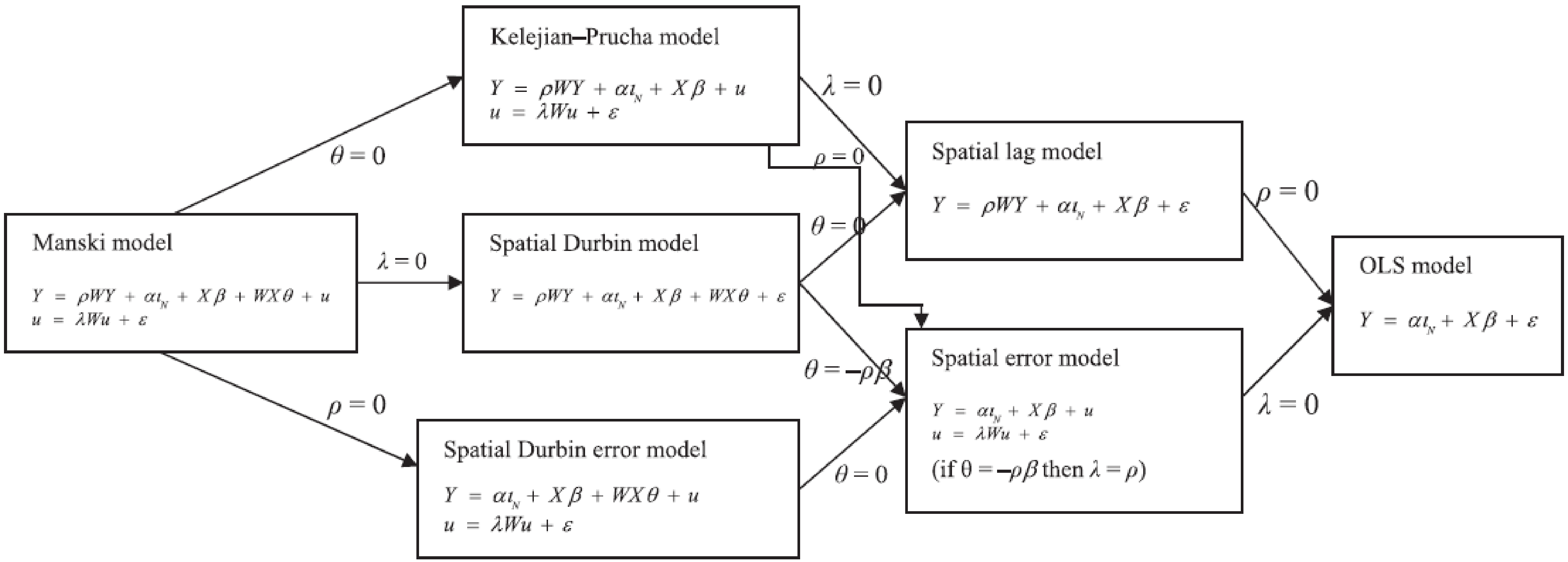

Figure 5.1 The relationships between different spatial dependence models (adopted from Elhorst, 2010)

The Cobb-Douglas production function in Equation 5.4 can be shown as follows in a spatial Durbin model framework:

$$Y_t = \rho W Y_t + X_t \beta + W X_t \theta + \mu + \alpha_t \iota_N + u_t \tag{5.8}$$

where *Y* is an *Nx1* vector of regional GDP, *X* is an 1x4 matrix of dependent variables which contains private capital per capita, employment, human capital stock, and transport infrastructure stock; *WY* is the endogenous interaction effects among the dependent variable; *WX* is the exogenous interaction effects among the independent variables, ρ is the spatial autoregressive coefficient, θ and β are 4x1 vector of fixed parameters, μ is a vector of spatial fixed or random effects, $\alpha_t$is the time period fixed or random effects, ι_N is an *Nx1* vector of ones. The logic behind a spatial Durbin model is that a change in the independent variable for a region may affect the dependent variable in neighboring regions (LeSage and Pace, 2009).

Unlike the spatial error model and spatial lag model, coefficients from spatial Durbin model results cannot interpret as elasticities (Arbués et al., 2015). Elhorst (2012) suggests using direct, indirect and total effects estimates by employing rewritten form of SDM as:

$$Y_t = (I - \rho W)^{-1} \alpha I_N + (I - \rho W)^{-1} (X_t \beta + W X_t \theta) + (I - \rho W)^{-1} \varepsilon \tag{5.9}$$

where I is the identity matrix, I_N is an $nx1$ vector of ones. By taking a partial derivative of Y, following *NxN* matrix which represents marginal effects can be obtained (Tong et al., 2013):

$$\frac{\partial Y}{\partial X_k} = (I - \rho W)^{-1} (\beta_k I + W \theta_k) \tag{5.10}$$

Lesage and Pace (2009) calculates the direct effects from the diagonal elements of the matrix while off-diagonal elements demonstrate indirect effects. The direct effect contains a change in an independent variable on dependent variable in a region and indirect effect (spillover effect) includes a change in an independent variable on dependent variable in all regions (Tong et al., 2013). Finally, total impact consists of direct and indirect (spillover effects) effects (Chen and Haynes, 2015).

In the spatial Durbin model, spatially lagged dependent variable WY may cause endogeneity problem with residuals. That is why ordinary least squares (OLS) estimation method results can be biased and inconsistent. Anselin (1988) suggests employing maximum likelihood (ML) estimation for this situation.

The stating point of spatial econometric models is justifying the existence of spatial autocorrelation in the data with specification tests. The most popular test for spatial autocorrelation is Moran's I test which is a measure of global spatial autocorrelation. We employ Moran's I test which can be expressed as:

$$I = \frac{N}{W} \frac{\Sigma_i \Sigma_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\Sigma_i (x_i - \bar{x})^2} \tag{5.7}$$

where x is the variable of interest, $\bar{x}$ is the mean of x; w_{ij} is a spatial weight matrix, N is the number of spatial units indexed by i and j, W is the sum all w_{ij} (Moran, 1950). The results from the models mentioned in this chapter will be demonstrated in the next chapter.

CHAPTER SIX
RESULTS

Taking into account the spatial spillover effects that highlighted in the literature review section, we test spatial autocorrelation in the model by using Moran’s I statistics as a spatial diagnostic test. Table 6.1 displays the results from Moran’s I statistics for both dependent and independent variables. Since testing Moran’s I with panel data is not possible, we use cross section data with a spatial weight matrix from the same year. The results show evidence of highly significant and positive spatial autocorrelation, which indicates a cluster tendency.

Tablo 6.1 Moran’s I statistics results for all variables

	Y	H	K	T	T-1	T-2	T-3
2004	0.714***	0.327***	0.405***	-0.021	-0.022	-0.019	-0.021
2005	0.712***	0.330***	0.408***	-0.021	-0.022	-0.019	-0.021
2006	0.712***	0.329***	0.408***	-0.021	-0.023	-0.020	-0.021
2007	0.712***	0.326***	0.405***	-0.022	-0.023	-0.020	-0.022
2008	0.712***	0.327***	0.403***	-0.022	-0.023	-0.020	-0.022
2009	0.711***	0.327***	0.402***	-0.022	-0.023	-0.020	-0.022
2010	0.711***	0.327***	0.402***	-0.022	-0.023	-0.020	-0.022
2011	0.714***	0.325***	0.401***	-0.022	-0.023	-0.020	-0.022
2012	0.714***	0.327***	0.407***	-0.020	-0.022	-0.020	-0.023
2013	0.714***	0.327***	0.407***	-0.020	-0.022	-0.020	-0.023
2014	0.712***	0.327***	0.402***	-0.021	-0.022	-0.020	-0.023

Note: *** denotes statistical significance at the 1% level

We also test Moran’s I statistics from OLS estimation residuals for Equation 5.6 to check robustness of the previous results. As seen at Table 6.2 and Figure 6.1, the results from different spatial weight matrices are very close. Basically the findings from both Table 6.1 and Table 6.2 support the hypothesis that the variables are spatially linked among regions, and omitting spatial effects of transport infrastructure may cause biased estimations. Thus, a simple OLS estimate would be insufficient for the analysis. Therefore, we analyze the relationship between transport infrastructure and regional economic output by using spatial econometric models.

Tablo 6.2 Moran's I statistics results from residuals of OLS estimation

Years	Moran's I
2004	9.323***
2005	9.421***
2006	9.402***
2007	9.492***
2008	9.487***
2009	9.532***
2010	9.533***
2011	9.471***
2012	9.512***
2013	9.512***
2014	9.517***

Note: *** denotes statistical significance at the 1% level

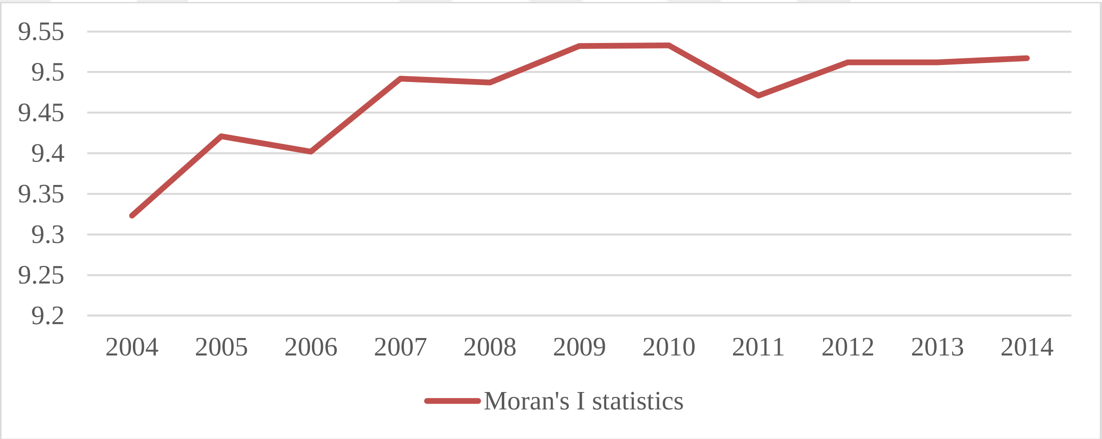

Figure 6.1 Changes in Moran's I statistic

To decide which model is more appropriate to test for spatial dependence, LM and robust LM tests can be used. These tests are based on the residuals of a non-spatial model and examine the possibility of simplifying spatial Durbin model to spatial lag model or spatial error model (Elhorst, 2012). LeSage and Pace (2009) suggest to choose spatial Durbin model when LM test is rejected for both spatial lag and spatial error model. Table 6.3 shows the LM test and robust LM test results for the Equation 5.6. The hypothesis of no spatially lagged dependent variable and the hypothesis of no spatially autocorrelated error term must be rejected at 1 percent significance. Basically, these rejected hypotheses point out to spatial Durbin model (Elhorst, 2012).

Tablo 6.3 Lagrange multiplier (LM) test results

	Spatial Error		Spatial Lag	
	LM	Robust LM	LM	Robust LM
2004	82.699***	23.775***	200.158***	141.235***
2005	84.420***	23.397***	203.405***	142.382***
2006	84.079***	23.279***	203.259***	142.456***
2007	85.691***	22.609***	205.817***	142.735***
2008	85.587***	22.509***	205.672***	142.594***
2009	86.395***	22.227***	207.021***	142.854***
2010	86.401***	22.238***	207.047***	142.883***
2011	85.285***	22.497***	204.847***	142.059***
2012	86.043***	22.527***	206.003***	142.487***
2013	86.043***	22.527***	206.003***	142.487***
2014	86.138***	22.379***	205.823***	142.064***

Note: *** denotes statistical significance at the 1% level

Following Elhorst (2012), we employ Hausman's specification test to distinguish between the random effects model and fixed-effects model in the spatial Durbin model. Hausman specification test results suggest using the fixed-effects models for Model 1. The results can be seen in Table 6.4. From a theoretical point of view, considering the spatial effects as random is also not sufficient (Arbués et al., 2015). Moreover, we only consider spatial fixed-effect and do not account time fixed effect in our model. Following Chen and Haynes (2015), we exclude the time fixed effect since all data are stationary according to panel unit root test, and thus time fixed effect is not essential in our model.

According to the SDM with spatial fixed-effects estimation results for Model 1 (Table 6.4), human capital (H) and private capital (K) have highly significant and positive effects on regional GDP (Y) for all spatial weight matrices from 2004 to 2014. However, it can be seen at Table 6.4 that none of transport infrastructure stock variables -including lagged transport infrastructure stock- have significant effect on output. The spatial autocorrelation coefficient (rho) is positive and significant for all estimations indicating the existence of spatial correlation among NUTS 2 regions. The spatial effects of explanatory variables in Table 6.4 reveal that human capital (H) and private capital (K) have also positive and significant spillover effects. These coefficients show that spillover effects of human and private capital variables are higher than main effects on regional GDP. For the case of transport infrastructure stock variables, the results are very convincing. While the transport infrastructure stock in the same year from the dependent variables (T) has neither main effects nor spatial effects, lagged transport infrastructure in the neighboring regions affects regional GDP positively. Although these estimators give a general idea about interactions among regions, in order to interpret the magnitude of the direct and indirect effects, we need to examine the results in Table 6.5.

Table 6.5 shows the results of direct, indirect (spillover), and total effects of the variables from the SDM estimations in Table 6.4. Human capital and private capital have significant direct and indirect effects for all estimations with different spatial weight matrices from 2004 to 2014. The total effects of human capital and private capital are in the range 0.737-0.754 and 0.805-0.831 respectively. These two capitals have significant contribution to regional GDP. Also it is noteworthy to indicate that the spillover effects of human and private capital are larger than the direct effects. Clearly this means that an increase in human capital or private capital in the region *i*, have a positive effect on the average regional GDP in other regions.

The results from transport infrastructure stock variables interestingly show that transport infrastructure do not have significant direct effect on regional GDP. On the other hand, three year-lagged transport infrastructure (T-3) and two year-lagged transport infrastructure (T-2) have significant positive spillover effects. The positive coefficients from indirect effect of lagged transport infrastructure stock indicate that development of transport infrastructure in a region causes an increase at the GDP of neighboring regions. It is also important to underline the evidence from Table 6.5 that the older the transport investments, the higher the impacts on GDP. Basically, a 1% increase in three year-lagged transport infrastructure stock in one region increases the regional GDP in all regions by in a range of 0.118%-0.120%. Similarly, a 1% increase in two year-lagged transport infrastructure stock in one region increases regional GDP in all regions by in a range of 0.101%-0.105%. Despite this, transport infrastructure stock variable (T) do not show any indirect contribution to the GDP.

Tablo 6.4 Spatial Durbin model with spatial fixed effects for Model 1(Standard errors are in italics * p<0,10, ** p<0,05, *** p<0,01)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	0.049***	0.048***	0.048***	0.047***	0.047***	0.047***	0.047***	0.048***	0.048***	0.048***	0.048***
H	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*	*-0.017*
	0.050***	0.049***	0.049***	0.049***	0.049***	0.049***	0.049***	0.049***	0.049***	0.049***	0.049***
K	*-0.013*	*-0.012*	*-0.013*	*-0.012*	*-0.012*	*-0.012*	*-0.012*	*-0.013*	*-0.013*	*-0.013*	*-0.013*
	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
T	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*
	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
T-1	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*
	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
T-2	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*
	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
T-3	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*	*-0.003*
	0.055*	0.057*	0.056*	0.055*	0.056*	0.055*	0.055*	0.054*	0.052	0.052	0.053*
W*H	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*	*-0.032*
	0.062**	0.062**	0.063**	0.064**	0.064**	0.064**	0.064**	0.064**	0.064**	0.064**	0.064**
W*K	*-0.03*	*-0.03*	*-0.03*	*-0.03*	*-0.03*	*-0.03*	*-0.03*	*-0.03*	*-0.029*	*-0.029*	*-0.03*
	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
W*T	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*
	0.012*	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011
W*T-1	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*	*-0.007*
	0.016**	0.016**	0.016**	0.016**	0.016**	0.016**	0.016**	0.015**	0.015**	0.015**	0.015**
W*T-2	*-0.007*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.007*	*-0.008*	*-0.008*	*-0.008*
	0.020**	0.020**	0.020**	0.020**	0.020**	0.020**	0.020**	0.020**	0.019**	0.019**	0.020**
W*T-3	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*	*-0.008*
	0.861***	0.861***	0.861***	0.862***	0.862***	0.863***	0.863***	0.863***	0.864***	0.864***	0.864***
rho	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*
	56.4	58.29	60.27	60.69	60.77	60.4	60.37	58.37	57.96	57.96	58.3
Hausman	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Log like.	526.57	528.13	528.06	528.50	528.55	528.86	528.87	527.55	527.67	527.67	527.71
N	286	286	286	286	286	286	286	286	286	286	286
R^2	0.811	0.811	0.811	0.811	0.81	0.811	0.811	0.811	0.812	0.812	0.811

Tablo 6.5 Direct, indirect and total effects of Model 1(Standard errors are in italics * p<0,10, ** p<0,05, *** p<0,01)

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Direct	H	0.094***	0.092***	0.092***	0.091***	0.091***	0.090***	0.090***	0.091***	0.091***	0.091***	0.091***
		-0.022	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*	*-0.022*
	K	0.098***	0.097***	0.098***	0.098***	0.098***	0.097***	0.097***	0.098***	0.098***	0.098***	0.098***
		-0.023	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*	*-0.023*
	T	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		-0.006	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*
	T-1	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.007
		-0.005	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*	*-0.005*
	T-2	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
		-0.006	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*
	T-3	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.006	0.006	0.006	0.006
		-0.006	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*	*-0.006*
Indirect	H	0.657***	0.661***	0.656***	0.654***	0.656***	0.654***	0.654***	0.650***	0.646***	0.646***	0.649***
		-0.167	*-0.168*	*-0.167*	*-0.169*	*-0.168*	*-0.169*	*-0.169*	*-0.169*	*-0.171*	*-0.171*	*-0.17*
	K	0.709***	0.708***	0.713***	0.725***	0.723***	0.727***	0.728***	0.729***	0.733***	0.733***	0.733***
		-0.224	*-0.225*	*-0.225*	*-0.228*	*-0.227*	*-0.228*	*-0.228*	*-0.228*	*-0.23*	*-0.23*	*-0.23*
	T	0.046	0.046	0.047	0.048	0.047	0.048	0.048	0.048	0.046	0.046	0.046
		-0.058	*-0.059*	*-0.059*	*-0.06*	*-0.059*	*-0.06*	*-0.06*	*-0.059*	*-0.061*	*-0.061*	*-0.06*
	T-1	0.092*	0.092*	0.092*	0.089	0.089	0.088	0.088	0.088	0.087	0.087	0.086
		-0.055	*-0.056*	*-0.056*	*-0.056*	*-0.056*	*-0.057*	*-0.057*	*-0.056*	*-0.057*	*-0.057*	*-0.057*
	T-2	0.102*	0.104*	0.105*	0.104*	0.103*	0.103*	0.103*	0.101*	0.102*	0.102*	0.102*
		-0.058	*-0.058*	*-0.058*	*-0.059*	*-0.059*	*-0.059*	*-0.059*	*-0.059*	*-0.06*	*-0.06*	*-0.06*
	T-3	0.120**	0.120**	0.119**	0.119**	0.119**	0.118**	0.118**	0.118**	0.119**	0.119**	0.119**
		-0.058	*-0.059*	*-0.059*	*-0.06*	*-0.06*	*-0.06*	*-0.06*	*-0.059*	*-0.06*	*-0.06*	*-0.06*
Total	H	0.751***	0.754***	0.748***	0.745***	0.747***	0.745***	0.745***	0.742***	0.737***	0.737***	0.740***
		-0.183	*-0.183*	*-0.183*	*-0.184*	*-0.184*	*-0.184*	*-0.184*	*-0.185*	*-0.186*	*-0.186*	*-0.185*
	K	0.807***	0.805***	0.811***	0.822***	0.820***	0.825***	0.825***	0.826***	0.831***	0.831***	0.830***
		-0.244	*-0.245*	*-0.245*	*-0.248*	*-0.247*	*-0.249*	*-0.249*	*-0.248*	*-0.25*	*-0.25*	*-0.25*
	T	0.05	0.049	0.051	0.052	0.051	0.052	0.052	0.052	0.05	0.05	0.05
		-0.063	*-0.064*	*-0.064*	*-0.065*	*-0.065*	*-0.065*	*-0.065*	*-0.065*	*-0.066*	*-0.066*	*-0.065*
	T-1	0.100*	0.100*	0.100*	0.097	0.097	0.096	0.096	0.096	0.094	0.094	0.094
		-0.06	*-0.061*	*-0.06*	*-0.061*	*-0.061*	*-0.061*	*-0.061*	*-0.061*	*-0.062*	*-0.062*	*-0.062*
	T-2	0.108*	0.110*	0.111*	0.111*	0.110*	0.110*	0.110*	0.107*	0.108*	0.108*	0.108*
		-0.063	*-0.063*	*-0.063*	*-0.064*	*-0.064*	*-0.064*	*-0.064*	*-0.064*	*-0.065*	*-0.065*	*-0.065*
	T-3	0.126**	0.126**	0.125*	0.125*	0.124*	0.124*	0.124*	0.124*	0.124*	0.124*	0.125*
		-0.063	*-0.064*	*-0.064*	*-0.065*	*-0.065*	*-0.065*	*-0.065*	*-0.064*	*-0.066*	*-0.066*	*-0.065*

It is also important to analyze the changes of the spatial effects of the variables, since we use 11 different spatial weight matrices. Based on the indirect effects of all transport infrastructure stock variables in Table 6.5, the changes of the indirect effect elasticities are shown in Figure 6.2. According to Figure 6.2, it is clear that the coefficients are stabile over different spatial weight matrices. This means that the estimation results are not affected by the usage of multiple spatial weight matrices.

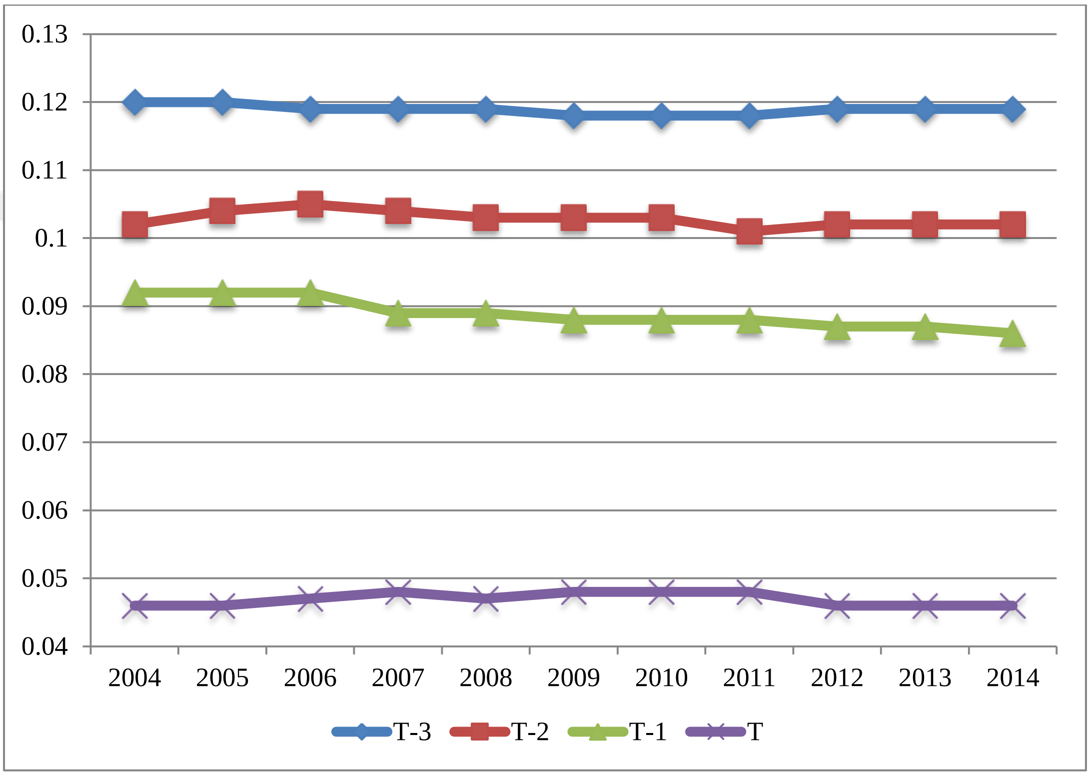

Figure 6.2 Changes in spillover effects for Model 1

Table 6.6 displays the results from SDM for Model 2. According to Hausman test, fixed-effects model is employed for all estimations with different spatial weight matrices. Following Chen and Haynes (2015), we exclude time fixed effect in Model 2 as well. The spatial autocorrelation coefficient (rho) is also positive and significant like in Model 1.

Tablo 6.6 Spatial Durbin model with spatial fixed effects for Model 2 (Standard errors are in italics * p<0,10, ** p<0,05, *** p<0,01)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
H	0.054*** *-0.017*	0.053*** *-0.017*	0.053*** *-0.017*	0.053*** *-0.017*	0.053*** *-0.017*	0.052*** *-0.017*	0.052*** *-0.017*	0.053*** *-0.017*	0.054*** *-0.017*	0.054*** *0.983*	0.053*** *-0.017*
K	0.050*** *-0.012*	0.050*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*	0.049*** *-0.012*
T-3	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*	-0.002 *-0.003*
W*H	0.035 *-0.031*	0.038 *-0.031*	0.037 *-0.031*	0.036 *-0.031*	0.037 *-0.031*	0.036 *-0.031*	0.036 *-0.031*	0.034 *-0.031*	0.033 *-0.031*	0.033 *-0.031*	0.034 *-0.031*
W*K	0.054* *-0.029*	0.053* *-0.029*	0.055* *-0.029*	0.056* *-0.029*	0.056* *-0.029*	0.056* *-0.029*	0.056* *-0.029*	0.057* *-0.029*	0.057** *-0.029*	0.057** *0.971*	0.057* *-0.029*
W*T-3	0.024*** *-0.008*	0.024*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *-0.008*	0.023*** *0.992*	0.023*** *-0.008*
rho	0.876*** *-0.021*	0.876*** *-0.021*	0.876*** *-0.021*	0.877*** *-0.02*	0.877*** *-0.02*	0.877*** *-0.02*	0.877*** *-0.02*	0.877*** *-0.02*	0.878*** *-0.02*	0.878*** *-0.02*	0.877*** *-0.021*
Hausman	43.08 *0.000*	43.65 *0.000*	44.11 *0.000*	46.00 *0.000*	46.16 *0.000*	46.23 *0.000*	46.22 *0.000*	45.81 *0.000*	45.77 *0.000*	45.77 *0.000*	45.67 *0.000*
log likelihood	522.3447	523.9787	523.8467	524.5332	524.6066	524.9853	524.9969	523.6552	523.967	523.967	523.9833
N	286	286	286	286	286	286	286	286	286	286	286
R-squared	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.81	0.81	0.81	0.81

Essentially, findings from Model 2 are similar with Model 1. Both human capital *(H)* and private capital *(K)* variables are highly significant and affect regional GDP in a positive way. Conversely, three year-lagged transport infrastructure variable (T-3) is not significant in Model 2 like in Model 1. One important difference between the results from Model 1 and Model 2 is about human capital variable's insignificant spillover effects (Table 6.6). While human capital is the biggest explanatory of regional GDP, it loses its significance when the spatial effects are considered. It is also noteworthy that the spatial effect of three year-lagged transport infrastructure variable is significant at 1% ($p<0.01$) level. We focus on the results from Table 6.7 to interpret the magnitude and the sign of the coefficients.

Table 6.7 represents the findings of direct and indirect effects of Model 2 with different spatial weight matrices. Based on the results, the three year-lagged transport infrastructure investments *(T-3)* at neighboring regions affect regional GDP in a positive and significant way in a range of 0.163-0.168. Along with this human capital *(H)* and private capital *(K)* variables have also great effect on neighboring region's GDP according to indirect spatial effects from Table 6.7. It is clear that human capital *(H)* private capital *(K)* and transport infrastructure (T-3) play important role on regional development.

Finally, we check the changes of the indirect effect elasticities of explanatory variables from Model 2 which can be seen at Figure 6.3. Based on the trend of the coefficients from explanatory variables, the results are not sensitive to different spatial weight matrices.

Tablo 6.7 Direct, indirect and total effects of Model 2 (Standard errors are in italics * p<0,10, ** p<0,05, *** p<0,01)

		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Direct	H	0.095*** *-0.022*	0.094*** *-0.022*	0.093*** *-0.022*	0.093*** *-0.022*	0.093*** *-0.022*	0.092*** *-0.022*	0.092*** *-0.022*	0.093*** *-0.022*	0.093*** *-0.022*	0.093*** *0.978*	0.092*** *-0.022*
	K	0.101*** *-0.023*	0.100*** *-0.023*	0.100*** *-0.023*	0.100*** *-0.023*	0.100*** *-0.023*	0.099*** *-0.022*	0.099*** *-0.022*	0.101*** *-0.023*	0.100*** *-0.022*	0.100*** *-0.022*	0.100*** *-0.022*
	T-3	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*	0.009 *-0.006*
Indirect	H	0.613*** *-0.178*	0.623*** *-0.178*	0.616*** *-0.178*	0.614*** *-0.179*	0.616*** *-0.178*	0.614*** *-0.179*	0.614*** *-0.179*	0.605*** *-0.179*	0.601*** *-0.18*	0.601*** *0.82*	0.606*** *-0.179*
	K	0.765*** *-0.234*	0.756*** *-0.235*	0.763*** *-0.235*	0.774*** *-0.236*	0.772*** *-0.236*	0.776*** *-0.237*	0.776*** *-0.237*	0.787*** *-0.237*	0.790*** *-0.238*	0.790*** *0.762*	0.788*** *-0.238*
	T-3	0.168*** *-0.061*	0.166*** *-0.062*	0.165*** *-0.062*	0.164*** *-0.062*	0.163*** *-0.062*	0.163*** *-0.063*	0.163*** *-0.063*	0.165*** *-0.062*	0.165*** *-0.063*	0.165*** *0.937*	0.165*** *-0.062*
Total	H	0.708*** *-0.194*	0.716*** *-0.194*	0.709*** *-0.194*	0.706*** *-0.194*	0.709*** *-0.194*	0.706*** *-0.194*	0.706*** *-0.194*	0.697*** *-0.195*	0.694*** *-0.195*	0.694*** *0.805*	0.698*** *-0.195*
	K	0.866*** *-0.254*	0.856*** *-0.254*	0.863*** *-0.254*	0.874*** *-0.255*	0.871*** *-0.255*	0.875*** *-0.256*	0.876*** *-0.256*	0.888*** *-0.256*	0.891*** *-0.257*	0.891*** *0.743*	0.888*** *-0.257*
	T-3	0.177*** *-0.066*	0.175*** *-0.067*	0.174*** *-0.067*	0.173** *-0.067*	0.172** *-0.067*	0.172** *-0.067*	0.172** *-0.067*	0.174*** *-0.067*	0.173** *-0.068*	0.173** *0.932*	0.174*** *-0.067*

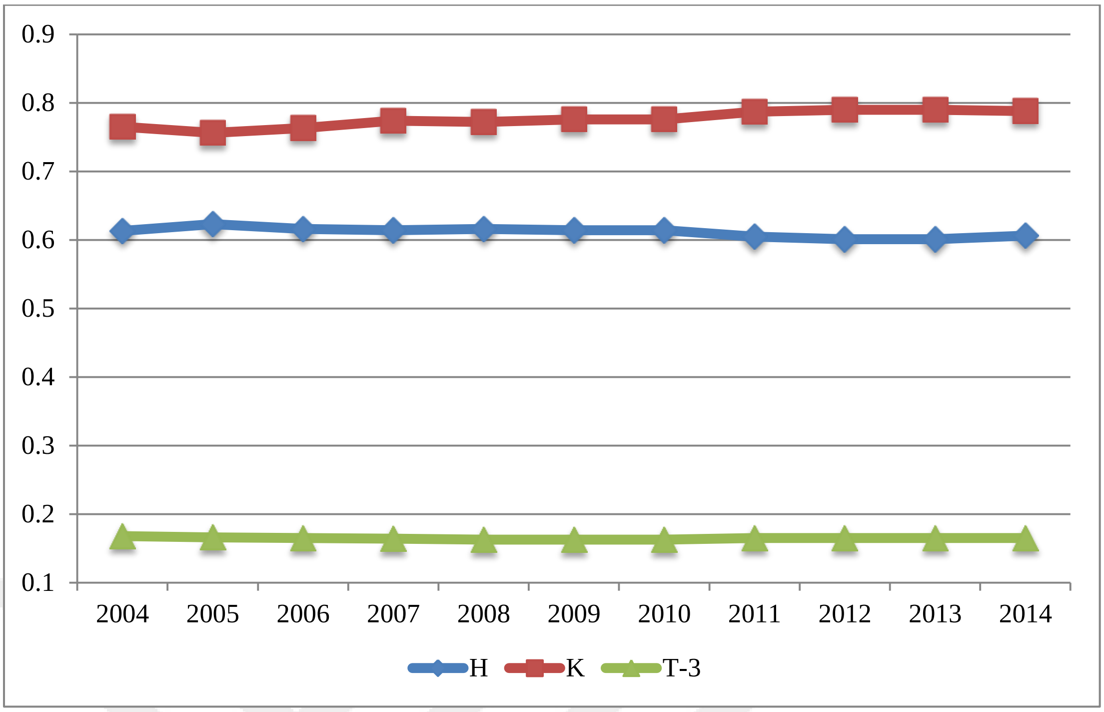

Figure 6.3 Changes in spillover effects for Model 2

CHAPTER SEVEN
CONCLUSION

In this study, the output elasticity of transport infrastructure stock in Turkish regions is estimated by using spatial Durbin model. To our knowledge, this is the first study to measure the spatial effects of the recent transport infrastructure investments in 26 NUTS regions in Turkey. The novelty of this study is defining the neighborhoods that change over time because of reduction of the travel time between regions. By considering the recent transport infrastructure investments which cause the reduction of the travel times in Turkey, we measure the real time distance between NUTS 2 regions for each year from 2004 to 2014 to create multiple spatial weight matrices. We use the augmented Cobb-Douglas production function with panel data and obtain highly significant results for human capital and private capital variables in all estimations. The most striking finding from both models is that lagged transport infrastructure variable has highly significant and positive spillover (indirect) effects on the regional output. The lagged transport infrastructures have no direct effects in none of two models, which are clearly surprising.

It can be summarized that the road transport infrastructure investments contribute the regional output indirectly in Turkey. The results also give important evidence on the impacts of using multiple spatial weight matrices in spatial econometric models. Basically the coefficients from the spatial models are stabile over different spatial weight matrices.

These results may have some policy implications. Essentially the findings expose the importance of spillover effects of road transport infrastructure. Any improvement in the road transport infrastructure in a region causes a GDP increase in the neighboring regions. Therefore, policy-makers may consider the road transport infrastructure network as a whole when deciding the allocation of the investments. Regarding the positive spillover effects of transport, boosting connectivity between developed and less-developed regions may increase growth rate of both regions.

Moreover, as indicated in the Introduction section, infrastructure plays a prominent role in both economic growth and income inequalities. Even though our empirical test results give no evidence on the effects of infrastructure on regional economic inequalities, it is possible to draw attention to prospective role of infrastructure on inequalities in Turkey by taking into account its effect on spatial location of economic activities. As a policy instrument for lower economic disparities, improving road transport infrastructure network and thus reducing transport costs may and may not lead to convergence (Puga, 2002). A better connection between developed and less-developed regions can cause widen the disparities, as Puga (2002, p.24) states “the roads have lanes going both ways”. Thus, instead of interregional and intra-core infrastructure improvement which fosters agglomerations, intra-periphery infrastructure improvements can be used to reduce regional disparities (Minerva and Ottaviano, 2009). However, it is clear from the targets of Ministry of Transport and Communication that Turkey encourages intra-core infrastructure by connecting the economic centers with highways (Figure 3.6). Since many researchers have analyzed the economic disparities in Turkey such as Gezici and Hewings (2004), Yıldırım et al (2009), Yıldırım and Öcal (2006), Karahasan (2015), Doğruel and Doğruel (2003), Filiztekin and Çelik (2010), and have underlined the high level of disparities between and within the regions since 1980s, there should be more improvements in local infrastructure in the less-developed regions in the eastern part of Turkey for 2023 targets to diminish regional disparities.

As Nijkamp (1986) noted, an advanced transport infrastructure generates sufficient conditions for regional development, however it does not adequate alone. Since there are no direct effects of transport infrastructure, policy-makers need to reflect transport infrastructure not as a major contributor of the regional economy anymore and need to reconsider the transport infrastructure based-regional development policies.

A limitation of this study is about the data-gathering process at the regional level from TurkStat. Further studies could extent the time period of the analysis if

TurkStat launches more recent regional GDP data. Another suggestion for further studies is using multiple spatial weight matrices in estimation instead of adding each year's spatial weight matrices separately as in our study. And lastly, investigating the impacts of transport infrastructure with a spatial econometric model on different sectors may reveal the spatial linkages of the road transport infrastructure network.

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APPENDICES

Appendix 1: Spatial weigtht matrix for 2004

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	98	249	363	423	337	145	55	262	431	461	584	700	322	488	200	326	483	729	828	948	727	1046	718	813	953
2	98	0	348	461	521	435	244	154	361	529	559	683	798	420	586	298	424	582	828	926	1047	825	1144	816	911	1052
3	249	348	0	114	174	88	104	194	377	376	343	610	725	423	581	339	463	621	867	965	1086	820	1183	746	844	985
4	363	461	114	0	71	26	217	307	428	395	309	629	744	472	606	452	576	701	944	1028	1148	846	1246	765	863	1003
5	423	521	174	71	0	86	277	367	427	369	238	603	718	472	580	508	583	701	944	1026	1147	819	1222	739	837	977
6	337	435	88	26	86	0	191	281	412	379	305	614	729	457	591	426	550	685	929	1012	1133	830	1231	749	847	988
7	145	244	104	217	277	191	0	90	273	342	360	570	685	319	477	235	359	517	763	861	982	716	1079	706	803	943
8	55	154	194	307	367	281	90	0	208	377	407	530	645	268	433	147	271	429	675	774	894	672	992	664	759	899
9	262	361	377	428	427	412	273	208	0	195	342	345	460	60	228	155	158	288	532	615	736	467	834	458	553	694
10	431	529	376	395	369	379	342	377	195	0	192	235	350	168	212	330	301	396	604	658	778	451	853	370	468	609
11	461	559	343	309	238	305	360	407	342	192	0	377	494	360	404	477	494	589	796	850	971	638	998	515	613	753
12	584	683	610	629	603	614	570	530	345	235	377	0	122	317	216	479	451	475	543	554	675	265	625	142	241	381
13	700	798	725	744	718	729	685	645	460	350	494	122	0	432	294	594	566	527	595	545	666	256	616	133	231	371
14	322	420	423	472	472	457	319	268	60	168	360	317	432	0	175	215	140	229	472	556	676	412	774	405	500	641
15	488	586	581	606	580	591	477	433	228	212	404	216	294	175	0	382	308	296	392	446	567	239	643	230	325	466
16	200	298	339	452	508	426	235	147	155	330	477	479	594	215	382	0	142	342	587	697	817	620	915	613	708	848
17	326	424	463	576	583	550	359	271	158	301	494	451	566	140	308	142	0	202	447	566	687	489	784	530	625	747
18	483	582	621	701	701	685	517	429	288	396	589	475	527	229	296	342	202	0	251	394	515	380	641	457	526	603
19	729	828	867	944	944	929	763	675	532	604	796	543	595	472	392	587	447	251	0	179	299	367	431	525	487	457
20	828	926	965	1028	1026	1012	861	774	615	658	850	554	545	556	446	697	566	394	179	0	125	288	256	426	328	285
21	948	1047	1086	1148	1147	1133	982	894	736	778	971	675	666	676	567	817	687	515	299	125	0	413	163	533	435	362
22	727	825	820	846	819	830	716	672	467	451	638	265	256	412	239	620	489	380	367	288	413	0	404	164	152	289
23	1046	1144	1183	1246	1222	1231	1079	992	834	853	998	625	616	774	643	915	784	641	431	256	163	404	0	483	385	296
24	718	816	746	765	739	749	706	664	458	370	515	142	133	405	230	613	530	457	525	426	533	164	483	0	98	239
25	813	911	844	863	837	847	803	759	553	468	613	241	231	500	325	708	625	526	487	328	435	152	385	98	0	140
26	953	1052	985	1003	977	988	943	899	694	609	753	381	371	641	466	848	747	603	457	285	362	289	296	239	140	0

Appendix 2: Spatial weigtht matrix for 2005

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	254	367	427	342	150	60	269	436	466	589	704	326	492	204	330	488	734	832	953	731	1051	722	817	958
2	102	0	348	461	521	435	244	154	363	529	559	683	798	420	586	298	424	582	828	926	1047	825	1145	816	911	1052
3	254	348	0	114	174	89	104	194	380	377	343	611	727	423	581	339	463	621	867	965	1086	820	1184	747	845	986
4	367	461	114	0	71	26	217	307	430	395	309	629	744	472	606	452	576	701	944	1028	1148	845	1246	765	863	1003
5	427	521	174	71	0	86	277	368	430	367	238	602	717	472	578	508	584	701	944	1024	1145	817	1220	737	835	976
6	342	435	89	26	86	0	192	282	415	379	305	614	729	457	591	426	551	686	929	1013	1133	830	1231	750	848	988
7	150	244	104	217	277	192	0	90	276	342	360	570	685	319	477	235	359	517	763	861	982	716	1080	706	803	943
8	60	154	194	307	368	282	90	0	211	377	407	530	645	268	433	147	271	429	675	774	894	672	992	664	759	899
9	269	363	380	430	430	415	276	211	0	198	344	347	462	63	231	158	161	291	535	618	739	470	837	461	556	697
10	436	529	377	395	367	379	342	377	198	0	192	235	350	168	211	330	301	396	603	657	778	450	853	370	468	609
11	466	559	343	309	238	305	360	407	344	192	0	377	494	360	404	477	494	589	796	850	970	638	998	515	613	753
12	589	683	611	629	602	614	570	530	347	235	377	0	122	317	216	479	451	475	543	554	675	265	625	142	241	381
13	704	798	727	744	717	729	685	645	462	350	494	122	0	432	294	594	566	527	595	545	666	256	616	133	231	371
14	326	420	423	472	472	457	319	268	63	168	360	317	432	0	175	215	140	229	472	556	676	412	774	405	500	641
15	492	586	581	606	578	591	477	433	231	211	404	216	294	175	0	382	308	296	392	446	567	239	643	230	325	466
16	204	298	339	452	508	426	235	147	158	330	477	479	594	215	382	0	142	343	588	697	817	620	915	613	708	848
17	330	424	463	576	584	551	359	271	161	301	494	451	566	140	308	142	0	203	448	566	687	489	784	530	625	747
18	488	582	621	701	701	686	517	429	291	396	589	475	527	229	296	343	203	0	251	394	515	380	641	457	526	603
19	734	828	867	944	944	929	763	675	535	603	796	543	595	472	392	588	448	251	0	179	299	367	431	525	487	457
20	832	926	965	1028	1024	1013	861	774	618	657	850	554	545	556	446	697	566	394	179	0	125	288	256	426	328	285
21	953	1047	1086	1148	1145	1133	982	894	739	778	970	675	666	676	567	817	687	515	299	125	0	413	163	533	435	362
22	731	825	820	845	817	830	716	672	470	450	638	265	256	412	239	620	489	380	367	288	413	0	404	164	152	289
23	1051	1145	1184	1246	1220	1231	1080	992	837	853	998	625	616	774	643	915	784	641	431	256	163	404	0	483	385	288
24	722	816	747	765	737	750	706	664	461	370	515	142	133	405	230	613	530	457	525	426	533	164	483	0	98	239
25	817	911	845	863	835	848	803	759	556	468	613	241	231	500	325	708	625	526	487	328	435	152	385	98	0	140
26	958	1052	986	1003	976	988	943	899	697	609	753	381	371	641	466	848	747	603	457	285	362	289	288	239	140	0

Appendix 3: Spatial weigtht matrix for 2006

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	254	367	427	342	150	60	269	436	466	589	704	326	495	204	329	488	718	832	953	737	1051	724	823	963
2	102	0	348	461	521	435	244	154	363	529	559	683	798	420	589	298	423	582	812	926	1047	831	1145	818	916	1057
3	254	348	0	114	174	89	104	194	380	377	343	611	727	423	585	339	462	621	851	965	1086	827	1184	747	845	986
4	367	461	114	0	71	26	217	307	430	395	313	629	744	472	608	452	576	701	931	1028	1148	850	1246	765	863	1003
5	427	521	174	71	0	86	277	368	434	371	243	606	721	476	585	507	587	705	935	1031	1151	827	1224	742	840	980
6	342	435	89	26	86	0	192	282	415	379	305	614	729	457	593	426	550	686	916	1013	1133	835	1231	750	848	988
7	150	244	104	217	277	192	0	90	276	342	360	570	685	319	481	235	358	517	747	861	982	723	1080	706	804	944
8	60	154	194	307	368	282	90	0	211	377	407	530	645	268	436	147	271	429	659	774	894	678	992	666	764	904
9	269	363	380	430	434	415	276	211	0	198	344	347	462	63	234	158	160	291	521	618	739	474	837	467	562	702
10	436	529	377	395	371	379	342	377	198	0	192	235	350	168	213	330	300	396	606	660	780	455	853	370	468	609
11	466	559	343	313	243	305	360	407	344	192	0	377	494	360	406	477	493	589	799	852	973	638	998	515	613	753
12	589	683	611	629	606	614	570	530	347	235	377	0	122	317	226	479	450	483	544	550	675	265	625	142	241	381
13	704	798	727	744	721	729	685	645	462	350	494	122	0	432	302	594	565	536	596	541	666	256	616	133	231	371
14	326	420	423	472	476	457	319	268	63	168	360	317	432	0	178	215	139	229	459	556	676	412	774	411	506	644
15	495	589	585	608	585	593	481	436	234	213	406	226	302	178	0	386	311	301	393	446	567	242	642	233	328	468
16	204	298	339	452	507	426	235	147	158	330	477	479	594	215	386	0	142	342	582	697	817	620	915	615	713	852
17	329	423	462	576	587	550	358	271	160	300	493	450	565	139	311	142	0	209	451	569	690	493	788	533	628	724
18	488	582	621	701	705	686	517	429	291	396	589	483	536	229	301	342	209	0	242	387	507	389	639	466	535	603
19	718	812	851	931	935	916	747	659	521	606	799	544	596	459	393	582	451	242	0	177	297	368	429	526	487	453
20	832	926	965	1028	1031	1013	861	774	618	660	852	550	541	556	446	697	569	387	177	0	125	285	256	426	328	283
21	953	1047	1086	1148	1151	1133	982	894	739	780	973	675	666	676	567	817	690	507	297	125	0	409	163	533	435	362
22	737	831	827	850	827	835	723	678	474	455	638	265	256	412	242	620	493	389	368	285	409	0	400	164	152	252
23	1051	1145	1184	1246	1224	1231	1080	992	837	853	998	625	616	774	642	915	788	639	429	256	163	400	0	483	385	288
24	724	818	747	765	742	750	706	666	467	370	515	142	133	411	233	615	533	466	526	426	533	164	483	0	98	239
25	823	916	845	863	840	848	804	764	562	468	613	241	231	506	328	713	628	535	487	328	435	152	385	98	0	140
26	963	1057	986	1003	980	988	944	904	702	609	753	381	371	644	468	852	724	603	453	283	362	252	288	239	140	0

Appendix 4: Spatial weigtht matrix for 2007

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	245	358	412	332	150	60	264	436	465	576	697	321	492	204	324	483	713	827	948	733	1046	711	808	948
2	102	0	339	452	506	426	244	154	358	530	559	670	790	415	586	298	418	577	807	921	1042	827	1140	805	902	1042
3	245	339	0	114	168	89	104	185	380	377	343	601	722	423	584	330	448	607	837	951	1072	826	1170	737	833	974
4	358	452	114	0	63	26	217	298	429	394	306	618	739	471	607	443	562	700	930	1027	1148	849	1226	753	850	990
5	412	506	168	63	0	80	271	352	434	371	243	595	716	476	585	497	587	705	935	1031	1151	827	1204	731	828	968
6	332	426	89	26	80	0	192	272	415	379	305	604	725	457	593	417	536	686	916	1013	1134	835	1212	739	836	976
7	150	244	104	217	271	192	0	90	276	342	360	560	681	319	480	235	353	512	742	856	977	722	1075	695	792	932
8	60	154	185	298	352	272	90	0	206	377	406	517	638	263	433	147	266	424	655	769	889	675	987	653	749	890
9	264	358	380	429	434	415	276	206	0	198	344	337	458	63	234	154	160	291	522	619	739	475	837	467	560	701
10	436	530	377	394	371	379	342	377	198	0	192	224	345	168	213	326	300	397	607	660	780	455	833	360	456	597
11	465	559	343	306	243	305	360	406	344	192	0	379	500	360	406	473	493	589	800	852	973	638	987	515	611	752
12	576	670	601	618	595	604	560	517	337	224	379	0	128	307	211	466	439	477	553	550	665	265	615	142	239	380
13	697	790	722	739	716	725	681	638	458	345	500	128	0	428	308	586	560	541	602	547	662	262	612	139	236	376
14	321	415	423	471	476	457	319	263	63	168	360	307	428	0	178	211	139	229	459	556	677	412	775	410	504	644
15	492	586	584	607	585	593	480	433	234	213	406	211	308	178	0	382	311	301	394	446	567	242	642	232	326	467
16	204	298	330	443	497	417	235	147	154	326	473	466	586	211	382	0	142	342	582	697	817	620	915	601	698	838
17	324	418	448	562	587	536	353	266	160	300	493	439	560	139	311	142	0	209	451	569	690	492	788	532	626	724
18	483	577	607	700	705	686	512	424	291	397	589	477	541	229	301	342	209	0	242	387	507	389	639	466	535	603
19	713	807	837	930	935	916	742	655	522	607	800	553	602	459	394	582	451	242	0	177	297	368	429	526	488	453
20	827	921	951	1027	1031	1013	856	769	619	660	852	550	547	556	446	697	569	387	177	0	125	285	256	416	329	283
21	948	1042	1072	1148	1151	1134	977	889	739	780	973	665	662	677	567	817	690	507	297	125	0	409	163	523	436	362
22	733	827	826	849	827	835	722	675	475	455	638	265	262	412	242	620	492	389	368	285	409	0	400	164	152	252
23	1046	1140	1170	1226	1204	1212	1075	987	837	833	987	615	612	775	642	915	788	639	429	256	163	400	0	473	386	288
24	711	805	737	753	731	739	695	653	467	360	515	142	139	410	232	601	532	466	526	416	523	164	473	0	97	237
25	808	902	833	850	828	836	792	749	560	456	611	239	236	504	326	698	626	535	488	329	436	152	386	97	0	140
26	948	1042	974	990	968	976	932	890	701	597	752	380	376	644	467	838	724	603	453	283	362	252	288	237	140	0

Appendix 5: Spatial weigtht matrix for 2008

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	246	358	412	332	150	60	264	436	465	576	697	321	489	204	324	483	713	827	948	730	1046	711	806	946
2	102	0	339	452	506	426	244	154	358	530	559	670	790	415	583	298	418	577	807	921	1042	824	1140	805	900	1040
3	246	339	0	114	168	89	105	186	381	378	343	602	723	424	582	330	449	608	838	952	1073	823	1170	738	833	973
4	358	452	114	0	63	26	217	298	429	394	309	618	739	471	604	443	562	700	930	1027	1148	845	1217	753	848	988
5	412	506	168	63	0	80	271	352	437	374	245	598	719	479	585	497	590	708	938	1029	1150	825	1198	734	829	969
6	332	426	89	26	80	0	192	272	415	379	305	604	725	457	590	417	536	686	916	1013	1134	831	1203	739	834	974
7	150	244	105	217	271	192	0	90	276	342	360	560	681	319	477	235	353	512	742	856	977	718	1075	695	790	930
8	60	154	186	298	352	272	90	0	206	377	406	517	638	263	430	147	266	424	655	769	889	671	987	653	747	888
9	264	358	381	429	437	415	276	206	0	198	344	337	458	63	231	154	160	291	522	619	739	472	837	463	554	695
10	436	530	378	394	374	379	342	377	198	0	192	224	345	168	211	326	300	397	603	655	776	451	824	360	455	595
11	465	559	343	309	245	305	360	406	344	192	0	379	500	360	403	473	493	589	795	848	968	638	979	515	609	750
12	576	670	602	618	598	604	560	517	337	224	379	0	128	307	208	466	439	477	553	550	656	265	606	142	237	378
13	697	790	723	739	719	725	681	638	458	345	500	128	0	428	307	586	560	541	602	546	653	262	603	139	234	374
14	321	415	424	471	479	457	319	263	63	168	360	307	428	0	175	211	139	229	459	556	677	412	775	406	498	639
15	489	583	582	604	585	590	477	430	231	211	403	208	307	175	0	379	308	299	392	444	565	241	641	231	323	463
16	204	298	330	443	497	417	235	147	154	326	473	466	586	211	379	0	142	342	582	697	817	620	915	601	696	836
17	324	418	449	562	590	536	353	266	160	300	493	439	560	139	308	142	0	209	451	569	690	492	788	532	624	724
18	483	577	608	700	708	686	512	424	291	397	589	477	541	229	299	342	209	0	242	387	507	389	639	466	534	603
19	713	807	838	930	938	916	742	655	522	603	795	553	602	459	392	582	451	242	0	177	297	368	429	526	488	453
20	827	921	952	1027	1029	1013	856	769	619	655	848	550	546	556	444	697	569	387	177	0	125	285	256	407	329	283
21	948	1042	1073	1148	1150	1134	977	889	739	776	968	656	653	677	565	817	690	507	297	125	0	409	163	514	436	362
22	730	824	823	845	825	831	718	671	472	451	638	265	262	412	241	620	492	389	368	285	409	0	400	164	151	252
23	1046	1140	1170	1217	1198	1203	1075	987	837	824	979	606	603	775	641	915	788	639	429	256	163	400	0	464	386	289
24	711	805	738	753	734	739	695	653	463	360	515	142	139	406	231	601	532	466	526	407	514	164	464	0	95	235
25	806	900	833	848	829	834	790	747	554	455	609	237	234	498	323	696	624	534	488	329	436	151	386	95	0	140
26	946	1040	973	988	969	974	930	888	695	595	750	378	374	639	463	836	724	603	453	283	362	252	289	235	140	0

Appendix 6: Spatial weigtht matrix for 2009

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	246	359	413	332	150	60	264	436	465	576	696	321	489	204	324	483	713	827	948	730	1046	711	806	944
2	102	0	340	453	507	426	244	154	358	530	559	670	790	415	583	298	418	577	807	921	1042	824	1140	805	900	1038
3	246	340	0	115	169	89	106	186	381	378	343	603	723	425	583	331	450	608	839	953	1073	823	1171	738	833	971
4	359	453	115	0	63	27	218	299	429	394	306	618	738	471	604	444	563	700	930	1027	1148	845	1217	753	848	986
5	413	507	169	63	0	81	272	353	435	372	243	596	717	477	582	498	588	706	936	1027	1148	823	1196	732	826	965
6	332	426	89	27	81	0	192	272	415	379	305	604	724	457	590	417	536	686	916	1013	1134	831	1203	739	834	972
7	150	244	106	218	272	192	0	90	276	342	360	544	665	319	477	235	353	512	742	856	977	718	1075	680	775	913
8	60	154	186	299	353	272	90	0	206	377	406	517	638	263	430	147	266	424	655	769	889	671	987	653	747	886
9	264	358	381	429	435	415	276	206	0	198	344	337	457	63	231	154	160	291	522	619	739	472	837	463	554	693
10	436	530	378	394	372	379	342	377	198	0	192	224	345	168	211	326	300	397	603	655	776	451	824	360	455	593
11	465	559	343	306	243	305	360	406	344	192	0	379	500	360	403	473	493	589	795	848	968	638	979	515	610	748
12	576	670	603	618	596	604	544	517	337	224	379	0	127	307	208	466	439	477	553	550	656	265	606	142	237	376
13	696	790	723	738	717	724	665	638	457	345	500	127	0	428	307	586	560	541	602	546	653	262	603	139	234	372
14	321	415	425	471	477	457	319	263	63	168	360	307	428	0	175	211	139	229	459	556	677	409	775	406	498	637
15	489	583	583	604	582	590	477	430	231	211	403	208	307	175	0	379	308	299	392	444	565	241	641	231	323	461
16	204	298	331	444	498	417	235	147	154	326	473	466	586	211	379	0	142	342	582	697	817	619	915	601	696	834
17	324	418	450	563	588	536	353	266	160	300	493	439	560	139	308	142	0	209	451	569	690	492	788	532	624	724
18	483	577	608	700	706	686	512	424	291	397	589	477	541	229	299	342	209	0	242	387	507	389	639	466	536	603
19	713	807	839	930	936	916	742	655	522	603	795	553	602	459	392	582	451	242	0	177	297	369	429	527	491	453
20	827	921	953	1027	1027	1013	856	769	619	655	848	550	546	556	444	697	569	387	177	0	125	285	256	407	332	283
21	948	1042	1073	1148	1148	1134	977	889	739	776	968	656	653	677	565	817	690	507	297	125	0	409	163	514	438	362
22	730	824	823	845	823	831	718	671	472	451	638	265	262	409	241	619	492	389	369	285	409	0	400	164	153	252
23	1046	1140	1171	1217	1196	1203	1075	987	837	824	979	606	603	775	641	915	788	639	429	256	163	400	0	464	388	289
24	711	805	738	753	732	739	680	653	463	360	515	142	139	406	231	601	532	466	527	407	514	164	464	0	95	233
25	806	900	833	848	826	834	775	747	554	455	610	237	234	498	323	696	624	536	491	332	438	153	388	95	0	140
26	944	1038	971	986	965	972	913	886	693	593	748	376	372	637	461	834	724	603	453	283	362	252	289	233	140	0

Appendix 7: Spatial weigtht matrix for 2010

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	102	246	359	413	332	150	60	264	436	464	576	696	321	489	204	324	483	713	827	947	730	1045	711	806	944
2	102	0	340	453	507	426	244	154	358	530	558	670	790	415	583	298	418	577	807	921	1041	824	1139	805	900	1038
3	246	340	0	115	169	89	106	186	381	378	343	603	723	425	583	331	450	608	839	952	1073	823	1171	738	833	971
4	359	453	115	0	63	27	218	299	428	393	307	617	738	470	603	444	563	699	929	1026	1147	844	1217	753	847	986
5	413	507	169	63	0	81	272	353	434	369	244	594	714	476	580	498	586	705	935	1025	1145	821	1194	729	824	962
6	332	426	89	27	81	0	192	272	415	379	307	604	724	457	590	417	536	686	916	1013	1134	831	1203	739	834	972
7	150	244	106	218	272	192	0	90	276	342	360	544	665	319	477	235	353	512	742	856	976	718	1074	680	774	913
8	60	154	186	299	353	272	90	0	206	377	406	517	638	263	430	147	266	424	655	768	889	671	986	653	747	886
9	264	358	381	428	434	415	276	206	0	198	344	337	457	63	231	154	160	291	522	619	739	472	837	463	554	693
10	436	530	378	393	369	379	342	377	198	0	192	224	345	168	211	326	300	397	603	655	776	451	824	360	455	593
11	464	558	343	307	244	307	360	406	344	192	0	379	500	360	403	473	493	589	795	848	968	638	979	515	610	748
12	576	670	603	617	594	604	544	517	337	224	379	0	127	307	208	466	439	477	553	550	657	265	607	142	237	376
13	696	790	723	738	714	724	665	638	457	345	500	127	0	428	306	586	560	541	602	547	653	262	603	139	234	372
14	321	415	425	470	476	457	319	263	63	168	360	307	428	0	175	211	139	229	459	556	677	409	775	406	498	637
15	489	583	583	603	580	590	477	430	231	211	403	208	306	175	0	379	308	298	392	444	565	241	641	231	323	461
16	204	298	331	444	498	417	235	147	154	326	473	466	586	211	379	0	142	341	582	696	817	619	914	601	696	834
17	324	418	450	563	586	536	353	266	160	300	493	439	560	139	308	142	0	208	450	568	689	492	787	532	624	723
18	483	577	608	699	705	686	512	424	291	397	589	477	541	229	298	341	208	0	242	387	507	389	639	466	536	602
19	713	807	839	929	935	916	742	655	522	603	795	553	602	459	392	582	450	242	0	177	297	369	429	527	491	453
20	827	921	952	1026	1025	1013	856	768	619	655	848	550	547	556	444	696	568	387	177	0	125	285	256	408	332	283
21	947	1041	1073	1147	1145	1134	976	889	739	776	968	657	653	677	565	817	689	507	297	125	0	409	163	514	439	362
22	730	824	823	844	821	831	718	671	472	451	638	265	262	409	241	619	492	389	369	285	409	0	400	164	153	252
23	1045	1139	1171	1217	1194	1203	1074	986	837	824	979	607	603	775	641	914	787	639	429	256	163	400	0	464	389	289
24	711	805	738	753	729	739	680	653	463	360	515	142	139	406	231	601	532	466	527	408	514	164	464	0	95	233
25	806	900	833	847	824	834	774	747	554	455	610	237	234	498	323	696	624	536	491	332	439	153	389	95	0	140
26	944	1038	971	986	962	972	913	886	693	593	748	376	372	637	461	834	723	602	453	283	362	252	289	233	140	0

Appendix 8: Spatial weigtht matrix for 2011

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	98	242	354	408	327	145	55	257	431	452	571	692	317	484	200	320	479	709	823	945	725	1045	707	802	937
2	98	0	340	453	507	425	244	154	356	530	551	670	790	415	583	298	418	577	807	921	1043	824	1143	805	900	1035
3	242	340	0	115	169	88	106	186	379	378	343	603	723	425	583	326	445	603	833	947	1069	823	1170	738	833	968
4	354	453	115	0	63	27	218	299	414	381	307	605	725	458	591	439	557	687	917	1015	1137	832	1205	740	835	970
5	408	507	169	63	0	81	272	353	431	368	244	593	713	476	579	490	586	705	935	1028	1150	820	1192	728	823	958
6	327	425	88	27	81	0	191	272	405	372	300	597	717	450	583	411	530	679	909	1006	1129	824	1197	732	827	962
7	145	244	106	218	272	191	0	90	273	342	360	543	664	319	477	227	346	504	734	848	971	718	1071	679	774	909
8	55	154	186	299	353	272	90	0	203	377	398	517	637	263	430	147	266	424	655	768	891	671	991	653	747	882
9	257	356	379	414	431	405	273	203	0	195	342	334	455	60	228	152	157	289	519	616	738	469	839	460	552	687
10	431	530	378	381	368	372	342	377	195	0	193	224	345	168	211	326	301	397	603	659	782	451	824	360	455	590
11	452	551	343	307	244	300	360	398	342	193	0	379	500	361	403	473	493	590	795	852	974	639	979	515	610	745
12	571	670	603	605	593	597	543	517	334	224	379	0	127	307	203	466	440	472	553	550	653	267	607	142	237	372
13	692	790	723	725	713	717	664	637	455	345	500	127	0	428	306	586	560	541	602	547	650	263	603	139	234	369
14	317	415	425	458	476	450	319	263	60	168	361	307	428	0	175	211	139	229	459	557	679	409	779	407	499	634
15	484	583	583	591	579	583	477	430	228	211	403	203	306	175	0	379	308	298	392	449	571	241	641	232	324	459
16	200	298	326	439	490	411	227	147	152	326	473	466	586	211	379	0	142	341	582	696	819	619	919	601	696	831
17	320	418	445	557	586	530	346	266	157	301	493	440	560	139	308	142	0	208	450	569	691	492	791	533	625	723
18	479	577	603	687	705	679	504	424	289	397	590	472	541	229	298	341	208	0	242	387	509	389	639	467	536	583
19	709	807	833	917	935	909	734	655	519	603	795	553	602	459	392	582	450	242	0	177	299	345	429	504	493	453
20	823	921	947	1015	1028	1006	848	768	616	659	852	550	547	557	449	696	569	387	177	0	126	285	256	408	332	283
21	945	1043	1069	1137	1150	1129	971	891	738	782	974	653	650	679	571	819	691	509	299	126	0	411	160	511	435	358
22	725	824	823	832	820	824	718	671	469	451	639	267	263	409	241	619	492	389	345	285	411	0	400	165	153	252
23	1045	1143	1170	1205	1192	1197	1071	991	839	824	979	607	603	779	641	919	791	639	429	256	160	400	0	464	389	289
24	707	805	738	740	728	732	679	653	460	360	515	142	139	407	232	601	533	467	504	408	511	165	464	0	95	230
25	802	900	833	835	823	827	774	747	552	455	610	237	234	499	324	696	625	536	493	332	435	153	389	95	0	140
26	937	1035	968	970	958	962	909	882	687	590	745	372	369	634	459	831	723	583	453	283	358	252	289	230	140	0

Appendix 9: Spatial weigtht matrix for 2012

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	95	246	359	413	331	150	60	262	435	457	575	696	321	489	204	324	483	713	827	949	729	1046	711	806	941
2	95	0	340	453	507	425	244	154	356	530	551	670	790	415	583	298	418	577	807	921	1043	824	1140	805	900	1035
3	246	340	0	115	169	88	106	186	379	378	342	603	723	425	583	326	445	604	834	948	1070	823	1166	738	834	968
4	359	453	115	0	63	27	218	299	414	381	305	605	725	458	591	439	558	687	917	1016	1138	832	1199	740	836	970
5	413	507	169	63	0	81	272	353	431	368	242	593	713	476	579	492	586	705	935	1028	1150	820	1187	728	823	958
6	331	425	88	27	81	0	191	272	405	372	297	597	717	450	583	412	530	679	909	1008	1130	824	1191	732	828	962
7	150	244	106	218	272	191	0	90	273	342	360	543	664	319	477	228	346	505	735	849	971	718	1067	679	774	909
8	60	154	186	299	353	272	90	0	203	377	398	517	637	263	430	147	266	424	655	768	891	671	987	653	748	882
9	262	356	379	414	431	405	273	203	0	195	340	334	455	60	228	152	157	289	519	617	740	469	836	460	552	687
10	435	530	378	381	368	372	342	377	195	0	195	224	345	172	211	326	304	401	603	659	782	451	819	360	455	590
11	457	551	342	305	242	297	360	398	340	195	0	379	500	367	406	471	495	596	798	855	977	639	974	515	610	745
12	575	670	603	605	593	597	543	517	334	224	379	0	127	304	197	466	436	465	553	548	652	267	601	142	238	372
13	696	790	723	725	713	717	664	637	455	345	500	127	0	424	306	586	557	543	602	545	649	263	598	139	234	369
14	321	415	425	458	476	450	319	263	60	172	367	304	424	0	175	211	139	229	459	558	680	409	776	407	499	634
15	489	583	583	591	579	583	477	430	228	211	406	197	306	175	0	379	308	297	392	449	571	241	634	232	324	459
16	204	298	326	439	492	412	228	147	152	326	471	466	586	211	379	0	142	338	581	696	819	618	915	601	696	831
17	324	418	445	558	586	530	346	266	157	304	495	436	557	139	308	142	0	205	448	569	691	491	788	533	625	726
18	483	577	604	687	705	679	505	424	289	401	596	465	543	229	297	338	205	0	242	387	509	392	638	469	537	587
19	713	807	834	917	935	909	735	655	519	603	798	553	602	459	392	581	448	242	0	177	299	345	428	504	480	441
20	827	921	948	1016	1028	1008	849	768	617	659	855	548	545	558	449	696	569	387	177	0	126	281	255	408	330	272
21	949	1043	1070	1138	1150	1130	971	891	740	782	977	652	649	680	571	819	691	509	299	126	0	406	153	510	432	356
22	729	824	823	832	820	824	718	671	469	451	639	267	263	409	241	618	491	392	345	281	406	0	393	165	151	244
23	1046	1140	1166	1199	1187	1191	1067	987	836	819	974	601	598	776	634	915	788	638	428	255	153	393	0	459	381	289
24	711	805	738	740	728	732	679	653	460	360	515	142	139	407	232	601	533	469	504	408	510	165	459	0	95	230
25	806	900	834	836	823	828	774	748	552	455	610	238	234	499	324	696	625	537	480	330	432	151	381	95	0	138
26	941	1035	968	970	958	962	909	882	687	590	745	372	369	634	459	831	726	587	441	272	356	244	289	230	138	0

Appendix 10: Spatial weigtht matrix for 2013

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	95	246	359	413	331	150	60	262	435	457	575	696	321	489	204	324	483	713	827	949	729	1046	711	806	941
2	95	0	340	453	507	425	244	154	356	530	551	670	790	415	583	298	418	577	807	921	1043	824	1140	805	900	1035
3	246	340	0	115	169	88	106	186	379	378	342	603	723	425	583	326	445	604	834	948	1070	823	1166	738	834	968
4	359	453	115	0	63	27	218	299	414	381	305	605	725	458	591	439	558	687	917	1016	1138	832	1199	740	836	970
5	413	507	169	63	0	81	272	353	431	368	242	593	713	476	579	492	586	705	935	1028	1150	820	1187	728	823	958
6	331	425	88	27	81	0	191	272	405	372	297	597	717	450	583	412	530	679	909	1008	1130	824	1191	732	828	962
7	150	244	106	218	272	191	0	90	273	342	360	543	664	319	477	228	346	505	735	849	971	718	1067	679	774	909
8	60	154	186	299	353	272	90	0	203	377	398	517	637	263	430	147	266	424	655	768	891	671	987	653	748	882
9	262	356	379	414	431	405	273	203	0	195	340	334	455	60	228	152	157	289	519	617	740	469	836	460	552	687
10	435	530	378	381	368	372	342	377	195	0	195	224	345	172	211	326	304	401	603	659	782	451	819	360	455	590
11	457	551	342	305	242	297	360	398	340	195	0	379	500	367	406	471	495	596	798	855	977	639	974	515	610	745
12	575	670	603	605	593	597	543	517	334	224	379	0	127	304	197	466	436	465	553	548	652	267	601	142	238	372
13	696	790	723	725	713	717	664	637	455	345	500	127	0	424	306	586	557	543	602	545	649	263	598	139	234	369
14	321	415	425	458	476	450	319	263	60	172	367	304	424	0	175	211	139	229	459	558	680	409	776	407	499	634
15	489	583	583	591	579	583	477	430	228	211	406	197	306	175	0	379	308	297	392	449	571	241	634	232	324	459
16	204	298	326	439	492	412	228	147	152	326	471	466	586	211	379	0	142	338	581	696	819	618	915	601	696	831
17	324	418	445	558	586	530	346	266	157	304	495	436	557	139	308	142	0	205	448	569	691	491	788	533	625	726
18	483	577	604	687	705	679	505	424	289	401	596	465	543	229	297	338	205	0	242	387	509	392	638	469	537	587
19	713	807	834	917	935	909	735	655	519	603	798	553	602	459	392	581	448	242	0	177	299	345	428	504	480	441
20	827	921	948	1016	1028	1008	849	768	617	659	855	548	545	558	449	696	569	387	177	0	126	281	255	408	330	272
21	949	1043	1070	1138	1150	1130	971	891	740	782	977	652	649	680	571	819	691	509	299	126	0	406	153	510	432	356
22	729	824	823	832	820	824	718	671	469	451	639	267	263	409	241	618	491	392	345	281	406	0	393	165	151	244
23	1046	1140	1166	1199	1187	1191	1067	987	836	819	974	601	598	776	634	915	788	638	428	255	153	393	0	459	381	289
24	711	805	738	740	728	732	679	653	460	360	515	142	139	407	232	601	533	469	504	408	510	165	459	0	95	230
25	806	900	834	836	823	828	774	748	552	455	610	238	234	499	324	696	625	537	480	330	432	151	381	95	0	138
26	941	1035	968	970	958	962	909	882	687	590	745	372	369	634	459	831	726	587	441	272	356	244	289	230	138	0

Appendix 11: Spatial weigtht matrix for 2014

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	0	95	246	359	413	331	150	60	262	435	457	575	696	321	489	204	324	483	713	827	949	729	1049	711	806	941
2	95	0	340	453	507	425	244	154	356	530	551	670	790	415	583	298	418	577	807	921	1043	824	1143	805	900	1035
3	246	340	0	115	169	88	106	186	379	378	343	603	723	425	583	326	445	603	833	947	1069	823	1170	738	833	968
4	359	453	115	0	63	27	218	299	414	381	307	605	725	458	591	439	557	687	917	1015	1137	832	1205	740	835	970
5	413	507	169	63	0	81	272	353	431	368	244	593	713	476	579	490	586	705	935	1028	1150	820	1192	728	823	958
6	331	425	88	27	81	0	191	272	405	372	300	597	717	450	583	411	530	679	909	1006	1129	824	1197	732	827	962
7	150	244	106	218	272	191	0	90	273	342	360	543	664	319	477	227	346	504	734	848	971	718	1071	679	774	909
8	60	154	186	299	353	272	90	0	203	377	398	517	637	263	430	147	266	424	655	768	891	671	991	653	747	882
9	262	356	379	414	431	405	273	203	0	195	342	334	455	60	228	152	157	289	519	616	738	469	839	460	552	687
10	435	530	378	381	368	372	342	377	195	0	193	224	345	168	211	326	301	397	603	659	782	451	824	360	455	590
11	457	551	343	307	244	300	360	398	342	193	0	379	500	361	403	473	493	590	795	852	974	639	979	515	610	745
12	575	670	603	605	593	597	543	517	334	224	379	0	127	307	203	466	440	472	553	550	653	267	607	142	237	372
13	696	790	723	725	713	717	664	637	455	345	500	127	0	428	306	586	560	541	602	547	650	263	603	139	234	369
14	321	415	425	458	476	450	319	263	60	168	361	307	428	0	175	211	139	229	459	557	679	409	779	407	499	634
15	489	583	583	591	579	583	477	430	228	211	403	203	306	175	0	379	308	298	392	449	571	241	641	232	324	459
16	204	298	326	439	490	411	227	147	152	326	473	466	586	211	379	0	142	341	582	696	819	619	919	601	696	831
17	324	418	445	557	586	530	346	266	157	301	493	440	560	139	308	142	0	208	450	569	691	492	791	533	625	723
18	483	577	603	687	705	679	504	424	289	397	590	472	541	229	298	341	208	0	242	387	509	389	639	467	536	583
19	713	807	833	917	935	909	734	655	519	603	795	553	602	459	392	582	450	242	0	177	299	345	429	504	493	453
20	827	921	947	1015	1028	1006	848	768	616	659	852	550	547	557	449	696	569	387	177	0	126	285	256	408	332	283
21	949	1043	1069	1137	1150	1129	971	891	738	782	974	653	650	679	571	819	691	509	299	126	0	411	160	511	435	358
22	729	824	823	832	820	824	718	671	469	451	639	267	263	409	241	619	492	389	345	285	411	0	400	165	153	252
23	1049	1143	1170	1205	1192	1197	1071	991	839	824	979	607	603	779	641	919	791	639	429	256	160	400	0	464	389	289
24	711	805	738	740	728	732	679	653	460	360	515	142	139	407	232	601	533	467	504	408	511	165	464	0	95	230
25	806	900	833	835	823	827	774	747	552	455	610	237	234	499	324	696	625	536	493	332	435	153	389	95	0	140
26	941	1035	968	970	958	962	909	882	687	590	745	372	369	634	459	831	723	583	453	283	358	252	289	230	140	0