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Sustainable Regional Development Scientific Journal, Vol. I, (1), Special Issue, Oct: 2024

Editorial Note

In the second semester of 2024, the Sustainable Regional Development Scientific Journal (SRDSJ), published under the scientific aegis of the Albanian Association of Regional Scientists (A.A.R.S), launches the special issue of its first volume (Vol. I) since the first day it was published. The SRDSJ is an international, open-access, and peer-reviewed journal that publishes research on various topics related to Regional Science and Sustainability. The journal aims to freely promote the academic dialogue in Regional Science worldwide, as well as to serve scientific research with solid quality standards in empirical, methodological, and theoretical contribution. It provides a platform for scholars, policymakers, and practitioners to share their research and insights on regional development, sustainability and its various dimensions.

Since July 2024, the SRDSJ has published 12 articles, on a wide range of topics (such as Regional Economics and Development; Spatial Analysis and Econometrics; Economic Geography and Transportation Economics; Urban Planning and Development; Tourism Economics and Development; Urban and Regional Sustainability; Regional Analysis and Policy; etc.). Serving its broad multidisciplinary scope, SRDSJ provides publication opportunities to researchers from various disciplines and an open-access platform for communicating regional science research and making it accessible to a wider audience. Also, SRDSJ supports a reasonably timely review process, promoting the academic dialogue by making scientific research accessible to the researchers' community in time.

The journal is indexed in various scientific databases (RePEc, EconpPapers, BnF, etc.) and its contribution to scientific research is accredited by scientific associations (such as Regional Science Association International, Albanian Association of Regional Scientists). Further, the SRDSJ has the merit to include in its editorial board reputable scholars from worldwide, who ensure that the published papers meet rigorous academic standards. Moreover, the SRDSJ systemically provides a forum for ideas exchange, news, and information, by covering topics of broader academic interest, such as events (conferences, workshops, and seminars), academic profiles (providing insights into the work and accomplishments of leading scholars in the field), and book reviews (offering a valuable service by summarizing and evaluating important publications). This broad academic framework enhances the value of SRDSJ as a resource for scholars and practitioners for readers interested in keeping up with the latest developments in Regional Science.

All these attributes and merits of SRDSJ have been so far fertile and promising for the journal's future path. Following this reputed heritage, the RSIJ continues working hard toward providing a reputable and respected publication, along with a valuable platform for high-quality research for anyone interested in regional science, regional development, and related fields. In this semester, the current issue (SRDSJ, Vol. I, Special Issue, October, 2024) includes five papers, which were carefully selected from a large pool of submissions so that to comply with the high journal's standards. These papers deal with modern and interesting topics of Regional Science research, such as regional economic resilience; labor market behavior and economic growth; public land transportation, air transport, and regional development; and business and entrepreneurship and economic growth.

In brief, the first paper, titled "INVESTMENT AND PRODUCTIVITY IN THE AGRO-INDUSTRIAL SECTOR: A CASE STUDY", authored by *Teresa SEQUEIRA, Conceicao REGO, Andreia DIONISIO* studies the productivity of a sector, an important determinant of competitiveness, depends, among other factors, on the investment made. In this context, the main aim of this work is to explore the relation between investment and productivity trends, based on the amounts of investment made in the agri-food industry in Northern Portugal (NUT II), as well as the asymmetries at sub-regional level, during the last two EU support frameworks, namely QREN (2007-13) and Portugal 2020 (2014-2020). This study will start by gathering information from organizations that manage EU funds related to the beverage and food industries. The results show that there is a positive and significant relation between gross fixed capital formation and the productivity of both industries: food and beverage. In what refers, specifically to the beverage industry, we obtain significant results in the elasticity model. The findings show that it possible to gauge the effectiveness of policies to support investment, namely by identifying the most dynamic sectors in terms of attracting funds and with the greatest impact in terms of productivity, i.e. assessing the return on investment that is essentially private and supported with public funds, as well as identifying strategic sectors and promoting transparency and accountability in the management of public resources.

The second paper, titled "A COMBINED GRAPH THEORETIC AND TRANSPORT PLANNING FRAMEWORK FOR THE ECONOMIC AND FUNCTIONAL ANALYSIS OF LARGE-SCALE ROAD

NETWORKS", authored by *Maria STAVARA, Dimitrios TSIOTAS,* studies road networks are the backbone of our society and a built capital enabling the movement of people and transportation of goods. Their design should comply with both traffic and technical requirements and economic demand, to ensure efficient connectivity, accessibility, optimum resource allocation, and long-term sustainability. Poised on the intersection of this bi-dimensional context, this paper develops a methodological framework incorporating these two dimensions in road network analysis to evaluate both functional and economic aspects of the network. Within this framework, we incorporate functional and economic information into an interurban road graph model constructed on empirical data from Greece, and we afterward evaluate the level of determination and the model's applicability and usefulness in transportation planning. Overall, our findings reveal the proposed approach capable of evaluating potential interventions in the network and estimating traffic volumes, especially in data-constrained situations. In empirical terms, they indicate that the socio-economic performance of the national road network is satisfactory, albeit not fully optimized.

The third paper, titled "SMART CITY INITIATIVES AND ECONOMIC GROWTH IN INDIA: AN EMPIRICAL ANALYSIS, authored by *Arshima KHAN, Sabyasachi TRIPATHI, Jyoti CHANDIRAMANI*", studies in developing countries, cities are vying with each other to improve their infrastructure to attract business activities and become more efficient, effective, and sustainable. Against this backdrop, the 'Smart City Mission' is one of the flagship Indian government initiatives started in 2015. In order to provide people with a high-quality living, smart cities are the latest urban conceptions. It is the idea of combining different technologies to create sustainable and intelligent practices. However, the quantitative assessment of this initiative on urbanization in India is very limited. In this study, we assess the impact of smart city projects on urbanization, which is measured by city population size and city gross domestic product. The results show that the mission has a mixed effect on urbanization. Though it increases the size of the city's population, it does not promote city income. Therefore, implementing a smart city mission has to be done in the hinterland area along with the core area of a city. Finally, it discusses the challenges faced and their potential solutions. The results suggest several policies for making urbanization a success and making India a developed country.

Last but not least, the fourth paper, titled "THE EFFICACY OF TECHNICAL ANALYSIS IN THE FOREIGN EXCHANGE MARKET: A CASE STUDY OF THE USD/JPY PAIR", authored by *Fernando TEIXEIRA, Susana Soares Pinheiro Vieira PESCADA, Filipos RUXHO, studies t*echnical analysis, rooted in the principle of market efficiency, focuses on price movements to predict future trends (Fang & Jacobsen, 2024). Originating in the 17th century, technical analysis has gained prominence in modern financial markets (Dongrey, 2022). Technical analysts rely on historical forex data (Garza Sepúlveda et al., 2023) and employ various tools, including candlestick patterns, moving averages, trendlines, resistance levels, and indicators like Bollinger Bands, MACD, RSI, and moving averages, to forecast price movements (Oktaba & Grzywińska-Rąpca, 2024). This study aimed to evaluate the effectiveness of technical analysis in the foreign exchange market by analyzing historical USD/JPY data from 2019, a period unaffected by major global events. The USD/JPY pair was chosen due to its high volatility and economic significance (Fiszeder, 2018 and Peng et al., 2021). Our analysis involved identifying support and resistance levels, trends, and applying various technical indicators to assess their effectiveness in predicting market movements (Mate & Jimeńez, 2021). The findings validate the use of technical analysis tools, demonstrating their ability to identify potential reversal and continuation zones.

All these interesting works are available on the next pages of the SRDSJ intending to promote the academic dialogue in Regional Science. Overall, the Editor in Chief, Professor Assistant Filipos A. Ruxho, the Editorial Board, and the signatory of this Editorial Note welcome the reader to the multidisciplinary journey of Sustainable Regional Development Scientific Journal that the current issue promises on its following pages.

On behalf of the Editorial Board
Professor Assistant **Filipos A. Ruxho**
Editor-in-Chief

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Articles

INVESTMENT AND PRODUCTIVITY IN THE AGRO-INDUSTRIAL SECTOR: A CASE STUDY

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Abstract

The productivity of a sector, an important determinant of competitiveness, depends, among other factors, on the investment made. In this context, the main aim of this work is to explore the relation between investment and productivity trends, based on the amounts of investment made in the agri-food industry in Northern Portugal (NUT II), as well as the asymmetries at sub-regional level, during the last two EU support frameworks, namely QREN (2007-13) and Portugal 2020 (2014-2020). This study will start by gathering information from organizations that manage EU funds related to the beverage and food industries. This data will be categorized by subsectors and regions to estimate access. The research will then analyse productivity trends in these sectors and the impact of investment on productivity using statistical analysis techniques. The results show that there is a positive and significant relation between gross fixed capital formation and the productivity of both industries: food and beverage. In what refers, specifically to the beverage industry, we obtain significant results in the elasticity model. The findings show that it possible to gauge the effectiveness of policies to support investment, namely by identifying the most dynamic sectors in terms of attracting funds and with the greatest impact in terms of productivity, i.e. assessing the return on investment that is essentially private and supported with public funds, as well as identifying strategic sectors and promoting transparency and accountability in the management of public resources.

Keywords: productive specialization, clusters, regional development

JEL classification: R12, R58

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Introduction

Investment is a variable that has long gained particular prominence in economic and social analyses, especially since the concepts of GDP multiplier and accelerator were developed. Likewise, its particularly virtuous nature as an engine of growth has been demonstrated, as opposed to other possibly less sustainable engines, such as private or public consumption. In addition, the so-called externalities (or spillover effects) of investment have been recognised as very beneficial for economic growth and development, facts that, taken together, make investment a variable that analysts are particularly attentive to and which justify investment decisions being supported and often, especially in the case of foreign direct investment, witnessing real disputes between local agents in order to attract investment to their territories (Ramos, 2006).

Since Portugal joined the European Union (EU) in 1986, it has received a significant amount of support for investment in various areas, under various funding agreements, which reflect the economic, social and territorial development policy defined to promote the country, taking into account the established State Budgets.

This financial support comes from the five European Structural and Investment Funds, namely the European Regional Development Fund (ERDF) and the European Social Fund (ESF), the European Agricultural Fund for Rural Development (EAFRD), as well as the current European Maritime, Fisheries and Aquaculture Fund (EMFAF) and the Cohesion Fund.

In this study, we will analyse the investment made in the agri-food industrial sector in the north of Portugal from 2007, when the "Quadro de Referência Estratégico Nacional (QREN)"/ National Strategic Reference Framework began to be implemented, until 2020, the final year of the most recently implemented framework, Portugal 2020 (PT2020).

Subsequently, the relationship between realised investment and productivity trends in the two sub-sectors of the agri-food industry will be studied, specifically the food industry and the beverage industry. After discussing the results, the main conclusions to be drawn will be presented, as well as pointing out the limitations encountered and avenues for future research.

1. Context

1.1. Conceptual framework

Economic theory has always identified investment as one of the determining factors of economic growth. This relationship, although it takes different forms, can be seen in the approaches associated with both the classical and neoclassical currents of economic thought, as well as the Keynesian and neo-Keynesian perspectives (Silva and Sequeira, 2011). Investment, whether it is made to increase the capital intensity of the production process, focusing on technological progress, research and development or improving human capital, always aims to improve the conditions and characteristics of production, making productive activities more profitable and competitive. Recently, studies that consider the territorial dimension of competitiveness, and the rationale based on regional innovation systems, suggest that the effects of investment are reflected in improved collective business efficiency once business clusters benefit from positive externalities arising from specialisation, reduced transaction costs, reduced uncertainty and the diffusion of innovative practices (Silva and Sequeira, 2011).

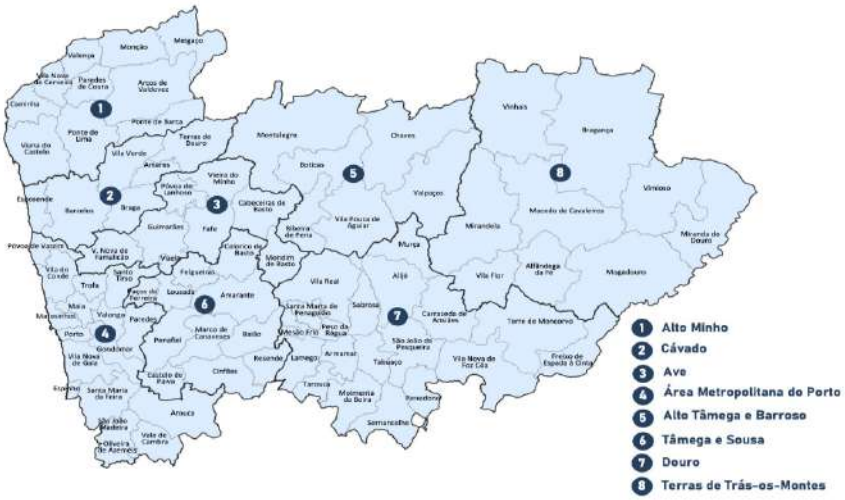
In Portugal, following integration into the European Union, most investment processes, whether private (entrepreneurial) or public, have benefited from the support of EU funds, many of which are structural. This funding has always been aimed at reducing development asymmetries from two perspectives: on the one hand, for the country in relation to the rest of the more developed member states and, on the other hand, internally, for the less developed regions in comparison to those with greater economic dynamism. Investments in environmental, social, cultural, productive, commercial and transport infrastructure, with the support of the structural funds, have profoundly transformed the country's territorial configuration, making it much less unequal basic conditions of access to quality of life (Mateus, 2013). Investment supported by European funding has made it possible to bring Portuguese regions closer together in terms of the living conditions offered to their populations, in areas such as housing, access to energy and sanitation, health, education or the 'road' distances between the country's main urban centres. Mateus (2013) consider that cohesion investments were prioritised over competitiveness and investments in potential conditions over the effective results of economic and social

development. According to the author, this choice has not made it possible to build regional dynamics of cumulative convergence of equal opportunities for both people and companies, whether in access to the most advanced factors of value creation (knowledge, culture, creativity) or in access to income generated outside the context of public policy action (Mateus, 2013). In this respect, Costa (2019) considers that, as a result of the regional policy pursued, there have been good results from the point of view of promoting territorial equity (access of citizens living in different territories to public goods and services and merit goods) but from the point of view of territorial competitiveness (the ability of territories to generate employment and income for their residents) the results have been insufficient.
In this context, analysing the contribution of investment to productivity is fundamental. Productivity is nothing more than a measure of economic efficiency that calculates the relationship between the resources used in the production (inputs) and the final product (outputs). But it is based on the measure and value of productivity in the productive sectors that countries and regions identify their wealth creation and competitive capacity. Studies carried out to assess the impact of European funding on Portuguese companies show that companies with approved projects have higher levels of employment, turnover, gross value added, productivity, capital and exports compared to those that have not received support, and these differences prevail over time (Cabral and Campos, 2023).
The effects of investment in the productivity of food and beverage sector in northern Portugal are analysed below. Even though manufacturing industry is losing weight in wealth creation in Portugal, this activity sector is among the largest contributors to industrial production.

1.2. A brief characterisation of the northern region and its agri-food industry sector

The region under study, the North of Portugal, is a level II region under the terms of the Nomenclature of Territorial Units for Statistics (NUTS) approved by the European Commission. The Norte region includes 86 municipalities, organised into eight Intermunicipal Communities (CIM), which make up eight level III regions (NUT III), as can be seen in figure 1.

Figure 1. The territorial distribution of the northern region of Portugal, by NUT III and municipality, 2024



Source: CCDR-N (2024)

With a population of around 3.6 million, the Northern Region is home to almost 35 per cent of Portugal's resident population, accounts for almost 35 per cent of national exports and represents around 30 per cent of the national economy's GDP (CCDR-N, 2024).
However, it is a region with deep asymmetries between the inland territories, with large areas considered to be low density and serious problems of economic and social cohesion, and the coastal area, which is richer and more populated.

Specifically, according to the information in Table 1.A in the appendix, with data for the year 2021, we can verify that although the north has a higher population density (169.4 inhabitants per square kilometre) than the average for Portugal, the inland regions, such as Terras de Trás-os-Montes (19.4), Douro (45.7) and Alto Tâmega (28.8) have very low densities. The level of education, shown in the table by the percentage of the population with a level of schooling upper than secondary, also indicates that the population of these NUT IIIs is less qualified and much older, a situation visible through the ageing index. The purchasing power and development index indicators, which are also present in the table, are index numbers that have a value of 100 for the country, and it can be seen that all regions, with the exception of the Oporto metropolitan area, have lower values, thus proving the situation of relative poverty and development lags.

As for the data on companies, we would emphasise the weight of the primary sector in regions such as Terras de Trás-os-Montes and the Douro, the latter being a deeply wine-growing region that includes the Alto Douro Vinhateiro, considered a World Heritage Site by Unesco in 2001.

As for the agri-food industry sector, which includes the food industry itself and the beverages industry, the North represents around 32 per cent of the number of companies in the country and, in 2021, (Table 2.A in the appendix) the gross added value (GVA) of the agri-food industry sector in the region totalled 989 M€, distributed 56 per cent by the food industry and 44 per cent by the beverages industry. This amount corresponds to 29% of the sector's gross value added at national level, as well as the same percentage in relation to the volume of employment. In terms of Gross Fixed Capital Formation (FBCF), the north has a relatively lower share, around 26 per cent.

However, investment is a broader concept than gross fixed capital formation, including other types of investment of an intangible nature, from investment in innovation and development, to strengthening labour capacities through human capital formation, and other activities that are fundamental to competitiveness. Thus, we are proceeding to analyse the investment made in the region during the most recent EU financial support frameworks.

2. Objectives and methodology

The first objective of this work is to assess the amounts of investment made in the agri-food industry in the north of Portugal (NUT II region) during the last two EU support frameworks, namely QREN (2007-13) and Portugal 2020 (2014-2020). This access to the region will be analysed both in absolute terms, by amount of investment and type of agri-food industry, and in relative terms, by comparison with the country as a whole. We will also try to ascertain possible asymmetries at sub-regional or NUT III level.

The second objective is to analyse the relationship between the investment realised and the evolution of the sector's productivity.

In methodological terms, and after a theoretical review, the empirical work began by reconstituting or identifying the various programmes that supported the sector and the corresponding management entities of these Community programmes (QREN,2023; PT20220, 2023).

Subsequently, data on projects carried out in the Northern region and funded under the QREN and PT2020 was requested from the "Agência para o Desenvolvimento e Coesão, I.P" (AD&C, 2023a and 2023b). We also analysed data from the specific agricultural support programmes, namely the "Programa de Desenvolvimento Rural" (PRODER) during the period corresponding to the operation of the QREN (2007-2013) and the "Programa de Desenvolvimento Rural de Portugal" (PDR 2020) during the PT2020 period (2014-2020), information provided by the "Instituto de Financiamento da Agricultura e Pescas, I.P". (IFAP, 2023).

After receiving lists of around 1,800 projects, they were analysed and classified based on various grouping criteria, namely by territorial unit and by sector. From these analysed lists, tables were drawn up to allow a comparative analysis of the relative dynamism of the various industries in the agri-food sector and the regions.

As regards the relationship between these investments and the evolution of productivity, the fact that the project lists in most cases did not indicate the municipality compromised the size of the sample for statistical purposes, so it was necessary to use another set of variables.

For this purpose, information on the FBCF of companies in the sector at municipal level was requested from INE-Statistics Portugal (INE, 2024g). As for productivity, the concept of labour productivity was

used, i.e. it was calculated using the ratio between Turnover/Number of Workers and thus the variation in productivity between the initial and final year under analysis was estimated.
The impacts of investment (FBCF) on the productivity of food and beverage industries was estimated using two simple regression models:

$$Ln(Prod)_i = \beta_0 + \beta_1 Ln(FBCF)_i + \varepsilon_i Ln(Prod)_i = \beta_0 + \beta_1 Ln(FBCF)_i + \varepsilon_i \quad (1)$$

Where Prod refers to the productivity level of each industry and FBCF the level of respective investment.
In order to assess the validity and consistency of the estimated models, the Reset test for model specification was applied, such as Jarque-Bera test for normality of errors and Breush-Pagan to teste the presence of homoskedasticity.
We also estimated the impact of investment in the annual variation of productivity. The equation in the base for this model was the following:

$$Var\_Prod_i = \beta_0 + \beta_1 Ln(FBCF)_i + \varepsilon_i Var\_Prod_i = \beta_0 + \beta_1 Ln(FBCF)_i + \varepsilon_i \quad (2)$$

The main goal is to assess the impact of investment (in percentual terms) on the possible increase in productivity between investment programmes.

3. Results

3.1. Access to EU funds for the agri-food industrial sector in the northern region

As mentioned above, Portugal has been receiving investment support since it joined the European Union. Focusing the analysis on the 2007-2020 period, it can be seen that this investment support fell under two support agreements, and it is estimated that Portugal received 21.5 billion euros (M€) of support under QREN, which, added to the estimated 25 billion euros under PT2020, totals more than 46 billion euros (AD&C, 2023b), i.e. an average of more than 2% of annual GDP (Pordata, 2023).
With regard to access to the agro-industrial sector, and according to the methodology indicated, after identifying the programmes that supported this sector, we obtained the project lists, which allowed us to construct table 1, with an overview of the situation.
During this period from 2007 to 2020, the agri-food industry in the North (NUT II) presented projects corresponding to an investment of 1,214.93 M€ and representing around 32.1% of the total value for Portugal, as shown in Table 1, built with the values available at the time. This investment was supported by public spending, corresponding to EU funds and the respective national contribution, totalling 453.83 M€, thus absorbing 34.5% of the public spending approved in this regard for the country as a total.
Continuing the analysis of Table 1, we observe that within the support for the agri-food industry in the north, the support received through the "Programa Operacional Fatores de Competitividade" (16.8% of the total support for the 2007-20 period) was particularly noteworthy during the QREN period; In the PT2020 period, the "Programa Operacional de Competitividade e Internacionalização" (34.9%) stands out, as does the "medida relativa ao apoio ao Investimento na Transformação e Comercialização de Produtos Agrícolas" under the PDR (11.4%). In total, these 4 instruments accounted for more than 80 per cent of the total public spending on support for the agri-food industry in the North.
Also, with regard to the distribution of investment and support by programme, in general there was a similar distribution between the North and Portugal, with the exception of QREN, which had a greater relative importance in supporting the North (21% of total support, compared to 14.6% for Portugal), while the situation was reversed under PRODER (29.6% for Portugal and 18.4% for the North, in terms of relative distribution).

Table 1. Investment in the agri-food industry in NUT II Norte, by programme (2007-2020)

Agri-food industry projects (CAE 10+11)							
Period	Programme	Projects		Investment		Public expenditure	
		Nº	% Total	Value (10^3 €)	% no Total	Value (10^3 €)	% Total
2007-2013	**QREN:**						
	Fatores de Competitividade	108	5.9%	143 286	11.8%	76 467	16.8%
	Regional Centro	1	0.1%	462	0.0%	230	0.1%
	Regional Norte	130	7.1%	30 639	2.5%	18 607	4.1%
	Total QREN Norte (CAE 10+11)	239	13.1%	174 387	14.4%	95 304	21.0%
	Total QREN Portugal (CAE 10+11)	685	12.2%	376 858	10.0%	191 586	14.6%
	PRODER:						
	Modernização e capacitação empresas	260	14.2%	302 426	24.9%	81 762	18.0%
	Criação e desenvolv. microempresas	55	3.0%	3 921	0.3%	1 710	0.4%
	Total PRODER Norte (CAE 10+11)	315	17.3%	306 347	25.2%	83 472	18.4%
	Total PRODER Portugal (CAE 10+11)	1 023	18.2%	1 296 635	34.3%	389 620	29.6%
Total Norte CAE10+11 (2007-2013)		**554**	**30.4%**	**480 733**	**39.6%**	**178 776**	**39.4%**
Total Portugal CAE 10+11 (2007-2013)		**1 708**	**30.4%**	**1 673 493**	**44.2%**	**581 206**	**44.2%**
2014-2020	**PT2020:**						
	Programa Op. Comp. e Internacionalização	403	22.1%	341 676	28.1%	158 225	34.9%
	Programa Op. Inclusão Social e Emprego	3	0.2%	86	0.0%	86	0.0%
	Programa Op. Regional Norte	308	16.9%	113 846	9.4%	46 041	10.1%
	Total PT2020 Norte (CAE10+11)	714	39.1%	455 609	37.5%	204 352	45.0%
	Total PT2020 Portugal (CAE10+11)	2 225	39.6%	1 256 897	33.2%	505 851	38.5%
	PDR:						
	Invest. Transf. e Comerc. Prod. Agrícolas	219	12.0%	226 748	18.7%	51 727	11.4%
	Pequenos Investimentos	206	11.3%	38 227	3.1%	11 977	2.6%
	Pequenos Inv. Transf. C. Prod. Agrícolas	132	7.2%	13 618	1.1%	7 002	1.5%
	Total PDR Norte (CAE10+11)	557	30.5%	278 594	22.9%	70 706	15.6%
	Total PDR Portugal (CAE10+11)	1 688	30.0%	854 470	22.6%	228 017	17.3%
Total Norte CAE10+11 (2014-2020)		**1 271**	**69.6%**	**734 202**	**60.4%**	**275 058**	**60.6%**
Total Portugal CAE 10+11 (2014-2020)		**3 913**	**69.6%**	**2 111 367**	**55.8%**	**733 867**	**55.8%**
Total Norte CAE 10+11 (2007-2020)		**1 825**	**100%**	**1 214 936**	**100%**	**453 833**	**100%**
Total Portugal CAE 10+11 (2007-2020)		**5 621**	**100%**	**3 784 859**	**100%**	**1 315 074**	**100%**
Norte/Portugal (2007-2020)		**32,5%**		**32.1%**		**34.5%**	

Source: Own elaboration through AD&C(2023a), and IFAP (2023)

Note: it was decided to keep the name in the original language of each programme, as they are mostly programmes for Portugal.

As for the total of 1,825 projects submitted to date, there was a significant 130% increase in the number of projects between the two programming periods (554 projects in the QREN period and 1,271 in the PT2020 period). Although this was not proportionally reflected in terms of the amount of investment and support received (480.73 M€ and 734.2 M€ respectively of investment in each period, and corresponding to actual public expenditure of 178.77 M€ and 275.05 M€), which translates into a significant decrease in the average size of projects during the periods under study.

According to the Portuguese Classification of Economic Activities (CAE) in its current version CAE-rev.3 (INE, 2007), since the agri-food industry is made up of the food industry (CAE 10) and the beverage industry (CAE 11), table 2 shows the breakdown of this investment and support between the two CAEs.

Table 2. Projects executed in the North by CAE (2007-2020)

Period	Programme	CAE											
		CAE 10 - Food industries						CAE 11 - Beverage Industries					
		Projects		Investment		Public expenditure		Projects		Investment		Public expenditure	
		Nº	%	10^3€	%	10^3€	%	Nº	%	10^3€	%	10^3€	%
2007-2013	QREN	137	13%	87 856	13%	54 199	19%	102	13%	86 531	16%	41 105	25%
	PRODER	135	13%	123 188	18%	37 376	13%	180	23%	183 159	35%	46 096	28%
	2007-13	**272**	**26%**	**211 044**	**31%**	**91 575**	**32%**	**282**	**35%**	**269 689**	**51%**	**87 201**	**52%**
2014-2020	PT2020	524	51%	352 622	51%	160 939	56%	190	24%	102 986	20%	43 413	26%
	PDR	231	22%	125 700	18%	34 254	12%	326	41%	152 894	29%	36 452	22%
	2014-20	**755**	**74%**	**478 323**	**69%**	**195 193**	**68%**	**516**	**65%**	**255 880**	**49%**	**79 865**	**48%**
Norte 2007-20		**1027**	**100%**	**689 366**	**100%**	**286 768**	**100%**	**798**	**100%**	**525 569**	**100%**	**167 066**	**100%**

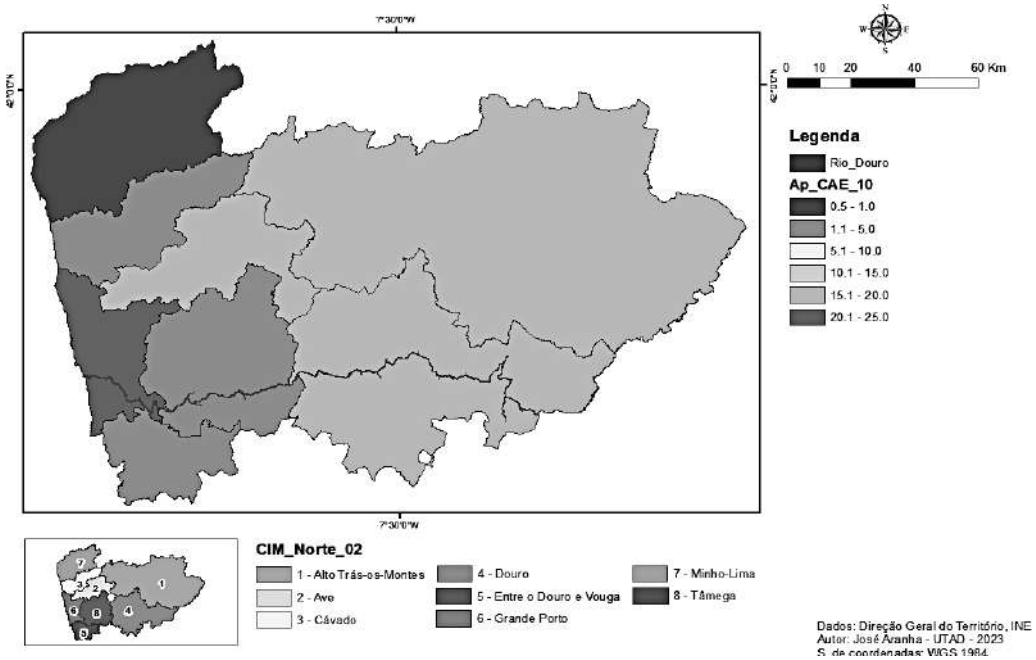
Source: Own elaboration through AD&C (2023a), and IFAP (2023)

It can thus be concluded that in the agri-food industry sector and over the total period 2007-2020, investment and public spending by the food industries (CAE 10) were higher than those by the beverage industry (CAE 11): 689.3 M€ of investment and 286.7 M€ of support received by the CAE 10 industries, compared to 525.5 M€ and 167 M€, respectively, by the CAE 11 industries.

Furthermore, while the overall performance of the food industries was better than that of the beverage industries (around 72% of the support received), there is a difference in behaviour between the two EU support frameworks: in fact, during the QREN and PRODER (2007-13) the values were more similar (211 M€ of investment and 91.5 M€ of support for CAE 10; and respectively 269.6 M€ and 87.2 M€ for CAE 11); in the second framework, the 2014-20 PT2020, the food industries invested and received much more (478.3 M€ of investment and 195.1 M€ of support for CAE 10, against 255.8 M€ and 79.8 M€, respectively, for CAE 11).

The following figures show the investment and public spending figures for the two CAEs, broken down geographically by NUT III. It should be noted that the change in the territorial composition of the NUT III during the period under analysis - namely the change from the 2002 to the 2013 version of the NUT III - meant that the data could not be presented together, making it necessary to analyse each sub-period separately. As a result, in the period 2007-2013, and based on the NUTS III (2002 version), the distribution of support for the food and drink industries was as shown in Figures 2 and 3.

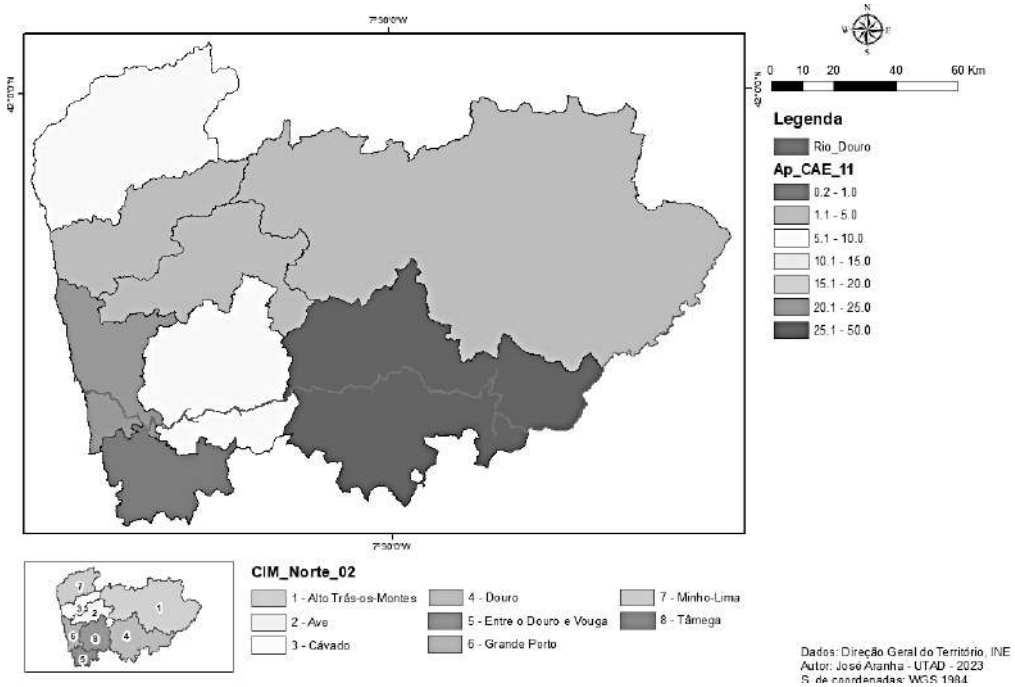
Figure 2. Distribution of support for food industry projects (CAE10), 2007-13, NUT III (2002)



Source: Own elaboration through AD&C (2023a), and IFAP (2023)

Analysing Figure 2, it can be observed that in the 2007-2013 period, in terms of the food industry, Greater Porto (absorbing 20.8% of the support received by the agri-food industry in the North), and Ave (19.8%), Alto Trás-os-Montes (16.3%) and Douro (16.1%), lead the way in attracting funds. For the same period, in terms of the drinks industry, the Douro stands out (44.5 per cent of support), followed by Greater Porto, with 24.7 per cent of approved public spending (Figure 3).

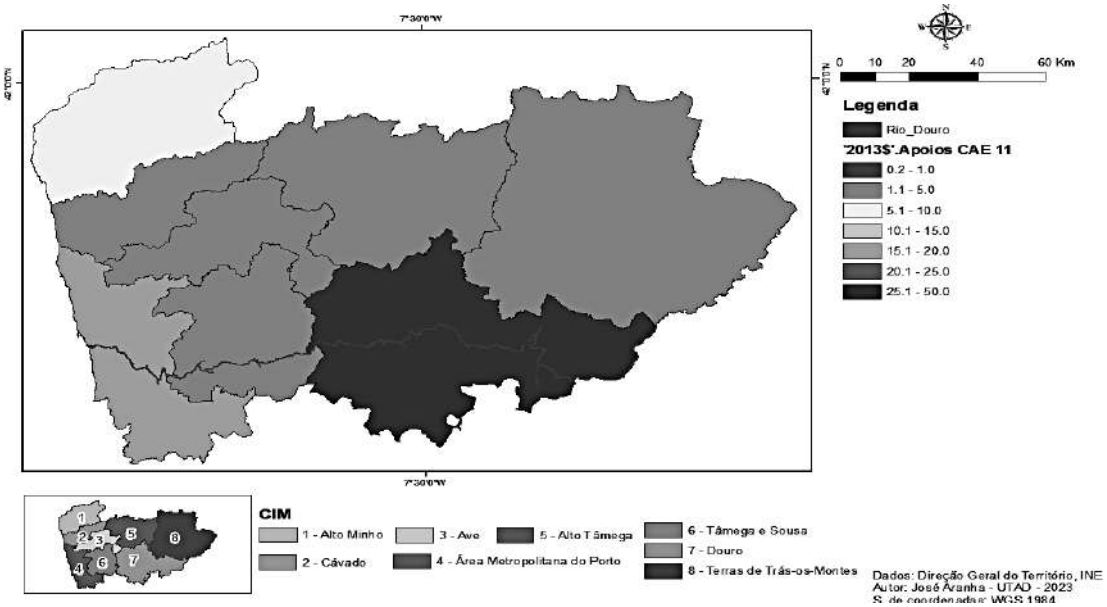
Figure 3. Distribution of support for beverage ind. projects (CAE11), 2007-13, NUTIII (2002)



Source: Own elaboration through AD&C (2023a), and IFAP (2023)

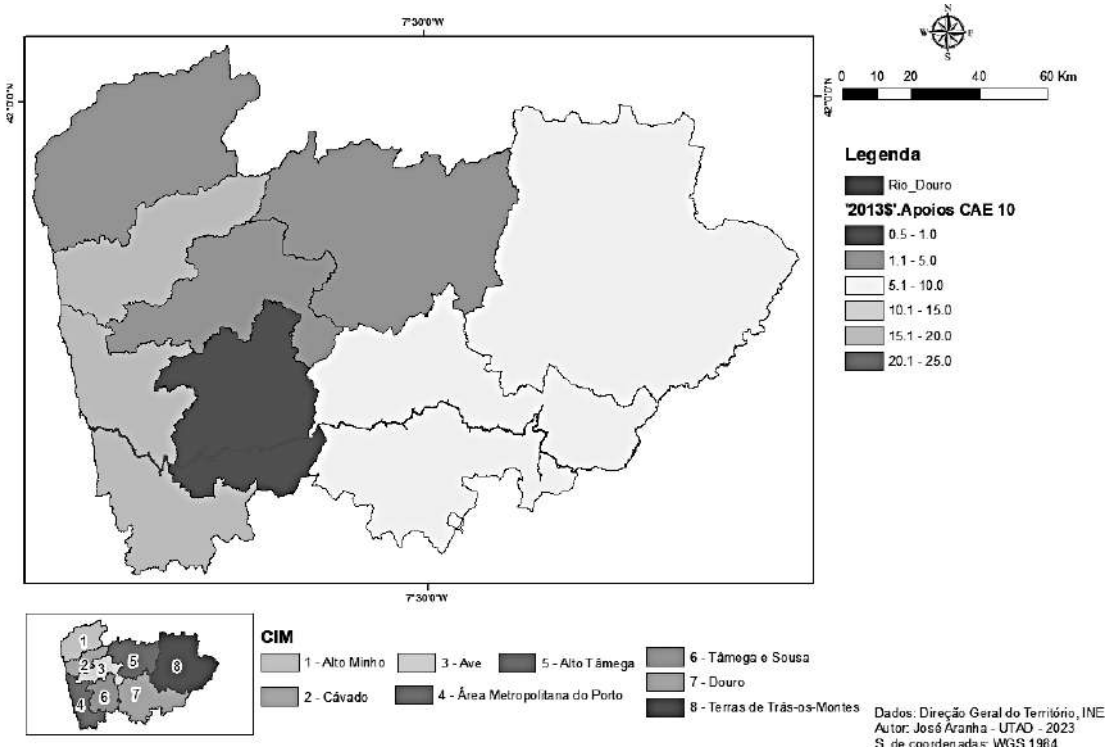
In the subsequent period, 2014-20, based on the current NUT III (2013) and as shown in Figure 4, the importance of the drinks industry, the Douro (with 26.6 per cent of support, although with a relative decrease compared to the previous table) and the so-called Area Metropolitana do Porto (AMP), with 16.7 per cent of public spending or support, also decreasing compared to the previous table, is maintained. It should be noted, however, that the geographical composition of NUT III has changed.

Figure 4. Distribution of support for beverage ind. projects (CAE11), 2014-20 NUT III (2013)



Source: Own elaboration through AD&C (2023a), and IFAP (2023)

Figure 5. Distribution of support for food industry projects (CAE10), 2014-20 NUT III (2013)



Source: Own elaboration through AD&C (2023a), and IFAP (2023)

In the food industries (Figure 5), the relative importance of AMP is also preserved, although less than in the previous period (15.7 per cent of support) and the importance of Cávado (which went from 4 per cent in the previous period to 17.7 per cent in this period). On the other hand, the Douro and Terras de Trás-os-Montes fell significantly compared to the previous period (the Douro fell to 5.9 per cent, while Terras de Trás-os-Montes fell to 6.6 per cent), but this may have been due, as already mentioned, to the change in the composition of the NUT III in terms of municipalities.
By analysing the subclasses of activity in these industries, table 3 provides more detailed information.

Table 3. Investment and public spending by specific CAE, 2007-2020

CAE	Denomination	Investiment		Public expenditure	
		10^3€	%	10^3€	%
10	**Food industries**:				
101	Slaughtering animals, preparing and preserving meat and meat products	182 163	15,0%	72 219	15,9%
102	Preparation and conservation of fish, crustaceans and molluscs	4 394	0,4%	3 478	0,8%
103	Preparation and preservation of fruit and vegetables	139 252	11,5%	52 396	11,5%
104	Production of animal and vegetable oils and fats	32 162	2,6%	11 713	2,6%
105	Dairy industry	91 372	7,5%	26 994	5,9%
106	Processing of cereals and leguminous plants; manufacture of starches and related products	20 034	1,6%	8 220	1,8%
107	Manufacture of bakery products and other flour-based products	82 668	6,8%	42 597	9,4%
108	Manufacture of other food products	112 851	9,3%	56 599	12,5%
109	Manufacture of animal feed	9 840	0,8%	7 757	1,7%
10	Other not specified	14 632	1,2%	4 793	1,1%
	TOTAL CAE 10 - Food industries	**689 366**	**56,7%**	**286 768**	**63,2%**
11	**Beverage industry:**				
1101	Manufacture of distilled alcoholic beverages	2 935	0,2%	1 559	0,3%
1102	Wine industry	438 144	36,1%	130 429	28,7%
1103	Manufacture of cider and other fermented fruit beverages	721	0,1%	333	0,1%
1104	Manufacture of vermouths and other fermented beverages	1 669	0,1%	401	0,1%
1105	Brewing beer	59 153	4,9%	26 236	5,8%
1107	Soft drink manufacturing; production of natural mineral waters and other	10 253	0,8%	4 130	0,9%
11	Other not specified	12 695	1,0%	3 978	0,9%
	TOTAL CAE 11 - Beverage industry	**525 569**	**43,3%**	**167 066**	**36,8%**
	Total North - Agri-food industries	**1 214 936**	**100,0%**	**453 833**	**100,0%**

Source: Own elaboration through AD&C (2023a), and IFAP (2023).

Thus, within the food industry and according to table 3, the following industries stand out: 101 - Slaughtering animals, preparing and preserving meat and meat products (with 15.9 per cent of the total support received by the agri-food industry in the 2007-2020 period); 108 - Manufacture of other food products (12.5 per cent); 103 - Preparation and preservation of fruit and vegetables (12.5 per cent); 103 - Preparation and preservation of fruit and vegetables (11.5%) and 107 - Manufacture of bakery and other flour products (9.4%) and, further away, 105 - Dairy industry (5.9%).
In terms of the drinks industry, it is practically concentrated in CAE 1102 - Wine industry (28.7 per cent of support from the agri-food industrial sector) and CAE 1105 - Brewing beer (5.8 per cent of total support). After analysing the agri-food industry's investment projects, in the next section we will try to establish a relationship between the investment made in this period and the sector's productivity evolution.

3.2. **Impact of investment on the sector's productivity**

As mentioned in the section on methodology, the first intention was to relate the investment supported by EU funds analysed in the previous section to the evolution of productivity. However, the lack of complete information at territorial level in the lists of projects received, namely the absence of information on the municipality where the investment took place for a large number of projects, impeded the use of this variable. The alternative found was to use the variable Gross Fixed Capital Formation (FBCF) for companies in the sector, at county level. The data on this variable is statistical information that is not available on the portal and can only be provided on request, which happened to be the case.
Therefore, the following work is based on the FBCF variable - data available for the years and for the companies in the sector under study (agri-food industry and the corresponding subdivision between food and beverage industries), and on calculating the evolution of productivity over the period analysed.
The evolution of productivity was calculated by the variation in the Turnover/Number of Employees ratio between 2008 and 2021.
Table 4 presents the results for the regression models estimated for food and beverage industry.

Table 4. Results of the regression model estimation for food industry and beverage industry

	Food industry				Beverage industry			
	Dependent variable				Dependent variable			
	LN(Prod)		Var_Prod		LN(Prod)		Var_Prod	
Intercept	6.719	***	-1.457	.	6.220	***	0.539	
	(0.455)		(0.744)		(0.724)		(2.972)	
LN(FBCF)	0.273	***	0.119	*	0.340	***	0.020	
	(0.029)		(0.047)		(0.047)		(0.186)	
DF	78		78		59		41	
F-statistic	88.11		6.235		51.27		0.012	
R^2	0.5304		0.074		0.465,		0.0002	
Reset (p-value)	0.011		0.091		0.075			
JB (p-value)	0.0031		< 2.2e-16		1.665e-15			
Breush-Pagan (p-value)	0.2669		0.1479		0.0225			

Notes: For each industry, we estimate two models with different dependent variables: the logarithm pf productivity of respective industry (LN(Prod)) and the variation of productivity (Var_Prod).

Estimation method OLS. The standard error of each parameter is in parentheses. Reset (p-value) refers to the p-value of Reset test for specification, JB (p-value) refers to the p-value of Jarque-Bera test for normality of errors and Breush-Pagan (p-value) refers to the p-value teste for the homoskedasticity test.

Significance codes: *** p< 0.001; ** p< 0.01; * p< 0.05; . p< 0.1

Results of Table 4 show that there is a positive and significant relation between gross fixed capital formation (FBCF) and the productivity of both industries: food and beverage. Regarding the results for food industry, we may see that an increment of 1% in FBCF will promote an increment in productivity of 0.273%. On the other hand, the influence in the variation of productivity is about 0.119.

In what refers to the beverage industry, the model where the dependent variable is the variation of productivity does not present global statistical significance. On this way, we focus on the elasticity model, in which results point to a increment of 0.34% in productivity when FBCF increases 1%.

4. Discussion and final considerations

Between 2007 and 2020, the agri-food industry in the North proposed an overall investment of 1,214.93 M€, which was supported by public spending totalling 453.83 M€. In relative terms, compared to the country's total agri-food industrial sector, these values for the North represent approximately 32.1 per cent of the total value of investment and 34.5 per cent of the total value of public spending in the sector. If we compare this information with that provided in table 2.A (in appendix), which states that in 2021 the North had 29% of the total GVA of the agri-food industry, 32% of the number of companies and 29% of the workforce, we can deduce a greater relative dynamism in the North compared to the rest of the country's agri-food industry companies.

This dynamism has shown a growing trend, with the relative weight of the sector in the Northern region in the total sector at national level increasing significantly between the first period analysed, corresponding to the QREN (2007-2013), and the second period, under the PT2020 (2014-2020). Specifically, the relative weight of investment in this sector in the North of Portugal increased from 29 per cent to 35 per cent.

In terms of the division of the agri-food industry into the food component (CAE10) and the beverage component (CAE 11), as well as by region, the food industries showed greater dynamism with 689.3 M€ of investment and 286.7 M€ of support received and where the NUT IIIs corresponding to Greater Porto and Ave, and later the Metropolitan Area of Porto and Cávado, stood out. The beverage industries absorbed 525.5 M€ and 167 M€ of investment and support, respectively, with great relevance for the NUT III Douro and Porto.

To sum up, cross-referencing the representativeness of the agri-food industry in the North in terms of investment and support (between 32-37%), with the 26.3% relative weight of GFCF declared by companies in 2021, reveals an investment gap that will potentially be of an intangible nature, namely in R&D, increasing innovation, competitiveness and internationalisation, fundamental factors for the competitiveness of the agri-food industry.

We anticipate that shortly, there will be increased access to data at a more granular level. This data will be sourced from the entities responsible for managing EU funds and from official statistical organizations. This data will be available at both regional levels and in terms of the specific industry sectors of companies. This enhanced data availability will facilitate advancements in our analysis of the impact of investments on productivity. Additionally, it may enable us to incorporate other relevant variables into our analysis.

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Appendices

Table 1.A. Indicators for the Northern region and the agri-food industrial sector (2021)

Indicators /Territories	Portugal	Norte	A. Minho	Cávado	Ave	AM Porto	A.Tâmega	T. Sousa	Douro	TT Montes
Socio-economic indicators										
Population density	112.9	169.4	104.6	336.3	289.1	857.1	28.8	223.6	45.7	19.4
Level schooling Upper-secondary (%)	23.5	21.9	21.7	22.9	21.2	22.8	17.6	20.3	19.9	19.9
Resident population (10^3 nº)	10 343	3 587	231	417	418	1 736	84	409	184	107
Ageing index (%)	182.1	184.1	251.9	146.5	167.3	174.7	383.9	149.5	274.4	359
Per capita purchasing power	100	92.9	82.25	91.74	85.65	103.27	73.46	75.93	79.81	81.51
Regional development composite index	100	99.59	98.82	101.36	97.1	103.32	88.63	92.6	88.89	96.5
Company indicators										
Gross value added (10^6 €)	108 914	32 988	1 707	3 886	3 940	18 890	388	2 888	865	424
Gross fixed capital formation ((10^6 €)	22 286	6 399	331	673	752	3 892	67	403	214	66
Total Employees (10^3 No.)	2 287	803	46	101	104	413	11	85	27	15
Agriculture, for. fishing (%)	2.0%	1.0%	1.6%	0.8%	0.8%	0.6%	1.6%	1.0%	6.1%	3.4%
Industry, const., energy and water (%)	30.4%	41.8%	45.5%	49.0%	60.0%	32.8%	33.3%	61.8%	26.7%	23.5%
Services Employees (%)	67.5%	57.2%	52.9%	50.2%	39.3%	66.6%	65.0%	37.3%	67.2%	73.1%
Sector Agroindustrial										
Nº Enterprises total agroindustrial										
Total agroindustrial	11 166	3 540	256	252	346	1 356	166	416	471	277
Manufacture of food products	9 186	2 787	197	211	294	1 178	136	287	226	258
Manufacture of beverages	1 980	753	59	41	52	178	30	129	245	19

Sources: INE (2024a,b,c,d,e,f); MTSSS/GEP (2024) and DGT/MCT-MAE (2024)

Table 2.A. Indicators for agri-food industrial sector and the Northern region (2021)

	Portugal	Norte	North in % Portugal
Gross value added (10^6€)			
Total agroindustrial	3 418	989	29,0%
Manufacture of food products	2 472	557	22,5%
Manufacture of beverages	946	432	45,7%
Gross fixed capital form. (10^6 €)			
Total agroindustrial	718	189	26,3%
Manufacture of food products	496	99	20,0%
Manufacture of beverages	222	90	40,5%
Employees (10^3No.) in enterprises			
Total agroindustrial	103.4	29.9	28.9%
Manufacture of food products	87.1	23.3	26.7%
Manufacture of beverages	16.3	6.6	40.6%

Sources: INE (2024e,f) and MTSSS/GEP (2024).

A COMBINED GRAPH THEORETIC AND TRANSPORT PLANNING FRAMEWORK FOR THE ECONOMIC AND FUNCTIONAL ANALYSIS OF LARGE-SCALE ROAD NETWORKS

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Abstract

Road networks are the backbone of our society and a built capital enabling the movement of people and transportation of goods. Their design should comply with both traffic and technical requirements and economic demand, to ensure efficient connectivity, accessibility, optimum resource allocation, and long-term sustainability. Poised on the intersection of this bi-dimensional context, this paper develops a methodological framework incorporating these two dimensions in road network analysis to evaluate both functional and economic aspects of the network. Within this framework, we incorporate functional and economic information into an interurban road graph model constructed on empirical data from Greece, and we afterward evaluate the level of determination and the model's applicability and usefulness in transportation planning. Overall, our findings reveal the proposed approach capable of evaluating potential interventions in the network and estimating traffic volumes, especially in data-constrained situations. In empirical terms, they indicate that the socio-economic performance of the national road network is satisfactory, albeit not fully optimized.

Keywords: Graph theory, Road networks, Traffic assignment, Economic performance, Functional performance

JEL classification: R41, R42

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Introduction

The transportation sector plays a pivotal role in modern society, and it is quite often described as its "blood system" (Banister et al., 2011). Just as the circulatory system ensures the distribution of vital nutrients to all parts of the body (Abeyrathne and Lanel, 2021), transportation networks facilitate the movement of people (Tsiotas and Tselios, 2022), goods (Hesse and Rodrigue, 2004; Nijkamp et al., 2004), and information (Barthelemy, 2011; Rodrigue et al., 2013), enabling economic and social interactions (Tsekeris and Stathopoulos, 2006; Capello, 2016; Polyzos and Tsiotas, 2020), as well as cultural exchanges on various geographical scales. Hence, the design of an effective transportation network has always been a great challenge (Tsiotas and Polyzos, 2024) for engineers and transportation decision makers. This stems from the need to meet a broad spectrum of demanding requirements that frequently conflict as well. Their design should comply with both traffic (McNally, 2007; Ahmed, 2012; Galib et al., 2014) and capacity requirements (Liu et al., 2017) and economic demand (Polyzos and Tsiotas, 2023), to ensure efficient connectivity, accessibility (Kondo, 2011), optimum resource allocation (Feng and Hsieh, 2009) and long-term sustainability (Roth and Kåberger, 2002).

Within this context, the scope of this paper is to provide an integrated methodological framework for evaluating both functional and economical dimensions of road networks. This can be achieved through the use of the network paradigm (Newman, 2010; Barabasi, 2013) and the results obtained from traffic assignment models (Matheu, 2011; Saw et al., 2015; Boyles et al., 2020), having as main goal to shape new indicators that provide a more comprehensive and realistic understanding of the network's characteristics and its interaction with surrounding socio-economic systems. Through the lens of graph theory (Rodrigue et al., 2013; Anderson and Dragićević, 2020), a transport network is conceptualized and analyzed as a graph, with nodes representing points and edges indicating connections among them (Tsiotas, 2021; Tsiotas and Polyzos, 2024). This approach allows for an investigation of the topological and geometrical characteristics of the network, enabling the identification of optimal routes for connecting various regions within the transportation system (Tsiotas, 2021). On the other hand, adhering to the principles of classical transport planning (McNally, 2007; Yao et al., 2008; Ahmed, 2012), introduces additional dimensions to the network analysis, incorporating parameters such as traffic demand and traffic assignment. This approach offers a more realistic understanding of the dynamic and behavioral characteristics of the network. By integrating both approaches, this study endeavors to provide valuable insights into the complex interplay between transportation infrastructure and socio-economic dynamics.

The structure of the paper is as follows. Section 2 provides the theoretical background of the study, including a topological analysis of transport networks, the structural characteristics of road networks, the urban transport planning framework, the fundamental principles of traffic assignment, and their implications for traffic flow and network efficiency. Section 3 describes the methodological approach of the study, relying on the theoretical framework of graph theory and traffic assignment principles. Section 4 presents and discusses the results, distinguishing them into graph theoretic and transportation design thematic axes, and introduces synthesized network efficiency indicators, comparing different scenarios of road infrastructure improvements. Finally, Section 5 summarizes the key findings, formulates conclusions, proposes avenues for future research.

Theoretical background

Topological analysis of transport networks

According to Park and Yilmaz (2010), the topology of a road network differs significantly from other common types of networks due to its "planar" design, which conforms to the Euclidean space. In planar networks, the edges (links) of the nodes do not intersect with each other (Barthelemy, 2011; Ducruet and Lugo, 2013). The representation of an urban network heavily relies on the topology of its road arteries, which in turn reflects the way a city is connected (Lin and Ban, 2013; Marshall et al., 2018). Two main representations of road networks have emerged so far. The first, and most common, representation considers path segments as edges/ links and their intersections or endpoints as nodes (Crucitti et al., 2006). Due to its simplicity, this representation has been widely adopted by numerous researchers and scientists in various traffic analyses requiring network simulations. The second

representation gained attention from several researchers a few years later as they sought to interpret the hierarchical structure of road arteries within urban areas (Barthelemy, 2011; Marshall et al., 2018). This approach assigns significance to nodes based on their connectivity with neighboring nodes, thus determining their hierarchical ranking within the network. By employing this method, the network is reshaped into a new topological representation, enabling the computation of a variety of graph theory measures. **Table 1** provides an overview of the main graph theory measures.

Table 1. Overview of major global graph theoretic measures

Measure	Type	Description	Formulation
Diameter	Network measure	The maximum eccentricity of the shortest path $p(i,j)$ $p(i,j)$ between any two edges within the graph.	$d(G) = max\{p(i,j) \mid i,j \in V\}$
Graph density	Network measure	The ratio of the number of edges presents in a graph to the maximum possible number of edges that the graph can have.	$d = \frac{2m}{n(n-1)}$ where nn number of nodes and mm number of edges
Average path length	Network measure	The mean number of steps along the shortest paths for all possible pair of nodes.	$a = \sum_{\substack{k \neq 0 \\ s,t \in V}} \frac{d(s,t)}{n(n-1)}$ where $d(s,t)d(s,t)$ the shortest path from ss to tt and nn the number of nodes.
Modularity	Network measure	How well a network can be divided into separate modules or clusters.	$M = \frac{1}{2m}\sum_{ij}\left(A_{ij} - \gamma\frac{k_i k_j}{2m}\right)\delta(c_i c_j)$ where m number of edges, A the adjacency matrix of g, $k_i k_i$ is the (weighted) degree of ii, $\gamma\gamma$ is the resolution parameter, and $\delta(c_i c_j)\delta(c_i c_j)$ is 1 if ii and jj are in the same community else 0.
Efficiency	Network measure	How easily a pair of nodes can communicate and is calculated as the inverse of the shortest path between them.	$E(G) = \frac{1}{n(n-1)}\sum_{i \neq j \in G}\frac{1}{dij}$ where nn is the number of nodes and $dijdij$ is the shortest path between these nodes.
Degree	Centrality measure	The level of connectivity of a node within a network. It corresponds to the number of edges directly connected to a given node.	$dc = \frac{di(g)}{(n-1)}$ where $didi$ is the degree of node ii, i.e., the total number of edges connected to node ii in network gg, and nn the number of nodes in network gg.
Betweenness	Centrality measure	Extent to which a node lies on the shortest paths between other pair of nodes in a network.	$b = \sum_{s,t \in V}\frac{\sigma(s,t\mid u)}{\sigma(s,t)}$ where $\sigma(s,t)\sigma(s,t)$ is the set of shortest paths in the graph and $\sigma(s,t\mid u)\sigma(s,t\mid u)$ is the number of shortest paths passing through the given node uu.

Measure	Type	Description	Formulation
Closeness	Centrality measure	The ease of traversing from one node to another within a network.	$Cc = \frac{n-1}{\sum_{u=0}^{n-1} d(v,u)}$ where $d(v,u)d(v,u)$ is the length of the shortest path between two nodes vv and uu.
Eigenvector	Centrality measure	The transitive influence of nodes. Having more influential neighbors makes the node more important.	$Ae = \lambda e$ where AA is the adjacency matrix of the network gg multiplied by $\lambda\lambda$.
Clustering coefficient	Centrality measure	How connected each node's neighbors are in a network.	$Cu = \frac{2T(u)}{deg(u)(deg(u)-1)}$ where $T(u)T(u)$ the number of triangles of node uu and $deg(u)$ the degree of that node. $deg(u)$

Source: Newman (2010); Barthelemy, (2011); Tsiotas (2021); Tsiotas and Tselios (2022)

The graph theoretic measures outlined in Table 1 offer valuable insights into the structural characteristics of a road network in its total (thus they are considered as global measures). Network diameter provides information about the size of the network (Newman, 2010), while density reflects the extent of interconnectivity among nodes (Newman, 2010; Barthelemy, 2011). In addition, average path length reveals how efficiently traffic and passenger movement are transmitted between nodes (Barthelemy, 2011). Modularity is crucial in transportation networks for identifying regions or transportation hubs, illustrating how effectively the network separates into distinct clusters (Blondel et al., 2008; Fortunato, 2010). Finally, centrality measures such as degree, betweenness, closeness, eigenvector centrality, and clustering coefficient each provide insights into the importance of the nodes, indicating for instance their influence on traffic flow and accessibility (Hellervik et al., 2019).

Transport planning framework

One of the fundamental aspects of urban transportation planning revolves around the process of predicting traffic flow on the roads (Maerivoet and De Moor, 2005). This involves the use of traffic forecasting models to anticipate future traffic patterns on road networks and form the basis for determining the need for new road infrastructure, as well as changes in land use policies (Ahmed, 2012). The history of demand modelling for person travel has been dominated by the approach that has come to be referred to as the four-step model, namely, trip generation, trip distribution, modal split, and assignment, addressing fundamental questions about travel patterns, destinations, modes, and routes (McNally, 2007). The trip generation depends on the desire for travel and its feasibility, influenced by socio-economic factors and land use characteristics such as the location and accessibility of the traffic zone, household income, or even car ownership status (Yao et al., 2008). Trip distribution involves allocating the number of movements generated and attracted to specific traffic zones. This step typically entails creating an origin-destination matrix, assigning the number of generated movements from each origin to each destination (Evans, 1970). Modal split entails distributing the trips among different modes of transport based on factors such as travel cost, comfort, and trip duration, reflecting the behavior of each person (Cingel, 2019). Finally, traffic assignment targets finding the optimal route, typically the shortest path, to accurately estimate how traffic flow will be distributed across the network (Galib et al., 2014).

Fundamental principles of traffic assignment

Traffic assignment is based on certain principles that reflect the way drivers choose a route, considering various factors such as the congestion on the roads and knowledge of the prevailing conditions (De dios Ortúzar and Willumsen, 2024; Bell and Iida, 1997). Moreover, these principles capture the behavior of drivers, which may be either selfish or oriented toward the common welfare of all drivers. Depending on the principle applied, traffic assignment can be classified into two types. The first one allows for selecting one single-route for each OD pair, while the other allows the selection of multiple routes per OD pair (Szeto and Wong, 2012). Estimating travel time for road segments is one of the most crucial factors in traffic assignment models. In its simplest case, travel time is calculated as the time required for a user to cross the respective road segment under free-flow conditions, even though this technique fails to account the real-world representation, especially in urban areas where congestion is variable (Boyles et al., 2020). The first principle of traffic assignment, known as "all or nothing", is grounded in this technique, where the assignment results from the estimated travel times under free-flow conditions (Saw et al., 2015). According to "user equilibrium", which is the second are characterized by a selfish behavioral model, seeking to minimize their personal travel time without regard for its impact on other drivers within the network (Morandi, 2024). Consequently, each user selects the route that optimizes their own travel time, irrespective of the choices made by others. On the other hand, the third principle, referred to as the "system optimum", suggests that drivers should collaborate to minimize the total travel time across the entire network (Morandi, 2024). Although this principle prioritizes network efficiency and overall performance over individual preferences, it is considered unrealistic as drivers cannot continuously be aware of the destinations of other drivers (Matheu, 2011).

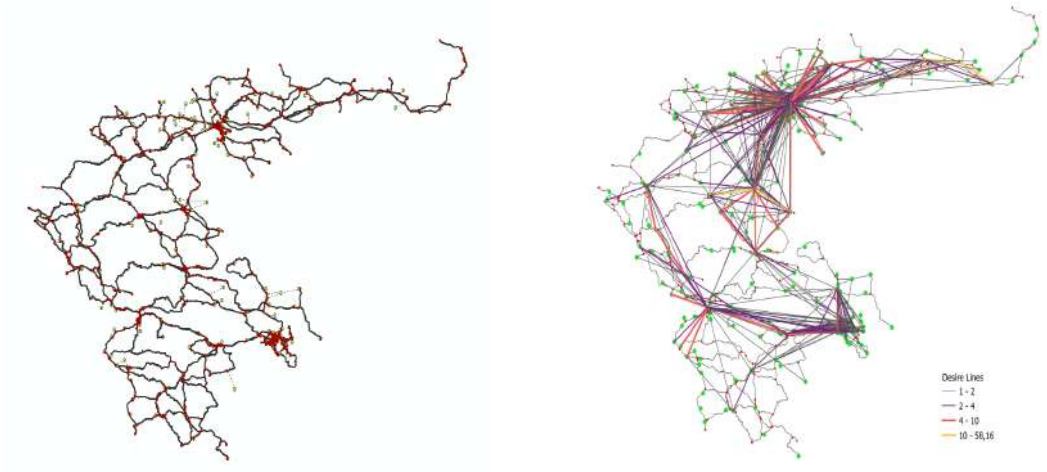
Methodology and Data

The methodological framework of this study relies to a significant extent on the theoretical background of graph theory and the fundamental principles of traffic assignment. On this basis, complex weighted indicators are synthesized based on key metrics and results derived from the traffic assignment process. These indicators are quantified within the context of a case study focusing on the Greek national road network (Tsiotas, 2021) in a generalized form. This network is comprised of 866 nodes and 2211 links in total, where of the 866 nodes, 250 are the origin-destination zones and 616 intersections. Accordingly, the 250 links of the network are non-physical topological elements of it, as they are considered the connectors of the respective zones. The traffic zones were chosen based on two main criteria. The first criterion was the population of the zones, while the second involved ensuring coverage of the national network to the fullest extent possible. Hence, all municipalities with populations exceeding 9,500 inhabitants were selected.

The topology and the overall layout of the network were developed using the ArcGIS software package, representing the network as a directed graph utilizing two main tools. The initial tool utilized was the NetworkX library (Igual and Seguí, 2024). Network Analysis. In Introduction to Data Science: A Python Approach to Concepts, Techniques and Applications (pp. 151-174). Cham: Springer International Publishing.), offering comprehensive capabilities for computing graph theory measures within the Python programming language. The second tool employed was the AequilibraE library (Camargo, 2023), which was utilized for addressing traffic assignment problems within the Python programming language as well. Moreover, this library facilitated the computation of both the shortest paths between traffic zones and the generalized travel cost matrix. Afterwards, all the results were visualized within the QGIS environment.

Subsequently, a crucial prerequisite for executing the traffic assignment algorithm involved the allocation of demand for each traffic zone. This was accomplished through the application of the gravity model (Tsekeris and Stathopoulos, 2006; Tsiotas et al., 2021; Tasopoulou et al., 2023), considering both the population size of each zone and the distances between them. As a subsequent step, statistical tools were employed to analyze the results. **Figure 1 (a)** represents the adopted national road network of Greece and **Figure 1 (b)** demonstrates the results obtained from the assessment of the origin-destination matrix in the "desired lines" format. It is noteworthy to mention that the average hourly demand for road traffic is 25,706 vehicles in total.

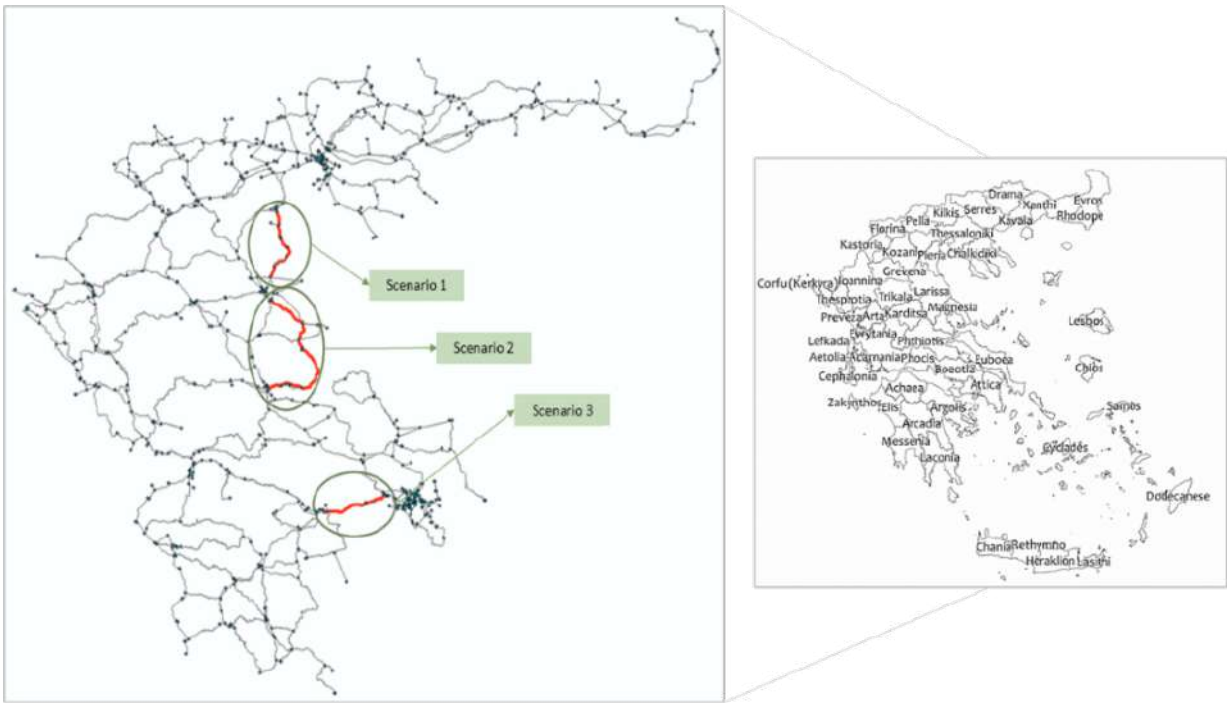
Figure 1: (a) adopted national road network of Greece, (b) illustration of traffic flows using the "desire lines" method.



Source: own elaboration

Furthermore, for the analysis of complex indicators that cannot be assessed independently but require comparison with values derived from network-level changes, such as the enhancement or deterioration of certain road infrastructures, three specific hypothetical scenarios were devised. These scenarios, depicted in **Figure 2**, reflect the road arteries designated for enhancement. The first scenario involves improving the Larissa-Katerini section, the second one the Lamia-Larissa, and the third one the Athens-Corinthos section. Across all scenarios, the methodology consisted of computing the unified efficiency indicator and comparing it with the same indicator calculated for the base network. This process involved iteratively running the traffic assignment algorithm to determine the generalized cost of traffic flow from each origin zone to each destination zone.

Figure 2: (a) proposed scenarios for road infrastructure improvement, (b) the NUTS III administrative division in Greece.



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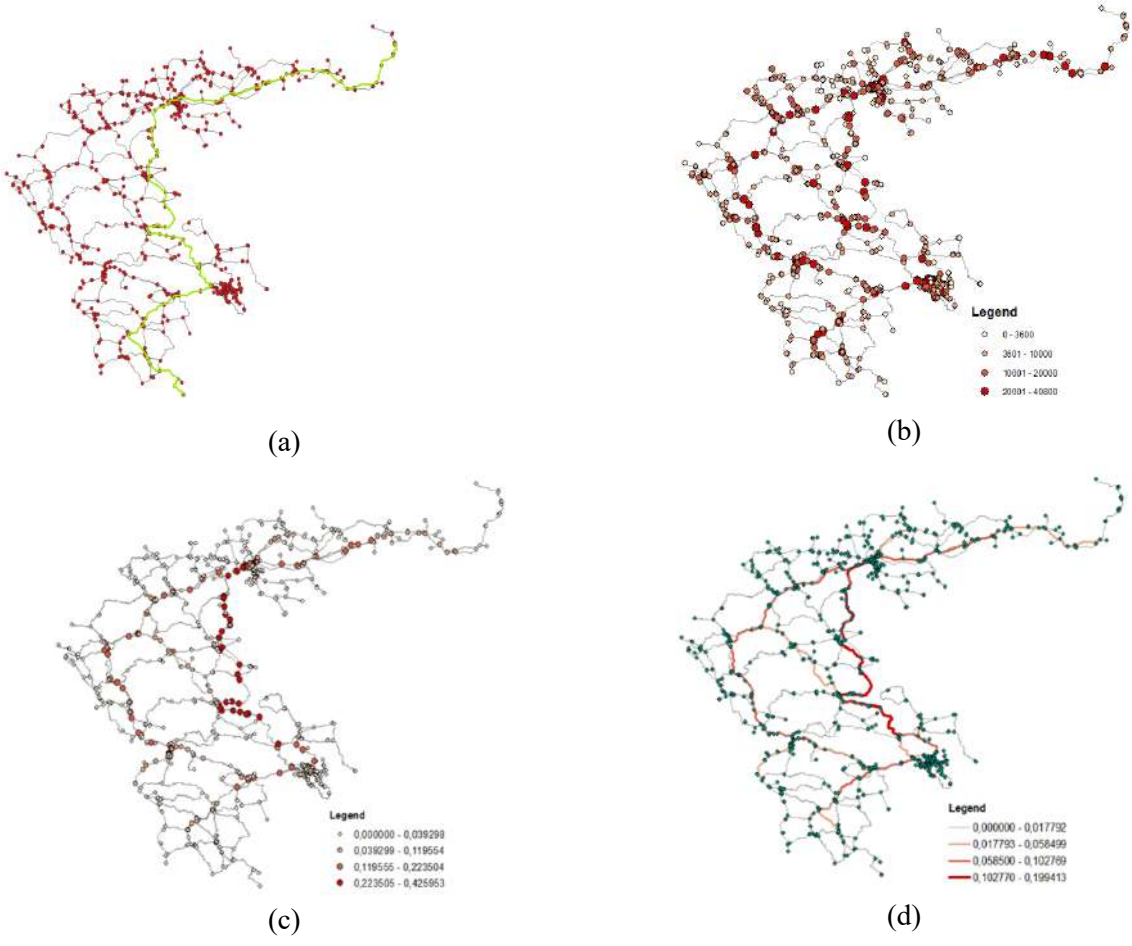
Results and Discussion

This section aims to present and explain important indicators characterizing the adopted road network. These indicators can be classified into those that derived from graph theory and those interpreting the road network from a transportation perspective. Moreover, new indicators are synthesized based on the results derived with the aim of describing the economic and operational dimensions of the road network. Finally, this section presents the results obtained through statistical analysis in an attempt to interpret the correlation that appears between specific indicators of the road network.

Graph theory measures

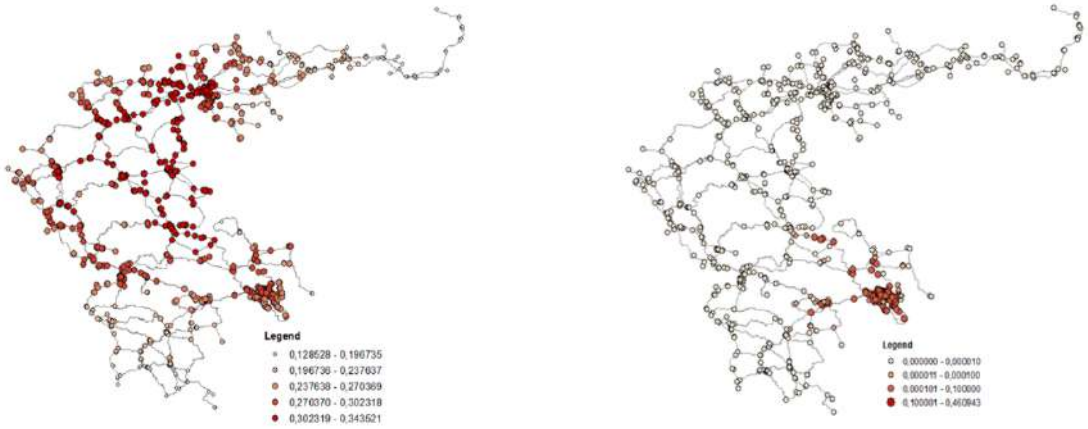
In this subsection, the results of the graph theory measures corresponding to the generalized national network are presented in **Figure 3**. It is important to mention that for computing these indicators utilizing the Dijkstra algorithm (Fan and Shi, 2010) to determine the shortest paths between origin and destination nodes, we focus only on the origin-destination traffic zones of the network rather than considering all nodes.

Figure 3: (a) diameter of the network, (b) node degree weighted by road capacity, (c) node betweenness weighted by free flow speed, (d) link betweenness weighted by free flow speed, (e) closeness centrality of network nodes weighted by free flow speed, (f) node eigenvector weighted by road capacity.



(a) (b)

(c) (d)



(e) (f)

Source: own elaboration

Figure 3a illustrates the diameter of the road network which signifies the longest path among the shortest routes. The diameter was determined to be 13.5 hours and derived from a matrix encompassing time distances for all pairs of zones within the network. **Figure 3b** visualizes the node degree centrality weighted by road capacity. Given the structure of the road network, it is worth pointing out that the degree is solely computed for each physical node, excluding centroids. Centroids within the network possess a singular connection, albeit non-existent in reality, distinguished by high speed and very low travel time and therefore, the degree does not serve as a representative indicator for centroids. The red-colored nodes indicate that they are connected with neighboring ones with high capacity. **Figure 3c** displays the betweenness centrality weighted by free flow speed for nodes, while **Figure 3d** does so for links of the road network. As anticipated, nodes situated along highways exhibit high betweenness centrality, since these highways serve as primary arteries connecting various regions and cities. Moreover, highways typically accommodate a substantial volume of long-distance traffic, connecting major population centers, thus reflecting their pivotal role in the road transportation network (Polyzos et al., 2014). Similarly, the links associated with highways demonstrate high betweenness centrality as well. Furthermore, betweenness centrality operates as a valuable metric for identifying critical elements, such as nodes, links, and potential bottlenecks, enabling the optimization of routing algorithms and facilitates the identification of alternative routes in case of network disruptions. **Figure 3e** presents closeness centrality of network nodes weighted by free flow speed. A node with high closeness centrality is easily and efficiently reachable from all other nodes (Tsiotas, 2021), thus serving as a crucial connecting element and facilitates the seamless movement of both people and goods throughout the transportation network. As it can be seen from the figure, the nodes exhibiting the highest closeness centrality are primarily situated in central Greece and major urban areas a result that aligns with existing literature (Polyzos, 2019, 2023; Tsiotas and Polyzos, 2024) and expectations considering that this metric relies on the computation of shortest path distances between nodes. Finally, **Figure 3f** depicts node eigenvector centrality weighted by road capacity. Nodes with high eigencentrality are those connected to other significant nodes within the network (Koschutzki et al., 2005; Tsiotas, 2021). In that case, the capacity of roads acts as a weighting factor on network edges, representing that strongly connected nodes are not necessarily linked to numerous nodes but rather to those adjacent to high-capacity roads. Notably, key junctions such as those situated along Attiki Street in Athens (capital of Greece), exemplify this reflection.

Outputs of the traffic assignment step

To distribute traffic flow across specific segments of the road network, a traffic assignment process is implemented following the principle of user equilibrium. The key requirement for executing this assignment involves establishing the traffic demand through an origin-destination matrix. To achieve this, a gravity model is employed, taking into account the population size of each zone and the distance between them, raised to a power α. In line with this model, when the distance between two or more

zones remains constant, areas with larger populations showcase increased mobility, thereby displaying a stronger attraction, as shown in relation (Polyzos, 2019, 2023):

$$ODij = \frac{pop(i)pop(j)}{tt(ij)^{\alpha}} ODij = \frac{pop(i)pop(j)}{tt(ij)^{\alpha}} \quad (1)$$

where $pop(i)pop(j)pop(i)pop(j)$ denotes the product of the populations of the two zones, and $tt(ij)$ $tt(ij)$ represents the minimum time distance that connects these zones.

To determine the parameter α, iterative execution of the traffic assignment was necessary until the distributed traffic flows at the links of the network, converged to approximate real values. To evaluate the values, data sourced from the National Access Point of Greece (Mylonas et. al., 2023). All you need is data: the added value of National Access Points as backbone European ITS data exchange infrastructures. arXiv preprint arXiv:2310.14054.) concerning real-time dynamic traffic flows at the Toll Stations of Hellastron's network, covering all highways of the country, was utilized. **Figure 4** presents the distributed traffic flow results, showcasing a strong correlation between the distributed traffic flow and the highways within the road network.

Figure 4: Estimated traffic flows

Source: own elaboration

Synthesized indicators

This section focuses on the calculation of unified network efficiency indicator weighted by the traffic flow through different scenarios. This indicator offers insights into the performance of the network by considering traffic demand and its impact on generalized travel costs (Rodrigue et al., 2013). As outlined in the methodology, the unified efficiency metric requires comparison across different stages to gauge its effectiveness. To facilitate this comparison, three scenarios were developed as shown in **Figure 2**, each evaluating the unified efficiency indicator before and after improvements to three specific network segments. To calculate unified efficiency, the traffic assignment model was iteratively executed in all scenarios to determine the generalized travel cost from each origin zone to each destination zone. In total, the unified efficiency was calculated four times as depicted in **Table 2**.

Table 2. Unified efficiency indicator results across all scenarios

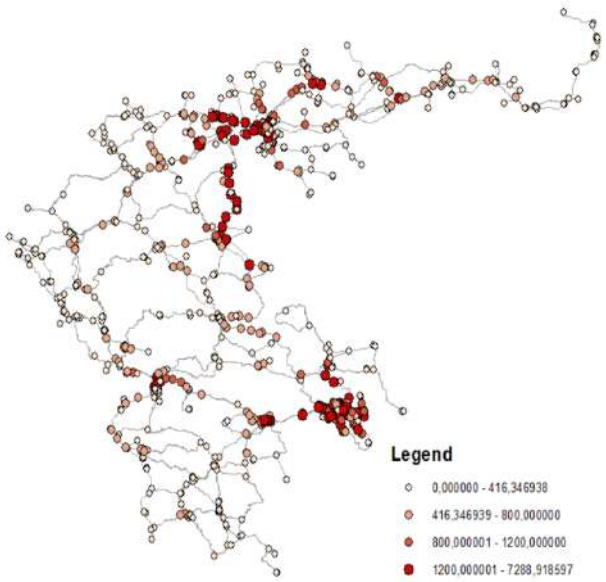
Scenarios	Unified efficiency indicator
Basic scenario	3.9786
Scenario 1	3.9794
Scenario 2	3.9796
Scenario 3	3.9885

Source: own elaboration

Observing the results, it becomes evident that the efficiency of the network improves across all scenarios. Notably, the most optimal scenario is the third one, exhibiting a value of 3.9885, signifying a substantial enhancement in terms of generalized travel cost. Therefore, based on these findings, Scenario 3 emerged as the most optimal choice for prioritizing improvements, suggesting that investing in enhancements along the Larissa-Katerini road would result in the most substantial benefits for overall network efficiency and performance.

The next synthesized indicator that is presented in **Figure 5**, is the node degree weighted by traffic flow as derived from the outcomes of the traffic assignment process.

Figure 5: Node degree weighted by estimated traffic flows



Source: own elaboration

As it can be seen from the above figure, the nodes exhibiting high degree are primarily concentrated in the two major urban centers of Greece, Nevertheless, several nodes exhibiting high degrees are also situated along highways, particularly along the route linking these urban centers. These findings can be considered logical according to the S-type model of spatial development in Greece (Tsiotas and Polyzos, 2023), given that the most important traffic flows resulting from the traffic assignment are also concentrated in these areas, as illustrated in **Figure 4**.

However, it is noteworthy to compare **Figure 3b** with **Figure 5**. In the former, node degree is computed by considering road capacity as the weighting factor for links, whereas in the latter by considering estimated traffic flows. In **Figure 3b**, the capacity reflects the presence of highways across the country. Consequently, given the extensive coverage of highways throughout the network, it is unsurprising to find high-degree nodes distributed across the entire network. On the other hand, in the second figure, estimated traffic flow acts as a "correction factor" for node degree centrality, reallocating strategically important nodes based on traffic demand. For that reason, we observed that nodes with high degrees are primarily located in regions with traffic demand, differing from the picture identified in the first case.

Statistical and quantitative assessments

The objective of this subsection is to assess the extent to which the proposed indicators provide a good picture on the operation of the road network, the way that people are moved from one region to another, and on the identification of key network components that best represent these aspects. In that evaluation,

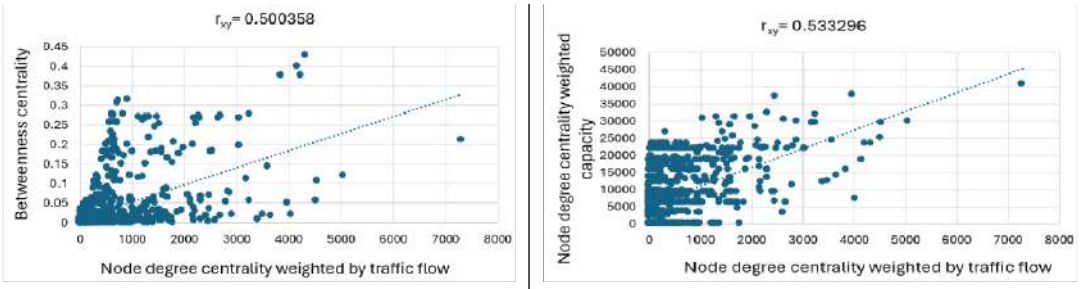
the indicators are treated as continuous variables, and thus their correlation is quantified using the Pearson correlation (Cohen et al., 2009; Walpole et al., 2012):

$$r_{xy} = \frac{Cov(\mathbf{x},\mathbf{y})}{\sqrt{Var(\mathbf{x})}\cdot\sqrt{Var(\mathbf{y})}} = \frac{Cov(\mathbf{x},\mathbf{y})}{\sigma_x \cdot \sigma_y} \quad (2)$$

where Cov(x,y) is the covariance of x,y, and Var(x)=σx , Var(y)=σy are the variances of the vector variables respectively. This evaluation involves two primary aspects: a) analyzing how node betweenness centrality relates to node degree centrality when edge weighting is based on traffic flow, and b) exploring the relationship between node degree centralities when edge weighting factors are on the one hand estimated traffic flows and on the other capacity of the roads.

As regards the first comparison, the underlying assumption is that these metrics are interrelated. Betweenness centrality identifies nodes frequently encountered on the shortest paths within the network, while degree centrality weighted by traffic flow highlights nodes through which a significant part of traffic passes (Koschutzki et al., 2005; Barthelemy, 2011). Therefore, given that travelers typically opt for routes minimizing travel time, there is an anticipated correlation between these two metrics. The second assessment seeks to compare the operational and economic dimensions of the network, premised on two key assumptions. Firstly, as already mentioned, degree centrality weighted by traffic flow identifies nodes through which a significant part of traffic flows. Secondly, degree centrality weighted by capacity highlights nodes adjacent to high-traffic-capacity road infrastructures. Consequently, comparing these two measures offers insights into the extent to which the network effectively serves the daily transportation needs of society. **Figure 6** presents the results derived from the aforementioned two assessments.

Figure 6: (a) Scatterplot between node degree centrality and betweenness centrality weighted by traffic flow and (b) scatterplot between node degree centrality weighted by traffic flow and node degree centrality weighted by capacity



Source: own elaboration

As can be seen from **Figure 6a** the degree to which the two measures are correlated is approximately equal to 0.50. This value indicates that the two measures show a positive and moderate correlation between them. Therefore, betweenness centrality can be considered to be a satisfactory estimator of traffic flows particularly in situations where comprehensive data and tools for traffic analyses are unavailable. **Figure 6b** presents the correlation between the two measures, showing a correlation of around 0.53. This indicates that while the road network design adequately meets the needs of travelers, there may be further room for optimization from an economic perspective.

Conclusions

The objective of this paper was to comprehend the functional and economic dimensions of road transportation networks. Hence, a literature review was conducted focusing on graph theory and on the identification of measures that can support the analysis of road network topology and the centrality of its individual components. In addition, the fundamental principles of traffic assignment models in a transport network were presented. Based on this foundation, a case study of the national road network of mainland Greece was constructed to test associated metrics and methodologies, yielding valuable

insights about their utility. Key findings from the case study include: i) the diameter of the analysed road network is significantly influenced by the geomorphology of mainland Greece, ii) nodes with high degree centrality weighted by the traffic capacity of network edges are primarily located along national highways, iii) both nodes and edges with high betweenness centrality are found along national highways due to their high speeds iv) nodes with high closeness centrality are located either in central regions of mainland Greece or near major urban centers, v) strongly connected nodes are not necessarily joined with many other nodes, but with nodes adjacent to high-capacity roads, vi) major "poles" of intercity travel generation and attraction are found in urban areas corresponding to Athens, Thessaloniki, Patras, and Larissa, due to their significant population densities, economic activities, and strategic locations within the national transportation network, vii) road infrastructures with the highest traffic flow for intercity travel are highways, viii) the unified network efficiency indicator is a useful tool for evaluating investments in road infrastructures aimed at simultaneously enhancing the functional and economic performance of a road network, ix) betweenness centrality can be considered a satisfactory estimator of traffic flows in cases where sufficient data and tools for traffic analysis are unavailable, x) the design of the road network adequately, though not optimally, meets the needs of travellers.

Proposals for extending the current research can follow several pathways. Firstly, it is recommended to recalculate and analyse all previously used indicators utilizing a more accurate network that incorporates a greater number of secondary road arteries to obtain more precise and comprehensive insights into the network's performance and to better capture the complexity of real-world traffic flows. Secondly, additional indicators should be examined, and their distribution at the network level should be investigated to determine in greater detail scale-free properties and power-law conditions. Finally, a sensitivity analysis can be conducted with different input data concerning travel demand to evaluate the robustness of the model and understand how variations in travel patterns impact network performance.

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SMART CITY INITIATIVES AND ECONOMIC GROWTH IN INDIA: AN EMPIRICAL ANALYSIS

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Abstract:
In developing countries, cities are vying with each other to improve their infrastructure to attract business activities and become more efficient, effective, and sustainable. Against this backdrop, the 'Smart City Mission' is one of the flagship Indian government initiatives started in 2015. In order to provide people with a high-quality living, smart cities are the latest urban conceptions. It is the idea of combining different technologies to create sustainable and intelligent practices. However, the quantitative assessment of this initiative on urbanization in India is very limited. In this study, we assess the impact of smart city projects on urbanization, which is measured by city population size and city gross domestic product. The results show that the mission has a mixed effect on urbanization. Though it increases the size of the city's population, it does not promote city income. Therefore, implementing a smart city mission has to be done in the hinterland area along with the core area of a city. Finally, it discusses the challenges faced and their potential solutions. The results suggest several policies for making urbanization a success and making India a developed country.

Key words: Smart City Mission, infrastructure, economic growth, development

JEL Classification: C10, I31, R11

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1. Introduction

Rapid urbanization in developing countries is straining traditional governance models. Cities grapple with issues like resource scarcity, traffic congestion, and crime. Sinha (2018) predicted a massive population shift in India, with an estimated 200 million people migrating from rural to urban areas over the next 15 years. This influx is nearly equivalent to the combined populations of France, Germany, and the United Kingdom. In response to this significant change, the Indian government is committed to improving the quality of life in its cities through various urban development initiatives (Nair, 2017).

To address these challenges, the concept of "smart cities" has emerged. The idea of "smart cities" emerged in the 1990s, focusing on how information and communication technologies could improve city infrastructure and networks. This widespread use of technology allows cities to enhance essential services related to safety, healthcare, governance, and service delivery (as discussed in Hernández-Muñoz et al., 2011 and Pereira et al., 2018).

In 2015, India's new federal government launched the Smart Cities Mission (SCM) by focusing on urban renewal and creating 100 sustainable smart cities. This ambitious program aims to improve governance and infrastructure in Indian cities. Notably, the SCM avoids a rigid definition of "smart city," allowing each city to define its own approach to smart solutions. Smart cities leverage technology and best practices in urban planning to drive economic growth, improve quality of life, and promote sustainable and inclusive development. It often involves public-private partnerships and utilize digital tools to deliver essential services to residents. Ideally, a smart city is a model of advanced infrastructure, efficient transportation networks, and a thriving economy, all achieved in an environmentally sustainable way. Additionally, it highlights the key components – environmental, economic, and social – that are addressed through the integration of sustainable and intelligent technologies. Essentially, a smart city is a place that leverages these technologies in a knowledgeable, practical, and innovative way to improve the quality of life for its residents. In essence, a "smart city" leverages science and technology, especially information and communication tools (ICT) like artificial intelligence and the Internet of Things, to drive urban development. With the use of the accepted ICT, city dwellers able to build an interconnected network with a variety of service providers, enabling all systems and services to operate in an intelligent and clever manner while still being comfortable for the residents (Kumar et al., 2018).

While there's no single agreed-upon definition of a "smart city," many experts around the world are working to understand the concept. A common thread across these perspectives is the central role of technology in creating a smart city.

In the context to importance of Indian smart cities, Save (2021) explored the concept of smart cities as a means to enhance the quality of life for urban residents. The study discussed how various smart technologies are integrated to create a more comfortable and efficient living environment. Madakam and Ramaswamy (2015) emphasized six key dimensions for smart cities: smart economy, mobility, environment, people, living, and governance. The authors also recognized the importance of "smart city enablers," tools that can significantly improve these aspects. Datta and Sharma (2017) conducted a study in New Delhi examining the architecture, protocols, security considerations, and smart city applications of the Internet of Things (IoT).

The literature review encompasses various studies on the SCM in India, focusing on different aspects such as infrastructure, sustainability, technology, and governance. Lende, and Ambadkar (2024) suggest to create a citizen-friendly urban environment using technology, highlighting a sustainable financing model leveraging public-private partnerships. Aijaz (2021) evaluated the mission's progress, identifying key administrative and financial challenges. Thimmavajjala (2023) emphasized the need for practical technical interventions and assessed the mission's overall benefits and shortcomings. Agrawal and Kumar (2022) discussed the technological and financial alternatives provided by smart city projects. Hoque and Prakash (2023) focused on the challenges and current status of smart cities, stressing the importance of digital services. Kumar and Dahiya (2017) analyzed the impact of smart city elements on urban economies. Ravi et al. (2021) advocated for customized solutions tailored to local needs. Agrawal and Doshi (2016) discussed enhancing urban living standards through smart solutions. Quan and Solheim (2023) reviewed the role of public-private partnerships in smart cities. Vaishampayan et al. (2020) highlighted the need for better stakeholder communication with the SCM. Arora (2018) stressed the importance of a developed financial system for smart city development. Murugaiah et al. (2018) compared the SCM with the Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

scheme, emphasizing sustainability. Finally, Ahmed and Ali (2020) analyzed the plans and policies of the SCM, showcasing its impact and the role of collective creativity in urban development. Appendix Table A1 presents the detailed review of literature.

However, the availability and quality of data on smart city initiatives and economic growth in India are limited. This makes it difficult to accurately measure the impact of smart city initiatives on economic growth. Many of the benefits of smart city initiatives may take time to materialize. This makes it challenging to capture the long-term effects of smart city initiatives on economic growth. The impact of smart city initiatives may vary across different types of cities and different sectors of the economy. This heterogeneity needs to be accounted for in empirical analyses.

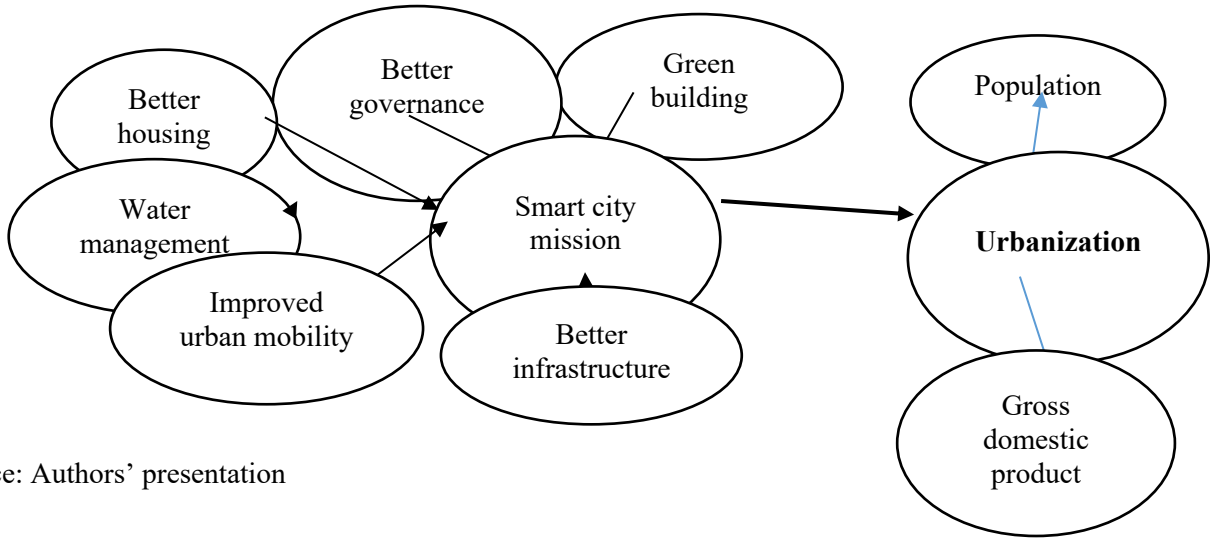
Against this backdrop, we assess the extent to which smart city initiatives contribute to economic growth in India via escalating urbanization. And what Policies need to be recommended to promote smart city initiatives that contribute to economic growth in India. The study performs econometric analysis to explore how factors like infrastructure development, number of implemented projects, population demographics, and a city's Gross Domestic District Product (GDDP) influence economic growth under the Smart City initiatives. In essence, the research investigates whether these factors play a significant role in driving India's economic expansion through smart city development.

The paper is organized as follows. Following section explains the conceptual framework of the study. Section 3 presents the data and methodology. Section 3 and 4 discuss the main empirical results and discussion. Finally, section 5 highlighted main conclusions and policy suggestions.

2. Conceptual framework

Figure 1 presents the conceptual framework of the study. Smart City Mission (SCM) accelerates urban growth by providing smart solutions to urban problems, such as urban sprawl, and enhances the quality of life for urban residents (Kumar et al., 2021). The SCM adopts a triple-zero framework: zero fossil-fuel energy use, zero waste, and zero emissions. A liveable city provides residents with a high quality of life, including access to on-time and efficient services, green spaces, clean air, and a healthy environment (Javidroozi et al., 2023). The SCM provides Smart water management systems, incorporating IoT and ICT technologies; these systems enable efficient water distribution, real-time monitoring of water quality, and effective wastewater treatment, thus ensuring a sustainable water supply for urban populations. This approach also helps mitigate water scarcity and promote sustainable urban development (Bajpai & Biberman, 2021). Implementing intelligent traffic management systems, which is part of the SCM, aims to enhance urban mobility in Indian cities. It upgrades the public transportation system and promotes non-motorized transport. Therefore, the SCM has increased urban mobility by reducing traffic contestation, lowering pollution levels, and improving overall urban connectivity (Gupta, 2022). The SCM contribute to economic growth by integrating Information and Communication Technologies (ICT) to improve the quality of life, efficiency of urban operations, and services that multiply the economy by establishing innovation clusters, creating jobs, attracting investments, and boosting productivity (Kumar et al., 2017).

Figure 1: Impact of Smart City Mission on urbanization



Source: Authors' presentation

Additionally, the SCM is associated with infrastructural developments by focusing on improvements in public amenities, healthcare, and education facilities. Therefore, it has transformed urban landscapes, making cities more liveable and resilient to future challenges. Figure 1 shows that the SCM is associated with better governance, housing, water management, urban mobility, green building, and the availability of better infrastructure. Therefore, the SCM promotes urbanization by attracting more people from rural areas and creates agglomeration economics that generates economic growth.

3. Data and Methodology

3.1 *Data*

The study leverages existing data sources to analyze the economic impact of India's Smart City Mission. Information was compiled from government entities like the Ministry of Housing and Urban Affairs, along with Census data, newspapers, journals, and books. Table 1 presents the data sources of all variables used for the analysis. The data are available for the year 2021-22. However, out of 100 smart cities, we could collect data for only 36 cities. Table 2 presents the cities those are consider for the study and the name of the states where they belong to. Table 2 shows that 36 cities belong to 10 states and union territories (UTs) in India.

Table 1: Data sources

Variable	Sources
Population	Census 2011 (Projected Population)
Gross District Domestic Product	Economic Survey Reports of each State
Number of Pan city projects	Standing Committee on Housing and Urban Affairs- 21st Report (2023-24)
Total cost of Pan city projects	Standing Committee on Housing and Urban Affairs- 21st Report (2023-24)
Density (density)	Census 2011
Completed Projects	Open Government Data (OGD) Platform India
Completed projects Amount	Open Government Data (OGD) Platform India
Total number of smart city projects relating to core infrastructure cost	Open Government Data (OGD) Platform India
Total number of smart city projects relating to core infrastructure elements	Open Government Data (OGD) Platform India
Number of area based development Projects	Standing Committee on Housing and Urban Affairs- 21st Report (2023-24)
Total cost of area based development projects	Standing Committee on Housing and Urban Affairs- 21st Report (2023-24)

Source: Authors' calculation

Table 2: Name of the cities considered for the study

State	City	State	City
Uttar Pradesh	Agra, Aligarh, Bareilly, Jhansi, Kanpur, Lucknow, Moradabad, Prayagraj, Saharanpur, Varanasi	Andhra Pradesh	Amaravati, Kakinada, Tirupati, Vishakhapatnam
Delhi	New Delhi	Himachal Pradesh	Shimla
Karnataka	Belagavi, Bengaluru,Davanagere, Hubbali-Dharwad, Mangaluru, Shivamogga, Tumakuru	Maharashtra	Aurangabad, Pune, Solapur, Thane, Nagpur, Nashik, Kalyan-Dombivali
Jammu and Kashmir	Jammu	Kerala	Kochi, Thiruvananthapuram
West Bengal	New Town, Kolkata	Telangana	Karimnagar, Warangal

Source: Authors' compilation

2.2 Methodology

Our econometric model to investigate the impact of smart city mission on urbanization takes the following representation:

$$URB = \beta_0 + \beta_1 \sum_{i=1}^{9} X_i + \varepsilon URB = \beta_0 + \beta_1 \sum_{i=1}^{9} X_i + \varepsilon \quad \text{---------- (1)}$$

where URB is the urbanization is measured by city population size and city GDP. $X_i X_i$ is the set of independent variables that includes; number of pan city projects, cost of pan city project, number of completed projects, completed project amount, smart city projects relating to core infrastructure cost, smart city projects relating to core infrastructure elements, number of area based development (ABD) projects, total cost of ABD projects, and city population density. Appendix Table 2 presents the variable definitions.

As smart city mission is intended to promote and facilitate urbanization in India, we expect all these variable have a positive effect on the urbanization. For example, density fosters energy-efficient building and transportation, increases productivity and innovation, enhances access to goods and services, shortens normal travel distances, and permits greater sharing of limited urban assets. Hence, density has a positive effect on the urbanization (Duranton and Puga, 2020). As the data is available for one year, we are using cross sectional econometrics model using Ordinary Least Square (OLS) technique.

4. Empirical results

Table 3 shows that the coefficient of variation (CV) of number of smart city projects relating to core infrastructure cost and total cost of ABD projects are relatively low, indicating a moderately symmetrical distribution. Conversely, city population size, city GDP, and number of Pan city projects have a higher CV, suggesting a wider range of values across the observations. Table 4 shows the correlation of the variables. The positive correlation is obtained for city population size with number of pan city projects, density, and completed projects. However, other variables show a negative correlation with city population size. Number of Pan city projects and density has a positive relationship with city GDP.

Table 3: Descriptive statistics

	Mean	Standard Deviation	Minimum	Maximum	CV
Total population (population)	2088306	2913318	103000	1.43E+07	139.51
Gddp (gddp)	100366.8	136305.2	3641	652649	135.81
Number of Pan city projects (pan_city_pro)	35.83333	29.69223	6	131	82.86
Total cost of Pan city projects (cost_pan)	911.2222	677.4302	71	2624	74.34
Density (density)	9733.912	6949.41	474.14	31594	71.39
Completed Projects (complete_proj)	70.33333	49.96913	10	216	71.05
Completed projects amount (crores) (complete_p_a)	1275.559	729.7973	376.85	3272.97	57.21
Total number of smart city projects relating to core infrastructure cost (project_infras)	1435.701	624.4069	417.87	2769.89	43.49
Total number of smart city projects relating to core infrastructure elements (infras_ele)	62.63889	43.43478	8	194	69.34
No. of ABD Projects (adb)	57.58333	34.66029	5	150	60.19
Total cost of ABD projects (adb_cost)	1048.806	499.6504	377	2786	47.64

Note: The estimation is based on 36 observations. Source: Authors' estimation

Table 4: Correlation coefficients of the variables

	population	gddp	pan_city_pro	cost_pan	density	complete_proj	complete_p_a	project_infras	infras_ele	adb	adb_cost
population	1.00										
gddp	0.79	1.00									
pan_city_pro	0.16	0.10	1.00								
cost_pan	-0.16	-0.08	0.28	1.00							
density	0.29	0.01	-0.04	-0.30	1.00						
complete_proj	0.06	-0.11	0.86	0.20	0.06	1.00					
complete_p_a	-0.07	-0.19	0.10	0.56	-0.09	0.35	1.00				
project_infras	-0.26	-0.20	0.14	0.75	-0.11	0.23	0.67	1.00			
infras_ele	-0.09	-0.17	0.78	0.03	-0.03	0.80	0.08	0.18	1.00		
adb	-0.11	-0.34	0.54	-0.10	0.15	0.77	0.15	0.06	0.81	1.00	
adb_cost	-0.12	-0.17	-0.16	-0.23	0.19	0.15	0.45	0.25	0.04	0.33	1.00

Note: See Table 3 for variable definitions. The correlation coefficients are based on 36 observations

Table 5 shows the results of estimated price regression models. We estimate parsimonious regression models as they fit the data well while utilising a small number of independent variables. Parsimonious regressions are used to obtain accurate results with minimal variables, allowing for easier interpretation and less overfitting, thereby identifying relevant variables influencing urbanization in India. We use robust standard errors to solve heteroskedasticity problem. Lower values of Variance inflation factor (VIF), indicates our regression results free of multicollinearity problem. As the dependent variables are in logarithmic form, the regression models are log-linear model. The R^2 values lies between 0.42 to 0.56, indicates better goodness of fit of the regressions.

Regression models 1 and 2 consider log of city population size as the dependent variables. The results show that total cost incurred under Pan city projects, city GDP, density, completed projects, and completed projects amount have a positive and statistically significant effect on the city population size. For instance, one-unit increase in completed project amount leads to increase in city population size by 0.9 percent. However, higher number of Pan city projects have a negative effect on city population size. Regression models 3-5 consider log of city GDP as the dependent variable. The results show that density and number of ABD projects has a negative effect on the city GDP. However, higher population size has a positive and statistically significant effect on the log of city GDP. Other variables related to smart city mission have no statistically significant effect on the city GDP.

Table 5: Impact of smart city mission on urbanization

	Dependent variable				
	Log of city population size		*Log of city GDP*		
VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5
Number of Pan city projects		-0.0196**			0.00464
		(0.00723)			(0.00596)
Total cost of Pan city projects		0.000396**			0.000147
		(0.000156)			(0.000207)
City GDP	4.58e-06***	5.11e-06***			
	(6.34e-07)	(8.58e-07)			
Density	6.65e-05**	6.49e-05***	-4.55e-05***	-4.40e-05**	-3.09e-05*
	(2.59e-05)	(2.08e-05)	(1.54e-05)	(1.72e-05)	(1.80e-05)
Completed Projects	-0.00271	0.00901*		-0.00583	
	(0.00281)	(0.00471)		(0.00363)	
Completed projects amount	0.000502***			3.16e-05	
	(0.000145)			(0.000234)	
Population			2.34e-07***	2.33e-07***	2.01e-07***
			(2.42e-08)	(2.54e-08)	(3.72e-08)
Total number of smart city projects relating to core infrastructure cost			0.000339		
			(0.000212)		
Total number of smart city projects relating to core infrastructure cost			-0.00979***		
			(0.00330)		
No. of ABD Projects					-0.0174***
					(0.00577)
Total cost of ABD projects					0.000452
					(0.000368)
Constant	12.43***	12.55***	10.98***	11.21***	11.01***
	(0.421)	(0.411)	(0.403)	(0.412)	(0.447)
Mean VIF	1.10	2.69	1.10	1.13	1.64
Observations	36	36	36	36	36
R-squared	0.571	0.563	0.509	0.416	0.559

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

5. Discussion

The results show that smart city mission has a mixed effect on the urbanization. Various projects related to smart city mission increases population but does not increases city GDP. The focus of smart city projects such increase in infrastructure elements is mainly devoted to core area of the cities than the hinterland area. It suggests that India's big cities are at capacity. Here, we have two main options: either we need to invest in the core area of cities again, or we may invest in the hinterland attached to a city. Given the limited amount of infrastructure investment available in India, we propose that it is preferable to invest in the outskirts rather than the centre of large cities since there are various benefits related to agglomeration economies and the relative cost of investment is significantly lower. The primary factors lowering operational expenses in the hinterland area are the large supply of land and the low wage rate. As a result, there are more potential rewards for investment than in a city's central area (Tripathi and Mitra, 2022). Therefore, to achieve higher benefits of smart city mission the location of investment in a city is very important.

Smart city mission is also facing major implementation problems. Convergence projects involving multiple agencies and external implementation face delays due to a lack of a unified monitoring system. Implementation speed varies greatly across cities, with many experiencing slow progress. A lack of clear governance structures and monitoring capacity within Special Purpose Vehicles (SPVs) hinders smooth operation. The number of completed projects falls short of the planned targets, indicating weak execution capabilities. Less emphasis is placed on core infrastructure projects compared to other initiatives. Smart city initiatives may have short-term negative economic impacts due to upfront costs before long-term benefits emerge. Restricted availability and quality of data on smart city projects and economic growth make it difficult to accurately assess the economic impact.

The standing Committee on housing and urban affairs believes smart city mission lacks adequate funding. Therefore, more fundraising efforts are needed, especially from-state and local governments. In light of this, the Committee suggested that-the-Central-Government should support-state-governments and-cities-that are in urgent-need-of-organisational-restructuring, personnel-training-and-capacity building-on-strategic-governance-and-financing-systems, and other support in order to fully realise a city's economic potential through creative finance mechanisms like-municipal-bonds-with ULB-credit-ratings, -pooled-financing-mechanisms, tax-increment-financing-(TIF).

One key concept behind the Smart Cities Mission is combining resources from various government programs. This approach aims to reduce overall project expenses, develop solutions that work seamlessly together, enhance environmental sustainability, and deliver maximum benefits to citizens. However, delays have noticed these "Convergence Projects" due to two main reasons: Involving agencies other than the Smart City Mission itself for execution and a lack of clarity regarding the role of Special Purpose Vehicles (SPVs) in implementing these projects.

The committee recommends that the Ministry establish a strong coordination mechanism across its various schemes whenever convergence is planned. This system, ideally managed at the District Collector level, would ensure smooth and unified monitoring. This will promote successful convergence, preventing duplication of efforts and wasted resources.

The committee acknowledges the limitations of the public sector in solely driving urban infrastructure growth. They recommend a multi-pronged approach where all levels of government actively engage and attract private companies. This public-private partnership (PPP) strategy offers a dual benefit. Private firms not only bring in additional funding but also introduce cutting-edge technologies, fostering innovation in infrastructure development. To maximize these advantages, the committee suggests the government analyze why some cities haven't adopted PPP models. By identifying the roadblocks and implementing corrective measures, all cities can leverage the potential of private sector involvement for a more robust and technologically advanced infrastructure.

6. Conclusion and policy implications

The Smart City Mission in India holds immense importance for the country's future. It aims to transform cities into hubs of innovation and sustainability, improving the quality of life for residents. By focusing on areas like infrastructure, sanitation, and technology, these smart cities can attract businesses and investment, leading to economic growth. Additionally, the mission prioritizes environmental concerns, promoting sustainable practices that benefit both citizens and the environment. Overall, the Smart City Mission has the potential to create a more prosperous, liveable, and future-proof urban landscape for India.

In order to understand how the Smart City Mission initiatives, impact the urbanization in India, a thorough evaluation was conducted. Urbanization is measured by city population size and city GDP. We use data by sourcing from various government offices, such as Census 2011, Economic Survey Reports of each State, Standing Committee on Housing and Urban Affairs- 21st Report (2023-24), Open Government Data (OGD) Platform India, Ministry of Urban and Housing Affairs for the year of 2021-22. The econometric model OLS (Ordinary Least Squares) has been performed for analysing the factors contributing to the economic growth of India through smart city mission initiatives.

The results show that smart city mission related various factors such as cost incurred under Pan city projects, completed projects, and completed projects amount all have positive effect on the city population size. However, number of ABD projects have negative effects on city GDP. The results suggest that smart city initiatives can contribute to economic growth in India, but there are caveats. There seems to be a positive correlation between city GDP and population size, and to a lesser extent, the total amount of money spent on smart city initiatives. However, the negative coefficient for total project costs suggests that spending needs to be efficient to maximize the positive impact.

The results are very important. Urban policymakers in India can develop better strategies to promote smart city projects that specifically contribute to and accelerate economic growth across India via smart city initiative.

First of all, the implementation of Smart city projects is important to extend in hinterland area near a big city than only in the core area of the city. It will facilitate to expand and extend the saturation points of a city. And the benefits of agglomeration economies can be achieved at its maximum.

The Smart Cities Mission has delivered a range of successful smart project initiatives across participating cities and towns. These completed projects demonstrably improve the social and economic well-being of residents, particularly those from marginalized communities. However, the report also highlights uneven progress among cities, with some lagging behind in implementation. While the COVID-19 pandemic undoubtedly played a role in these delays, the study identifies additional administrative and financial hurdles that require attention.

To enhance transparency and accountability, civil society organizations should establish a nationwide network connecting all Smart Cities. This network could then utilize tools like public report cards to independently assess the performance of each city's Special Purpose Vehicle (SPV). By conducting such evaluations, the network could generate unbiased efficiency rankings of the SPVs, providing valuable insights into the strengths and weaknesses of each Smart City program. This information would be crucial for promoting best practices and ensuring that all cities are effectively leveraging the Smart Cities Mission.

Integrated Command and Control Centres (ICCC) can be transformed into powerful hubs for managing various critical city services. This expansion would encompass healthcare, public safety, waste collection, traffic flow, disaster response, and e-governance initiatives. Consistent funding is essential to support these efforts. Additionally, continuous technological advancements should be integrated to ensure seamless coordination across these services.

Furthermore, an assessment should be conducted to determine the optimal number of ICCCs needed within each city. This would pave the way for the creation of a state-level ICCC, functioning as a central platform to connect and unify all city-based ICCCs. This comprehensive network would establish a unified e-governance platform for the entire state.

To quicken progress under the Smart Cities Mission (SCM), it's crucial to identify and analyze the reasons behind delays. A comprehensive plan should be formulated to bolster the capabilities of ULBs in smaller cities that are not fully benefiting from the initiative. This will ensure timely completion of SCM projects and optimize the Mission's impact.

The study has few limitations. First, once the data is available, consideration of panel data model to capture common and individual’s characteristics is essential. Data also has to provide for all smart cities so that a robust regression results are obtained. These issues are topic for future research.

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Appendix Table A1: Review of literature

Author(s)	Main Objective	Variables Used	Source of Data	Methodology	Conclusion
Aijaz (2021)	This report evaluates the first five years of the Mission, and draws lessons from its successes and failures. It discusses the physical and financial status of the projects taken up so far, and identifies the most crucial challenges—administrative, financial, and technology-related—that impede progress.	Infrastructure and services, Area-based development	Ministry of Housing and Urban Affairs (MoHUA), "Vision".	Descriptive Statistics	The completed projects are providing social and economic benefits, especially to the marginalised sections of the populations of these cities. However, the study also shows that several cities are lagging in project implementation. No doubt the COVID-19 pandemic has impeded progress, but there are also various administrative and financial reasons for the underperformance.
Thimmavajjala (2023)	This report evaluates the progress of the mission and draws lessons found over last 8 years	Infrastructure, sustainable environment, Special economic zones	Ministry of Housing and Urban Affairs, March 2023 ITDP (The Institute for Transportation and Development Policy) 18th Report of Standing Committee on Housing and Urban Affairs (2022-23)	Descriptive Statistics	Smart solutions are fine but who is benefiting from it should also be assessed. Technical interventions have to be practical as well. There should be an assessment made if the powers of a Smart City SPV to implement are overlapping those of the local municipal body
Agrawal and Kumar (2022)	to strengthen the urban infrastructure through the application of technology and smart solutions.	Special-Purpose Vehicles (SPVs), ABD (area-based development), economic infrastructure	The report by the Planning Commission of India in its 12th and last Plan (2012-17) Ministry of Housing and Urban Affairs (MoHUA) 15th Finance Commission for the years 2021-26	Distributive Statistics	Multidisciplinary projects such as Smart Cities Urban projects may not necessarily have the only solution, but they do have a technologically and financially sounder alternative for providing a method for a way of life suitable to the city.

Hoque and Prakash (2023)	1. To examine the current status and performance of smart cities in India. 2. To find out the challenges of implementing of smart city in India.	Infrastructure, Mobility, Sustainable Development, Technology	Ministry of Housing and Urban Affairs (MoHUA)	Descriptive Statistics	smart city development is more concerned with making progress as concerned with the smart indicators and providing digital and smart services to the urban dwellers rather than rating the city.
Kumar and Dahiya (2017)	To examine what constitutes smart city commerce services, transportation, and communication, and how they impact on smart city economy.	economic growth, Urbanization	IBEF [India Brand Equity Foundation] and Aranca (2013), PWC [PriceWaterHouse Coopers Private limited] (2015) Statista	Descriptive Statistics	The development of conventional urban economy relied on public sector-led planning, design, investment, implementation, and monitoring of development process.
Agrawal and Doshi (2016)	to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions.	Infrastructure, sustainable environment, economic growth	Census 2011, Ministry of Urban Development Government of India, Smart city Guidelines, 2015, Pune Smart City – Making It a Reality 2015, Pune Muncipal Corporation.	Descriptive Statistics	With a vibrant cultural heritage, a strong human capital and strong business environment as key strengths, Pune aspires to become one of the most livable cities in India by making its infrastructure world class & future proof, and by transforming its neighborhoods on key dimensions of livability like mixed use, open spaces and sustainable energy usage.
Aijaz and Hoelscher (2015)	To improve economic and physical infrastructure of urban settlements having populations of up to 500,000, so that these would be in a position to generate economic growth and control the problem of migration to larger cities.	Infrastructure, SPV (Special Purpose Vehicle)	Ministry of Housing and Urban Poverty Alleviation, Annual Report 1999-2000; Planning Commission, Eleventh Five Year Plan 2007-12; Ministry of Urban Development, Smart Cities Mission	Descriptive Statistics	Previous city improvement efforts under centrally sponsored schemes, such as Mega City and JNNURM, have been helpful to some extent in various ways. The new Mission offers the State and the local government institutions yet another opportunity to think creatively and work towards the betterment of their cities.

			Statement and Guidelines, 2015.		
Quan and Solheim (2023)	This study examines (1) the current state of empirical research on PPP in smart cities, and (2) assesses emerging themes of interest for smart city research and practice.	Public-private partnerships,Urban development,Cross-sector collaboration	In 2007 inaugural IEEE-IES (Institute of Electrical and Electronics Engineers- Industrial Electronics Society) digital EcoSystems and technologies conference, Social Science Computer Review, Journal of Strategy and Management,	This study reviews, critiques, and synthesizes representative literature on PPP in smart cities through an integrative literature review	In this paper, they conducted an in-depth empirical evidence synthesis to enhance our understanding of PPP in smart cities, which was distilled into four cross-cutting themes encompassing the fragmented and varied body of literature on the topic.
Praharaj et al. (2018)	this research critically assesses the ability of Indian cities to transform their traditional bureaucratic governments into a more accountable collaborative governance.	SPV (Special Purpose Vehicle), E-Governance,	The Ministry of Urban Development, Government of India. 13th Finance Commission (2010–2015)	Descriptive Statistics	This study finds that emerging smart cities governance in India encourages institutional compartmentalism due to poor convergence and integration mechanism among interventions, which fails to realise the added value offered by coordination of resources and from the joint efforts of agencies
Vaishampayan et al. (2020)	(a) to evaluate the adequacy of measures taken; and (b) application of project stakeholder management theory in enhancing the citizen engagement process.	socio-economic and political variables, Area Based Development	Census 2011, Project Management Institute (PMBOK Guide), 6th Edition	Descriptive Statistics	Literature shows that a key reason for lack of participation is poor communication and collaboration amongst various project stakeholders.
Arora (2018)	This study aims to fill in the gap in the current literature on smart cities and examines existing financial sector development of selected smart cities in the Indian context	Infrastructure, economic growth.	Journal of Urban Technology, Indian Journal of Public Administration, Swedish Institute for Financial Research, IMF Working Paper, WP/15/22,	Assign weights (denoted by αj for dimension j to each dimension). compute the financial services index (FSI) for	A policy implication drawing from this research is that for a ‘smart city’ to develop the government should pay attention not only to adequate availability of water supply, electricity, IT facilities, governance and environment, but also should consider a developed financial system which provides access to

			Journal of International Affairs	each smart city as follows. $FSI = \sum_{j=1}^{J} \alpha_j D_j$	financial services and facilitates investment in health, education and businesses and strengthening human capital.
Murugaiah et al. (2018)	1.To understand and compare Smart cities Mission and AMRUT scheme. 2.To analyze the Sustainability component in the Smart cities Mission and AMRUT scheme.	Sustainability, Economy, Environment & Society	Government of Karnataka Report 2015, The Ministry of Urban Development, Journal of the Knowledge Economy,	Descriptive Statistics	There is need for further research to work out the parameters, definitions and guidelines for the development of new cities on green field developments. More and more sustainable development projects to be included as add on components in the schemes.
Ahmed and Ali (2020)	This research tracks the smart city mission that was launched by the Indian government along with the plans and policies put forth by the authorities.	Housing, IT connectivity, Governance, Education	IEEE (Institute of Electrical and Electronics Engineer) International Conference on Technologies for Smart-City Energy Security and Power, smartcities.gov.in	Document Analysis, Qualitative Content Analysis	The study demonstrates significant effects from an Indian standpoint for a fundamental perception of the smart city framework and for identifying the role of collective creativity in promoting smart city progress and healthier development activities.

Source: Authors' compilation

Appendix Table 2: Variable definitions

Variable	Definition
Population	The total number of people living in a given urban area, typically measured within the geographical boundaries of a city or district.
Gross District Domestic Product	Proxy of Gross Domestic Product (GDP)
Number of Pan city projects	The count of projects implemented across the entire city to improve urban infrastructure and services using smart technologies, such as intelligent traffic management systems or city-wide Wi-Fi.
Total cost of Pan city projects	The aggregated financial investment required to execute all pan-city projects within a smart city initiative.
Density (density)	The number of people living per unit area of land, typically measured in persons per square kilometer or mile, indicating how crowded or sparse the urban area is.
Completed Projects	The total number of smart city projects that have been fully implemented and are operational.
Completed projects Amount	The total financial expenditure on all completed smart city projects, reflecting the investment made to achieve the planned developments.
Total number of smart city projects relating to core infrastructure cost	The count of smart city projects specifically focused on core urban infrastructure, such as water supply, sewage systems, and energy grids, including their associated costs.
Total number of smart city projects relating to core infrastructure elements	The count of individual projects aimed at enhancing specific elements of core urban infrastructure, such as transportation networks, waste management, and public safety.
Number of area based development Projects	The count of projects targeting specific areas within the city for redevelopment or improvement, aiming to transform these areas into better-planned and serviced human settlements.
Total cost of area based development projects	The aggregated financial investment required to complete all area-based development projects, encompassing the redevelopment and retrofitting of specific urban zones.

Source: Authors' compilations

THE EFFICACY OF TECHNICAL ANALYSIS IN THE FOREIGN EXCHANGE MARKET: A CASE STUDY OF THE USD/JPY PAIR

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Abstract
Financial markets, known for their unpredictability (Lee, 2020), present significant challenges for researchers. Technical analysis, rooted in the principle of market efficiency, focuses on price movements to predict future trends (Fang & Jacobsen, 2024). Originating in the 17th century, technical analysis has gained prominence in modern financial markets (Dongrey, 2022). Technical analysts rely on historical forex data (Garza Sepúlveda et al., 2023) and employ various tools, including candlestick patterns, moving averages, trendlines, resistance levels, and indicators like Bollinger Bands, MACD, RSI, and moving averages, to forecast price movements (Oktaba & Grzywińska-Rąpca, 2024). This study aimed to evaluate the effectiveness of technical analysis in the foreign exchange market by analyzing historical USD/JPY data from 2019, a period unaffected by major global events. The USD/JPY pair was chosen due to its high volatility and economic significance (Fiszeder, 2018 and Peng et al., 2021). Our analysis involved identifying support and resistance levels, trends, and applying various technical indicators to assess their effectiveness in predicting market movements (Mate & Jimeńez, 2021). The findings validate the use of technical analysis tools, demonstrating their ability to identify potential reversal and continuation zones.

Keywords: Financial markets; Forex market; Technical analysis; Exchange rate; Volatility.

JEL Classification: G10, G14, G15.

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1. Introduction

Forecasting financial markets, encompassing shares, commodities, and foreign exchange, presents significant challenges for researchers and quantitative analysts due to their inherently chaotic and unpredictable nature (Lee, 2020). echnical analysis is founded on the principle of market efficiency, which posits that asset prices fully reflect all available information, leading technical analysts to focus their studies on price movements (Fang & Jacobsen, 2024). Dongrey (2022) asserts that technical analysis originated in 17th-century Japan, where rice traders pioneered the study of price patterns. However, it wasn't until recent decades that technical analysis gained widespread recognition alongside the growth of modern financial markets. Historical forex data is a pivotal component in the analytical methods employed by technical analysts (Garza Sepúlveda et al., 2023).Investors utilise various tools to predict future price movements, but technical analysis tools like candlestick patterns, moving averages, trendlines, resistance levels, and indicators such as Bollinger Bands, Moving Average Convergence Divergence (MACD), Relative Strength Index (RSI), and moving averages are particularly popular in behavioural finance (Oktaba & Grzywińska-Rąpca, 2024).

This study seeks to evaluate the efficacy of technical analysis in the foreign exchange market. To achieve this, a historical analysis of the USD/JPY exchange rate from 3 May 1993 to 31 December 2018 was conducted, focusing on identifying support and resistance levels and prevailing trends. Subsequently, the pair's movements were analyzed to assess the impact of these levels. The study also explored various technical indicators, including chart patterns, candlestick patterns, Fibonacci retracements, and price breakouts. Particular attention was given to reversal candlestick patterns, as they are commonly used by investors to signal market entry points.

This research has substantiated the efficacy of the technical analysis tools scrutinized, affirming their applicability and utility within the foreign exchange market. Trends, trendlines, and channels, along with support and resistance levels, and Fibonacci retracements, have exhibited their reliability in forecasting potential trend reversals or continuations. Graphical and candlestick reversal patterns have proven to be accurate, as their occurrence within the charts of the analyzed currency pairs, coupled with the fulfillment of their underlying assumptions, has demonstrated their effectiveness in predicting trend reversals. Similarly, graphical continuation patterns have shown their reliability in forecasting trend continuations, as their presence within the charts of the analyzed currency pairs, followed by a breakout, has resulted in the persistence of the prevailing trend.

2. Literature Review

Ayitey Junior et al. (2023) state that the foreign exchange market, or forex, is the world's largest financial market for trading currencies. Ho et al. (2017) highlight the Forex market as a 24-hour, electronically traded market with an estimated daily trading volume of $3.2 trillion, making it the world's largest financial market. This dynamic environment contributes to the market's distinctive volatility. The decentralized structure and lower entry barriers of the Forex market make it highly attractive to investors, while its high trading volumes and continuous trading hours render it sensitive to shifts in the political and economic landscape (Wen & Wang, 2020). Information acquisition remains crucial in shaping asset prices, even within the highly liquid foreign exchange market (Goddard et al., 2015). Forex traders extensively employ technical analysis, delving deep into market data to inform their trading decisions (Hassanniakalager et al., 2021). Hernes et al. (2024) state that technical analysis involves the study of historical market data using statistical methods to identify patterns and trends, with the goal of developing trading models and rules based on indicators like the relative strength index, moving averages, and correlation analysis to gain a predictive advantage. The principles of technical analysis are underpinned by three core concepts: firstly, the 'market efficiency hypothesis' posits that all available information is fully reflected in asset prices; secondly, 'prices move in trends' suggests that price movements exhibit a directional bias, either upward, downward, or sideways; lastly, the concept of 'market history repeating itself' proposes that investor behaviour is cyclical, influenced by recurring patterns of emotion and psychology (Wagdi et al., 2023). Jiang et al. (2023) assert that technical analysis entails the study of price patterns in charts to forecast future price movements. Candlestick patterns, which visually depict price movements, are a pivotal component. By analyzing these patterns, traders can anticipate market trends and make informed trading decisions.

3. Methodology

This study aims to assess the effectiveness of technical analysis in the foreign exchange market by examining historical USD/JPY exchange rate data from January 1st to December 31st, 2019. This

timeframe was selected to mitigate the potential impact of the COVID-19 pandemic and the ongoing Russia-Ukraine and Middle East conflicts. The USD/JPY exchange rate pair was selected for analysis, as argued by Fiszeder (2018) and Peng et al. (2021), due to its high volatility and economic significance. Secondary data extracted from the Tradingview platform was utilized to facilitate the study and achieve the stated objectives.

In order to attain the study's objective, we employed key technical analysis tools, including trends, support and resistance levels, Fibonacci retracements, and graphical patterns, to evaluate their efficacy and reliability within the foreign exchange market (Fernández & Crespo, 2022 and Zafeiriou & Kalles, 2023). The analysis began with a weekly timeframe (Umoru et al., 2024), providing a broad overview of the USD/JPY exchange rate's historical movements from 3 May 1993 to 31 December 2018. This was followed by the adoption of a daily timeframe for a more detailed examination of the pair's behaviour during 2019 (Milke et al., 2024). The study involved a comprehensive analysis of various technical tools, such as trends, support and resistance levels, Fibonacci retracements, and candlestick patterns, to assess their effectiveness in the foreign exchange market (Mate & Jimeńez, 2021). Our approach included several steps: first, selecting the USD/JPY currency pair due to its high volatility; second, analysing its historical movements to identify key support and resistance levels, along with prevailing trends; third, reviewing the pair's movements in 2019 to evaluate the impact of those levels; fourth, examining various technical indicators like chart patterns, candlestick patterns, and price breakouts; and finally, focusing on reversal candlestick patterns, commonly used to signal market entry points.

4. Results

As can be seen in Figure 1, the USD/JPY pair has been following a downward trend since 1998. Moreover, it is possible to observe an upward trend since 2012, only broken in 2018. Similarly to the analysis of the previous pairs in the weekly chart, it was possible to define some support/resistance zones that the price has been respecting since 1993 (blue lines), only identified within the price oscillation range of the pair during 2019 (white lines).

Figure 1 - Global Overview of USD/JPY

Source: Own elaboration on the Tradingview platform

Figure 2 shows that the price followed three trends throughout the year. The first trend, upward, is delimited by a trendline (LTA1) and a channel line 1 (LC1) until the end of March, when the price breaks above LTA1 but continues to rise until May, once again confirming Pring's (2014) premise with LTA1 acting as resistance. The second trend, this time downward, begins when the price fails to break the resistance at the 112,122 level and starts its descent in a channel also delimited by the downward trendline 1 (LTD1) and the channel line 2 (LC2). In early July, the price breaks below LTD1 but continues its downward movement until the end of August, in turn, LTD1 then acts as support until the end of its downward movement. Failing to break the resistance around 104,795, the price rises again, respecting the upward trendline 2 (LTA2) until breaking it at the beginning of December.

Figure 2 - USD/JPY Trends

Source: Own elaboration on the Tradingview platform

In the u*pward movement at the beginning of the year, the price encounters difficulty in breaking the resistance at the 112,122 level and forms a bearish reversal pattern, a double top, as can be seen in Figure 3. The pattern is characterized by two peaks at the same level separated by a trough (Chen, 2010). The price finds some indecision at the trough line but eventually declines as expected after the pattern. Between July and October, a bullish reversal pattern, an inverse Head and Shoulders, was formed. As discussed by Pring (2014), in the complete pattern of Figure 46, the price is seen rising, then making a small correction and finding support at the neckline. It is possible to observe how the volume is high on the first shoulder and the head, and slightly lower on the second shoulder, a very important premise in the pattern under analysis.

Figure 3 - Head & Shoulders USD/JPY

Source: Own elaboration on the Tradingview platform

Similar to the analysis of the previous pairs in Figure 47, bearish reversal patterns are visualized in red and bullish reversal patterns in green. In this analysis, it can be observed that after the bearish reversal patterns, the price tends to decline, as expected, contrary to what happens in the bullish reversal patterns. Once again, it is important to emphasize that the patterns that deserve the most attention are those located in potential reversal zones.

Figure 5 - EUR/USD Candlestick Patterns

Source: Own elaboration on the Tradingview platform

The price fails to break the resistance at the 112,122 level, as seen in Figure 48, and a breakout is identified, in this case, a downside breakout in another important support zone. According to Chen (2010), the pattern is confirmed since the breakout breaks the support zone located around 111,021 and the gap is not filled.

Figure 5 - USD/JPY Breakout Point

Source: Own elaboration on the Tradingview platform

When the LTA 1 is broken and the upward momentum is interrupted, the Fibonacci retracement method is applied to discover the retracement zones. Once again, as Chen (2010) argues, it can be observed in Figure 49 how the most important areas of the retracement act as resistance/support.
In this situation, the price finds resistance at the 0.00% zone and fails to break through it, descending and showing some indecision about which direction to follow in the retracement zones, until finally reaching the 100% retracement zone.

Figure 6 - Fibonacci Retracement I USD/JPY

Source: Own elaboration on the Tradingview platform

When the LTD 1 is broken, the retracement method is applied again, and once more, Figure 50 shows the retracement zones acting as support/resistance.
After breaking the 50% resistance zone, there are several attempts to use it as support on the downside, but the price remains between the 50.00% and 61.80% zones, with some difficulty in breaking out until the end of the year under study.

Figure 6 - Fibonacci Retracement II USD/JPY

Source: Own elaboration on the Tradingview platform

5. Conclusions

This study validates the efficacy of technical analysis in the foreign exchange market, aligning with findings from Grądzki & Wójcik (2024). Tools like trendlines, support and resistance levels, and Fibonacci retracements effectively identify potential reversal and continuation zones, offering valuable trading opportunities (Dammak et al., 2024). Baker (2024) and Padmavathy (2024) support the significance of these tools, emphasizing their psychological underpinnings. The Head and Shoulders pattern, in particular, has proven reliable in predicting trend reversals (Wan et al., 2020). Other reversal and continuation patterns, such as double tops/bottoms, triangles, rectangles, and flags, have also demonstrated their effectiveness in forecasting price movements (Edwards et al., 2018). Studies by Shah et al. (2019), Dichtl (2020), and Ayala (2021) further confirm the predictive nature of these patterns across various markets, including the NYSE and Nasdaq. Candlestick reversal patterns have similarly proven effective in identifying reversal zones (Heinzet al., 2021; Cohen, 2023). Additionally, research by Low (2022) and Liang (2023) validates the predictive power of price breakouts. In conclusion, technical analysis can be a valuable tool for forex traders, but a holistic view that includes fundamental factors is essential for sustainable success.

6. References

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Announcements, Conferences, News

1st International Scientific Conference on Sustainable Regional Development

"Demographic Transition in 2050 and Regional Policies"

Prishtina, Kosovo, 10-11 Oct 2024

Event Overview

On 11 October 2024, the 1st Scientific Conference on Sustainable Regional Development was held, at the National University Library of Kosovo "Pjeter Bogdani", Prishtina (Kosovo). The conference was organized by the Institute for Scientific Research on Sustainable Development (IKSZQ) and the University "Haxhi Zeka", Peja (Kosovo), under the aegis of the Ministry of Regional Development of Kosovo. The thematic area of the conference was "Demographic Transition in 2050 and Regional Policies", aiming to explore the challenges and opportunities for sustainable regional development due to demographic change.

The conference opened with a welcome speech by Dr. Filip Ruxho, Assistant Professor and Director of the IKSZQ Institute (Kosovo). Dr. Filip Ruxho stressed the need to consider spatial dimension and spatial variables in Kosovo's regional policies more deeply. In this direction, he underlined, Kosovo needs to draw on all the potential tools provided by current scientific research in Regional Science, such as artificial intelligence, multi-sectoral development, strengthening key sectors of the economy, and utilizing successful models and examples that international experience has to offer. Next, a welcome speech was delivered by Prof. Dr. Armand Krasniqi, Chair of the Conference's Scientific Committee and Rector of "Haxhi Zeka" University, which was a co-organizer of the conference, who commented, among other things, on the importance of education and research in the pursuit of sustainable regional development. Dr. Refike Sulcevsi, Director of the Department of European Integration and Policy Cooperation of the Ministry of Regional Development in Kosovo, among other things, highlighted the importance of cooperation between public and private actors, underlining cooperation as a key driver of progress and sustainable development.

The conference proceedings included a series of lectures by keynote speakers, who highlighted different dimensions of the demographic transition issue toward the future of sustainable regional development. Dr. Tuzin Baycan, Professor of the Department of Urban and Regional Planning, at Istanbul Technical University, and President of the Turkish National Committee of Regional Science (Turkey), highlighted the importance of the digital transition by presenting indicators and related methods for the case study of Turkey. Dr. Dimitrios Tsiotas, Assistant Professor at the Department of Regional and Economic Development, School of Applied Economics and Social Sciences, Agricultural University of Athens (Greece), highlighted the importance of reading the map of inter-regional flows in the European Union

and of the emerging challenges through the detection of spatial patterns by presenting an empirical study in the EU.

Dr. Ana VINUELA, Professor at the University of Oviedo (Spain), and Future Executive Director of the Regional Science Association International - RSAI (from Jan 1, 2025), through her online participation, highlighted the importance of social inclusion as a key pillar for harnessing social capital towards sustainable regional development. Dr. Petraq Papajorgji, Professor (Emeritus) at the European University of Tirana, (Albania), highlighted the opportunities emerging through the selective use of AI, presenting an empirical study comparing AI and human-based responses on the same set of inputs. Finally, Dr. Marinela Krstinic Nizic, Prof. and Vice-Dean for Development, Faculty of Tourism and Hospitality Management, Opatija, University of Rijeka (Croatia), pointed out the crucial role of the comparative advantage of regions with an economic basis in tourism as a factor of sustainable regional development, presenting data from Croatia.

During the conference, a cooperation agreement was signed between the University “Haxhi Zeka”, under its representative, Rector Prof. Dr. Armand Krasniqi, and the University of Rijeka, under its representative Marinela Krstinic Nizic, Vice-Dean for Development, Faculty of Tourism and Hospitality Management, Opatija, University of Rijeka (Croatia). The cooperation agreement aimed at strengthening international relations and cooperation in the field of research and education.

The conference participants expressed their optimism that, through the common goals of addressing demographic challenges and adopting the imperatives of sustainable regional development for a better future, scientific research and politics will find their common ground for convergence. They committed to continue efforts to ensure that their research contributes to the promotion of innovative and sustainable approaches toward a better, equitable, inclusive, and prosperous society. This conference was not only an opportunity to exchange scientific ideas but also an opportunity to forge further partnerships towards the common goal of sustainable regional development.

Event overview edited by Filipos Ruxho,

Assistant Professor, SRDS-J.

Academic Profiles

KATHARINE G. ABRAHAM, President-Elect *of The American Economic Association for 2025*. Distinguished University Professor of Economics and Survey Methodology, University of Maryland, College Park

Statement of Purpose: The Association includes members employed in many different settings, not only research universities but also teaching colleges, government agencies, nonprofit organizations and the private sector. As President-elect, my central goal will be to ensure that the Association serves the needs of all its members. Historically, the Association's annual meeting has provided a venue for its diverse membership to gather. In recent years, reflecting in part the move to conducting initial job-market interviews online rather than in person at the annual meetings, fewer people have attended. One of my specific priorities will be to find ways to ensure that the annual meeting is a well-attended event that continues to serve its historical function of bringing the members of the profession together. Sustaining the Association's many activities of course requires that it remain on a sound financial footing. That is something I will keep sharply in focus during my tenure.

Previous and Present Positions: Distinguished University Professor of Economics and Survey Methodology, 2021–, Professor of Economics and Survey Methodology, 2013–21, Professor of Survey Methodology, 2001–13, Professor of Economics, 1991–97 and Associate Professor of Economics, 1987–91, University of Maryland, College Park; Member, President's Council of Economic Advisers, 2011–13; Commissioner, Bureau of Labor Statistics, 1993–2001; Research Associate, Brookings Institution, 1985–88; Associate Professor of Industrial Relations, 1985–87 and Assistant Professor of Industrial Relations, 1980–85, Sloan School of Management, Massachusetts Institute of Technology.

Degrees: Ph.D. in Economics, Harvard University, 1982; B.S. in Economics, Iowa State University, 1976.

Publications: "Measuring the Gig Economy: Current Knowledge and Open Issues," (with Haltiwanger, Sandusky, and Spletzer), in C. Corrado, J. Haskel, J. Miranda, and D. Sichel, eds., *Measuring and Accounting for Innovation in the 21st Century*, Chicago: University of Chicago Press, 2021; "How Tight is the U.S. Labor Market?" (with Haltiwanger and Rendell), *Brookings Papers on Economic Activity*, 2020; "Framing Effects, Earnings Expectations and the Design of Student Loan Repayment Schemes," (with Filiz-Ozbay, Ozbay, and Turner), *Journal of Public Economics*, 2020; "The Consequences of Long-term Unemployment: Evidence from Matched Employer-Employee Data," (with Haltiwanger, Sandusky, and Spletzer), *ILR Review*, 2019; "Nonresponse in the American Time Use Survey: Who is Missing from the Data and How Much Does It Matter?", (with Maitland and Bianchi), *Public Opinion Quarterly*, 2006; "Financial Aid and Students' College Decisions: Evidence from the District of Columbia Tuition Assistance Grant Program," (with Clark), *Journal of Human Resources*, 2006; "Firms' Use of Outside Contractors: Theory and Evidence," (with Taylor), *Journal of Labor Economics*, 1996; "Job Duration, Seniority and Earnings," (with Farber), *AER*, 1987; "Cyclical Unemployment: Sectoral Shifts or Aggregate Disturbances?", (with Katz), *Journal of Political Economy*, 1986; "Experience, Performance and Earnings," (with Medoff), *Quarterly Journal of Economics*, 1980.

AEA Offices, Committee Memberships, and Honors: Ad Hoc *AEJ: Economic Policy* Editor Search Committee, 2022; Ad Hoc Search Committee for Washington DC Representative, 2021–22; Distinguished Fellow, 2020; Nominating Committee, 2018; AEACGR Chair, 2009–11; AEA Vice President, 2008; AEAStat (Chair 2006–09), 2009–11; CSWEP, 2005–08.

Other Affiliations and Honors: Member, Congressional Budget Office Panel of Economic Advisers, 2015–; Member, Bureau of Economic Analysis Advisory Committee, 2014–23; Member, National Academy of Sciences, elected 2022; Member, American Academy of Arts and Sciences, elected 2020; Prize for Contributions to Data and Measurement, Society of Labor Economists, 2019; Chair, Commission on Evidence-Based Policymaking, 2016–17; Fellow, Society of Labor Economists, elected 2007; Fellow, American Statistical Association, elected 2003; D. Sc., Iowa State University, 2002; Julius Shiskin Memorial Award for Economic Statistics, American Statistical Association, 2002.

Academic Profile by:
Professor Assistant Filipos Ruxho
Sustainable Regional Development Scientific Journal - SRDSJ

References: https://www.aeaweb.org/about-aea/leadership/election-winners

ASSOCIATE PROFESSOR ANA VINUELA

Ana Vinuela is Doctor in Economics and Associate Professor at the Department of Applied Economics at the University of Oviedo. Recently appointed Executive Director of the Regional Science Association International, RSAI (starting in January 2025).

She is an active member of the AECR (Asociacion Espanola de Ciencia Regional) and part of the research group on Regional Economics REGIOlab (Regional Economic Analysis Laboratory) founded in 2011, with active presence and research activity in the regional, national and international arena

She was visiting professor in REAL (University of Illinois, Urbana-Champaign), the University of Aberystwyth in Wales or the Universitá degli Studi G d´Annuzio Chieti-Pescara in Italy. She was -or has been- involved in several national and European competitive projects dealing with spatial justice, the left behindness concept and its manifestations, and the importance of data science in Human and Social Sciences. At present she is responsible of the quantitative part of the European Project EXIT and is collaborating with local authorities in the field of territorial inequalities and (un)equal opportunities. Member of scientific and editorial committees in many national-international conferences and journals, at present is strongly committed to Regional Science Policy and Practice (RSPP), which is one of the journals of the RSAI.

She is the author of more than 20 international scientific articles, several reports for the European Commission related to territorial inequalities and some book chapters published by Thomson or Springer.

Her most recent indexed publications are related to the adequacy of using local data to analyze the sources and consequences of territorial inequalities as includes:

Viñuela, A. (2022) "Immigrant´s spatial concentration: Region or locality attractiveness?", *Population, Space and Place,* 45 (3): 352-369. *Impact Factor SSCI-JCR 2020: 2,477 (Q3 Urban Studies).* DOI: https://doi.org/10.1177%2F01600176211056237

Fernández, E., Díaz, A., Rubiera, F., Viñuela, A. (2020) "Spatial disaggregation of social indicators: an info-metrics approach", *Social Indicators Research*, 152: 809–821. Impact Factor SSCI-JCR 2020: 1,874 (Q2 Social Sciences). DOI: https://doi.org/10.1007/s11205-020-02455-z

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Gutiérrez, D., Rubiera, F., Viñuela, A. (2018) "Ageing places in an ageing country: the local dynamics of elderly population in Spain", *Tijdschrift voor economische en sociale geografie – Journal of Economic and Social Geography*, 109 (3): 332-349. *Impact Factor SSCI-JCR 2018: 1,122 (Q2 Economics).* DOI: https://doi.org/10.1111/tesg.12294

Academic Profile by:
Professor Assistant Filipos Ruxho
Sustainable Regional Development Scientific Journal - SRDSJ

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https://scholar.google.es/citations?user=BbHaoC0AAAAJ&hl=es&oi=sra

ERMIRA "MIRA" MURATI
Member of the Academy of Sciences of Albania.
She is an Albanian engineer, researcher, and tech executive. In June 2024, Dartmouth College awarded Murati an honorary Doctor of Science for having "democratized technology and advanced a better, safer world for us all". She served as chief technology officer of OpenAI from May 2022 to September 2024. California, USA.

Murati was born on 16 December 1988 in Vlorë, Albania. At age 16, Murati won a scholarship and attended the Pearson United World College of the Pacific on Vancouver Island, British Columbia, Canada, from which she graduated in 2005. Murati studied at a dual-degree program in the United States, receiving a Bachelor of Arts from Colby College in 2011, followed in 2012 by a Bachelor of Engineering from the Thayer School of Engineering at Dartmouth College.
Murati briefly worked for Zodiac Aerospace as an intern before joining electric car company Tesla in 2013. In Tesla she joined as a product manager on the Model X directly after her bachelor's in Mechanical engineering. From 2016 until joining OpenAI in 2018, she worked for augmented reality start-up Leap Motion (now Ultraleap). In 2018, She joined as the VP of applied AI, and partnerships and has since been promoted to CTO in OpenAI , despite having no research background in AI or computer science.

OpenAI

Murati joined OpenAI in 2018 as the "VP of Applied AI and Partnerships" in December 2020, and became chief technology officer (CTO) in May 2022.[17] As CTO, she led its work on ChatGPT, Dall-E, Codex and Sora, while overseeing its research, product and safety teams.[13][18][19][20] She oversaw technical advancements and direction of OpenAI's various projects, including the development of advanced AI models and tools. Her work was instrumental in the development and deployment of some of OpenAI's most notable products, such as the Generative Pretrained Transformer (GPT) series of language models. Her work included pushing the boundaries of machine learning while advocating for the responsible and ethical use of AI technologies.
In November 2023, Murati briefly took over as interim chief executive officer of OpenAI following the removal of Sam Altman from the job. She was replaced by Emmett Shear three days later, who was in turn ousted when Altman was reinstated five days after being removed. Following this series of events, Murati returned to her role as CTO.
In September 2024, Murati announced that she was stepping down as CTO to allow her the opportunity to "do my own exploration". In her exit memo, she expressed gratitude towards the OpenAI team and highlighted the success of their recent developments in AI, including speech-to-speech technology and OpenAI's work on "robust, aligned, and steerable" models. This move came amid a wider executive exodus as OpenAI chief research officer Bob McGrew and a vice president of research, Barret Zoph, also announced their departures soon after.

Awards and recognition

- In October 2023, Murati was ranked 57th on Fortune's list of "The 100 Most Powerful Women in Business of 2023".
- In September 2023, when writing for Time's 2023 100 Next list of rising leaders across industries, Microsoft CEO Satya Nadella praised Murati's "ability to assemble teams with technical expertise, commercial acumen, and a deep appreciation for the importance of mission". Nadella went on to say, "Mira has helped build some of the most exciting AI technologies we've ever seen, including ChatGPT, DALL-E, and GPT-4."
- In September 2024, Murati was included in Time's list of "The 100 Most Influential People in AI 2024".

Publications

- Murati, Ermira (Spring 2022). "Language & Coding Creativity". Dædalus (Journal of the AAAS). **151** (2). Cambridge, MA: American Academy of Arts and Sciences (AAAS): 156–167. doi:10.1162/daed_a_01907. Retrieved 25 September 2024.

Academic Profile by:
Professor Assistant Filipos Ruxho
Sustainable Regional Development Scientific Journal - SRDSJ

PROF. DR. TUZIN BAYCAN
Professor of Urban and Regional Planning, Istanbul Technical University, Faculty of Architecture, Department of Urban and Regional Planning.

Research areas: urban and regional development and planning; environment; climate change; urban systems; sustainable development; creativity, innovation and entrepreneurship; diversity and multiculturalism

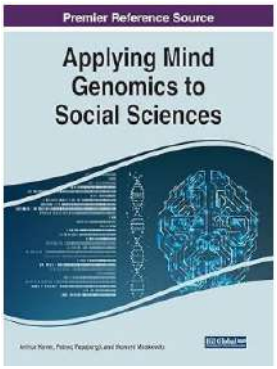
She obtained her MSc degree in Urban Planning (1993) and PhD degree in Urban and Regional Planning (1999) at Istanbul Technical University. She worked between 1991-2000 as Research Assistant, 2000-2004 as Assistant Professor and 2004-2010 as Associate Professor at Istanbul Technical University. Between 2001-2003, she worked at VU University Amsterdam (visiting scholar) and she continued her project basis works and regular collaboration with the VU University Amsterdam between 2003-2010. She became Full Professor in 2010 at Istanbul Technical University. She worked at George Mason University between 2010 and 2011 (visiting scholar) and at University of Cambridge between 2019-2020 (visiting scholar). Since 2020 she is working at Istanbul Technical University. Prof. Baycan was the Chair of the EU Center at Istanbul Technical University between 2005-2009 and 2014-2016. She was a Commission Member of the Turkish Council of Higher Education (YOK) for the "Regional Development-Oriented Mission Differentiation and Specialization of Universities Program" between 2016-2021. She has more than 20 years of experience in leading and participating in international (UNDP) and EU Projects (FP5, FP6, FP7), European Cooperation in Science and Technology (COST Action) Program and Erasmus+ Program as well as bilateral joint research projects with various European Institutions. She was also an Expert and Panel Member of ERC Advanced Grants for Social Science and Humanities: Environment and Society (2008-2015) and JPI Urban Europe (2012-2020).
She served as external evaluator for different research programs of the EU countries including Austria, Germany, Greece, Hungary, Ireland, Norway, Portugal as well as ESF-European Science Foundation (2010-2024). Prof. Baycan is Fellow of the Academia Europaea since 2011 with her studies in Social Sciences. She is President of Turkish Regional Science Association and Council Member of Regional Science Association International (RSAI) and European Regional Science Association (ERSA). She has served as Editor and Editorial/Advisory Board Member of Asia and Pacific Journal of Regional Science; Regional Science Policy and Practice; Economic and Social Changes: Facts, Trends, Forecast; Social Value & Intangibles Review; Region; Journal of Independent Studies and Research-Management: Social Sciences and Economics; Romanian Journal of Regional Science; Studies in Regional Science; International Journal of Sustainable Society; A/Z ITU Journal of Faculty of Architecture; Anadolu Economics – Anadolu University Journal of Faculty of Economics; Journal of Design for Resilience in Architecture and Planning; Architecture and Life; ICONARP International Journal of Architecture and Planning; and TRIA International Journal of Urban Planning. She is Co-editor of Resilience, Crisis and Innovation Dynamics (2018); Editor of Knowledge Commercialization and Valorization in Regional Economic Development (2013) and Co-editor of Sustainable City and Creativity: Promoting Creative Urban Initiatives (2011) and Classics in Planning: Urban Planning (2008). Prof. Baycan has contributed to the development of Regional Science and to the fields of urban and regional economic, social and spatial development at national and international level with a wide range of studies she has done from sustainable development to climate change; from migration and migrant entrepreneurship to creativity, innovation and regional development; from urban economy to social innovation. She has over 150 publications, including journal articles, symposium proceedings, book chapters and books.

Academic Profile by:
Professor Assistant Filipos Ruxho
Sustainable Regional Development Scientific Journal - SRDSJ

References:

http://akademi.itu.edu.tr/tbaycan
http://www.ae-info.org/ae/Member/Baycan_Tüzin

Book Reviews



Book Review

Kover, Papajorgji, and Moskowitz's book "Applying Mind Genomics to Social Sciences" is a new addition to a series of books using quantitative approaches to understand and explain political and social phenomena.

Mind genomics is a new technology representing the next level of apprehension of human behavior. It seeks to comprehend what drives consumers and people in their daily decision-making. It offers solutions where surveys and focus groups are inadequate tools to help us better understand how people feel and how they will behave in a particular situation. Mind genomics also seeks to simultaneously understand emotional and rational drivers in social behavior, what motivates people and what does not, and how to react to stimuli in a given situation.

Previous separate studies by the authors P. Papajorgji, A. Kover, and H. Moskowitz have already contributed a great deal to our understanding of this new epistemology and methodology. This understanding has practical implications that are relevant to a wide range of fields, from the food industry to legal services. The present book, while giving an overview of those findings, pushes the boundaries further by opening new avenues of mind genomics in social and political sciences, demonstrating its relevance and applicability in various fields.

Mind Genomics sides with the hypotheses-free paradigm and seeks to offer a better and more dynamic study of the independent-dependent variable relationship. Its experimental design allows us to relate the presence and absence of the different elements, while the findings tend to quantify the individual and collective experiences. Therefore, while allowing for a more encapsulating method that works well with big data, it offers a more nuanced view of the complex societal and political reality. Furthermore, it helps companies to be more successful and competitive by sharpening their innovation edge.

Among many empirical studies that the actual book offers, particularly of interest is the focus on elements such as the decline of America, particularly under the presidency of Donald Trump (2017-2021), which it seeks to dissect, analyze, and comprehend in order to understand voters' reactions, supporters' mobilization, as well as the waves of antipathy or anger that were present at a broad swath of territory and belonged to large segments of the population. Or, for that matter, understanding the storming of the United States Capitol in January 2021. On the other hand, it offers prescient insights into who runs America and how different classes, ethnicities, ages, or income clusters perceive that. Overall, the book offers a combination of rich data with a new methodological approach and fresh analytical insights, which helps us better grasp and understand the complex reality of American society at present and trends toward the new future.

Researchers and academics in various disciplines will find this book invaluable. It significantly contributes to the academic community and offers much-needed value to the ongoing research in the multidisciplinary field of mind genomics. The book's potential to enhance university libraries and contribute to ongoing research underscores its academic value. Doctorate and post-doctoral candidates who are genuinely interested in this developing topic may also find the manuscript to be very helpful. Developing mind genomics in the social and political sciences also broadens the body of knowledge already available and creates new research directions.

Finally, because of its synthetic approach, analytical methods, and complex data analysis, it has potential significance for the business and corporate sectors.

Book Review by
Filipos A. RUXHO, Professor Assistant,
Sustainable Regional Development Scientific Journal - SRDSJ

GUIDELINES

For the Writers & a format model for the articles
submitted to be reviewed & published in the journal

Sustainable Regional Development Scientific Journal

(EconPapers, RePec, RSAI, (BnF) Paris) – www.srdsjournal.eu

Guidelines for the Writers & a format model for the Articles submitted to be reviewed & published in thejournal

The Title of the paper must be centered, and the font must be Times New Roman,size 12, in Uppercase, in Bold

For the writers' personal information use the Times New Roman font, size 11, in bold, and centered. Use lowercase for the first name and uppercase for the last name. The line below the name includes the professional title and workplace; use the Times New Roman font, size 10, centered. In the third line write only the contact e-mail address in Times New Roman 10, centered.

Name LAST NAME
Professional Title, WorkplaceE-mail Address

Name LAST NAME
Professional Title, WorkplaceE-mail Address

Abstract

The abstract consists of a single paragraph, no longer than 250 words. The font must be Times New Roman, size 11. The text must be justified. The title "Abstract" must be aligned left, in Times New Roman, size 11, in bold. A space of one line must be left between the title and the text of the abstract. The abstract must contain sufficient information, be factual, and include the basic data of the paper.

Keywords: Use 3 to 5 keywords, separated by commas

JEL classification: We kindly request that you classify your paper according to the JEL system, which is used to classify articles, dissertations, books, book reviews, and a variety of other applications. The use of the JEL classification is necessary so that your paper be properly indexed in databases such as EconLit. Select the codes that represent your article and separate them by commas. You can find information on the JEL system here: https://www.aeaweb.org/jel/guide/jel.php

1. Introduction

All articles must begin with an introduction, a section which demarcates the theoretical background and the goals of the paper.
The present document provides the necessary information and formatting guidelines for you to write your article. We recommend that you copy this file to your computer and insert your own text in it, keeping the format that has already been set. All the different parts of the article (title, main text, headers, titles, etc.) have already been set, as in the present document- model. The main text must be written in regular Times New Roman font, size 11, justified, with a 0.5 cm indent for the first line of each paragraph.
We recommend that you save this document to your computer as a Word document model. Therefore, it will be easy for you to have your article in the correct format and ready to be submitted. **The only form in which the file will be accepted is MS Word 2003**. If you have a later version of Microsoft Office / Word, you can edit it as follows:

- Once you have finished formatting your text, create a pdf file, and then save your file as a Word "97-2003" (.doc) file.
- Compare the two files – the pdf one and the Word "97-2003" (.doc) one.

- If you do not note any significant differences between the two, then – and only then – you can submit your article to us, **sending both the pdf and the Word "97-2003" (.doc) files** to our e-mail address.

If you use a word processor other than Microsoft Word, we recommend that you follow the same procedure as above, creating a pdf file and using the appropriate add-on in order to save your document in MS Word "97-2003" (.doc) form. Once you compare the two files (and find no significant differences), send us both.

2. General Guidelines on Paper Formatting

2.1. Body

The body of the text consists of different sections which describe the content of the article (for example: Method, Findings, Analysis, Discussion, etc.). You can use up to three levels of sections – sub-sections. For the Body of the text, use the default format style in Word, selecting the Times New Roman font, size 11, justified, with a 0.5 cm indent for the first line of each paragraph (this is further detailed in the section "Paragraphs").

2.2. References

The references included in the paper must be cited at the end of the text. All references used in the body of the paper must be listed alphabetically (this is further detailed in the section "References").

2.3. Appendices

The section "Appendices" follows the section "References".

3. Page formatting

3.1. Page size

The page size must be A4 (21 x 29,7 cm), and its orientation must be "portrait". This stands for all the pages of the paper. "Landscape" orientation is inadmissible.

3.2. Margins

Top margin: 2,54cm Bottom
margin: 1,5cm
Left and right margins: 3,17cmGutter
margin: 0cm

3.3. Headers and Footers

Go to "Format" → "Page", and select a 1,25cm margin for the header and a 1,25cm margin for the footer. Do not write inside the headers and footers, and do not insert page numbers.

3.4. Footnotes

The use of footnotes or endnotes is expressly prohibited. In case further explanation is deemed necessary, you must integrate it in the body of the paper.

3.5. Abbreviations and Acronyms

Abbreviations and acronyms must be defined in the abstract, as well as the first time each oneis used in the body of the text.

3.6. Section headers

We recommend that you use up to three sections – sub-sections. Select a simple numbering for the sections – sub-sections according to the present model.

3.7. First level header format

For the headers of the main sections use the Times New Roman font, size 11, in bold and underlined,

and leave a size 12 spacing before the paragraph and a size 6 spacing after the paragraph. The header must be aligned left. Use a capital letter only for the first letter of the header.

3.8. Second level header format

For second level headers, follow this model. Use the Times New Roman font, size 11, in bold, and leave a size 12 spacing before the paragraph and a size 3 spacing after the paragraph. Select a 0.5 cm indent. The header must be aligned left. Use a capital letter only for the first letter of the header.

3.8.1. Third level header

For third level headers, follow this model. Use the Times New Roman font, size 11, in bold and italics, and leave a size 6 spacing before the paragraph and a size 0 spacing after the paragraph. The header must be aligned left, with a left indent of 1 cm. Use a capital letter only for the first letter of the header.

4. Paragraphs

In every paragraph, use the Times New Roman font, size 11, with single line spacing. We recommend you modify the default (normal) format style in Word and use that in your text. For all paragraphs, the spacings before and after the paragraph must be size 0, and the line spacing single. Use a 0,5cm indent only for the first line of each paragraph. Leave no spacings nor lines between paragraphs.

4.1. Lists

In case you need to present data in the form of a list, use the following format:

- Bullet indent: 1,14cm
- Text:
    - Following tab at: 1,5 cm
    - Indent at: 1,5cm

Use the same format (the above values) if you use numbering for your list.

1. Example of numbered list 1
2. Example of numbered list 1

5. Figures, images, and tables

5.1. Figures and images

Insert your figures and images directly after the part where they are mentioned in the body of text. They must be centered, numbered, and have a short descriptive title.
Figures put together “as they are”, using Office tools, are absolutely inadmissible. The figuresused must have been exclusively inserted as images in Word, in gif, jpg, or png form (with an analysis of at least 200dpi), and in line with the text. The width of an image must not exceed 14,5cm so that it does not exceed the margins set above.
The images, figures, and tables must be inserted “as they are” in the text, in line with it.

Figures and images which have been inserted in a text box are absolutely inadmissible.

5.1.1. Reference inside the text

Avoid phrases such as “the table above” or the “figure below” when citing figures and images. Use instead “in Table 1”, “in Figure 2”, etc.

5.1.2. Examples

A model of how to format figures/images follows. For the title, use the Times New Roman font, size 10, in bold. Write the title above the figure, and set a size 6 spacing before the title anda size 0 spacing after it. The line spacing of the title must be 1.5 line. Both the image and its title must be centered.

Image 1: Title

Source: cite the source

Directly below the figure you must cite the source from which you took the image, or any note regarding the figure, written in Times New Roman, size 10. Write it below the figure, leaving a size 0 spacing before and after it, use a line spacing of 1.5 line, and make it centered.

5.2. Tables

For the title, use the Times New Roman font, size 10, in bold. Write the title above the table, and set a size 6 spacing before the title and a size 0 spacing after it. The line spacing of the title must be 1.5 line. Both the table and its title must be centered. The width of the table must not exceed 14,5cm so that it does not exceed the page margins set.

Table 1. Example of how a table must be formatted

Age	Frequency	Percentage %
Under 40	44	32.1
40 - 49	68	49.6
Over 50	25	18.2
Total	**137**	**100.0**

Source: cite the source

If the table needs to continue on the next page, select in the "Table properties" that the first line be repeated as a header in every page, as in the above example of Table 1. **Tables (or figures or images) which are included in pages with a "Landscape" orientation are absolutely inadmissible.**
Every table must have horizontal lines 1 pt. wide at the top and bottom, as shown in the example. The use of vertical lines and color fill at the background of the cells is strictly prohibited.
Directly below the table you must cite the source or any note regarding the table, written in Times New Roman, size 10. Write it below the table, leaving a size 0 spacing before and a size 6spacing after it, and make it centered.

6. Mathematical formulas

There is a variety of tools in order to insert and process mathematical formulas, such as the "Mathematics", found in the most recent editions of Word, "Math Type", "Fast Math Formula

Editor", "MathCast Equation Editor", "Math Editor". Since it is impossible for us to provide youwith compatibility with all these tools in all their editions, **we can only admit your paper if it contains mathematical formulas solely in the form of images.**
Keep a continuous numbering for the mathematical formulas and center them in the page, as shown in the following example:

$$y = ax^2 + bx + c \quad (1)$$

The same stands for formulas or particular mathematical symbols you may have integrated in your text. For instance, if you want to use the term in your text, you must insert it as an imaged, in line with the text. The images containing the mathematical formulas must be legible (at least 300dpi). **In the exceptional case of a text which may contain a great number of mathematical formulas, the writer may send it to us in TeX form if they so wish.**

7. References

We recommend that you use the Chicago Manual of Style Author-Date system, as it is recommended by the AEA (American Economic Association) for the journals included in the EconLit database, and it is the dominant style of bibliography in the field of Economics. For more information, you can go to the following links:

- https://www.aeaweb.org/journals/policies/sample-references
- http://www.chicagomanualofstyle.org/tools_citationguide.html
- http://libguides.williams.edu/citing/chicago-author-date#s-lg-box-12037253

7.1. Online references (internet citations)

Check your links again before sending your file, to confirm that they are active.
Avoid long internet links. Where possible, also cite the title of the website operator-owner. Return the font color to black, and remove the hyperlink. Links such as the following are impractical and distasteful, therefore should be avoided.

Example of an inadmissible hyperlink

https://el.wikipedia.org/wiki/%CE%9F%CE%B9%CE%BA%CE%BF%CE%BD%CE%BF%CE%BC%CE%B9%CE%BA%CE%AC

7.2. References Formatting

For your list of references, use the Times New Roman font, size 10, with single line spacing. The paragraph format must include a size 0 spacing before the paragraph and a size 0 spacing after it, aligned left. Use a 0,5 cm indent only for the first line of each paragraph. Leave no spacings or lines between paragraphs.

7.3. Example of how References must be formatted

Bureau of Labor Statistics. 2000–2010. “Current Employment Statistics: Colorado, Total Nonfarm, Seasonally adjusted - SMS08000000000000001.” United States Department of Labor. http://data.bls.gov/cgi- bin/surveymost?sm+08 (accessed February 9, 2011).

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Heidhues, Paul, and Botond Kőszegi. 2005. “The Impact of Consumer Loss Aversion on Pricing.” Centre for Economic Policy Research Discussion Paper 4849.