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The Effects of Public Infrastructure Capital on the Economic Development and Productivity of the Metropolitan and Peripheral Regions of Greece: 1976-1992

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"It is interesting that Humans try to find Meaningful Patterns in things that are essentially random"

Mr. Data

Star Trek: The Next Generation

[cited in K. White (1993): *Shazam, Econometrics Computer Program: User's Reference Manual* (7.0), p. 159]

Abstract

The relationship between economic development and public infrastructure capital has puzzled economists, economic geographers, planners, and other social scientists, for many years. This thesis presents an attempt to theorise and conduct empirical research on this field in the context of a developing economy within the European Union - Greece. Key to understanding the work undertaken in this thesis is the wider theoretical and applied research, which has flourished in the US and other countries during the last decade. The thesis examines the effects of public capital investment on Greek economic development viewed at different spatial scales. More specifically, it explores the role of infrastructure spending at national, regional, and urban (metropolitan area of Athens) levels.

The empirical presentation begins with a description of the Public Investment Programme from 1976 onwards. This is the main channel for public investment in infrastructure capital in Greece. Its various public capital sub-categories have been aggregated into two basic types, 'productive' and 'social' infrastructure. The next step was to utilise a production function analytical framework and panel data analysis to explore the direct and network effects of infrastructure investment on manufacturing industry. Positive effects of infrastructure spending are apparent. An alternative approach, cost function analysis, is deployed in the second major empirical section. Using various spatial levels, the role of public capital on the private costs of production can be examined by the calibration of a cost function for industrial sectors. The results show that infrastructure investment reduces private costs in manufacturing at most spatial levels.

Finally, the thesis investigates other direct and indirect channels by which public capital can affect the non-manufacturing and manufacturing sectors of the private economy. The empirical findings show that there is no significant infrastructure impact on the former sector, whereas there are mixed results for the indirect channels on manufacturing. It can be safely argued that the public capital and regional development relationship is a complex one, especially as infrastructure effects can be different at different spatial levels.

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Abbreviations

DEH	=	Public Company for Electricity
DEKO	=	Public companies (public utilities)
EYDAP	=	Athens-Pireaus Water Company
G	=	Part of PIPR materialised to actual investment (see chapter 3)
GDP	=	Gross Domestic Product
LSDV	=	Least Squares Dummy Variables (model)
NSSG	=	National Statistical Service of Greece
OLS	=	Ordinary Least Squares
OTA	=	Local governments
OTE	=	Greek Telecommunications Organisation
PIPR	=	Public Investment Programme
Prod or P(G)	=	Productive part of PIPR (see chapter 3)
SAD	=	Collective Decisions for Administrative Expenditure
SAE	=	Collective Decisions for Works
SAM	=	Collective Decisions for Research
SANT	=	Collective Decisions for Prefectural Funds
Soc, or S(G)	=	Social part of PIPR (see chapter 3)
SUR	=	Seemingly Unrelated Regression

Chapter 1
Introduction

1.1 The infrastructure 'puzzle'

The relationship between public infrastructure capital and development has puzzled economists and other researchers for a long time. This thesis aims to examine empirically the economic impact of public investment in infrastructure capital in Greece during the period 1976 to 1992 with a view to shedding some light on this fascinating relationship. One fundamental problem is that all the elements of this relationship are far from being theoretically unproblematic, and that, as with all social/economic phenomena, such a relationship is extremely complex. As will be demonstrated in the subsequent chapters, public capital may well have different effects on different aspects of private sector production activity (productivity, cost structure, returns of scale, etc.) when viewed at different spatial scales. It is this underlying complexity that has given rise to the 'puzzle' characterisation of the relationship between public infrastructure and development in some of the research literature.

Even though eminent writers from previous times, such as Adam Smith, showed an interest in the effects of public works on the economy, it was not after the second World War that there has been a systematic attempt to theorise and assess the impact of infrastructure on development (see chapter 2). During the last decade, however, an even more intense interest in the effect of public infrastructure on national and regional economies has generated a voluminous literature. The renewed debate was sparked by the works of Ratner (1983) and especially Aschauer (1987; 1988; 1989a), about the way in which public capital in the United States has affected development and productivity. Despite the fact that there are numerous examples of similar research, both from the US and other countries, the term public infrastructure capital (here used interchangeably with the terms public capital, public infrastructure, or just infrastructure) remains problematic.

It tends to have different meanings in different contexts, as the introduction to definitional issues on infrastructure by Diamond and Spence (1989) indicates.

The are only two previous attempts before this thesis to examine the infrastructure investment effects in Greece utilising a modern analytical framework, those by Dalamagas (1995), and Segoura and Christodoulakis (1997). This thesis differs from these earlier attempts in the sense that it uses a much narrower definition for public capital, and employs panel data instead of time series analysis. The most crucial difference, however, is that there is the explicit introduction of the spatial dimension in the analysis.

1.2 The spatial dimension of the infrastructure-development relationship

The introduction of space creates an additional difficulty in the examination of the problem at hand. There is no guarantee that public capital can have the same impact in all regional economies. As economic and social structures vary regionally so it is plausible to expect different infrastructural effects in such varying contexts. However, as will be argued later in this thesis, the introduction of the spatial dimension is essential for the understanding of the infrastructure effects on the economy, even if the only objective of the research sets out to understand the role of public capital at the national level.

To be more specific, the majority of recent infrastructure studies have been based on the analysis of time-series datasets. However, the use of such data, apart from the obvious shortcoming of the relatively few available observations, has an even more significant disadvantage. As infrastructure effects can be different at the *micro*-spatial level (for instance prefectural or NUTS III levels), the use of aggregate data, at national level for instance, can result in the loss of such crucial information. For this reason a different approach has been used in this thesis (which, it must be confessed, was also dictated by the lack of sufficiently long enough time-series for the Greek regions, either at prefectural levels, or regional or NUTS II levels) - that of panel analysis.

In a typical time-series analysis, a dataset of say some 15 or 20 observations in time is used for the country or the region under investigation. In contrast, in the cross-section analysis say some 30 or 40 observations of, for example, spatial units or firms are used for a given moment in time. In the panel data analysis, the time-series observations for all similar cross-sectional units (prefectures, regions, sectors, firms, etc.) are stacked together. This method has some very significant advantages (a concise description is offered in Appendix I), of which the most important are the important increase in the number of available observations, and the enhanced 'richness' of the dataset (for instance, the information say derived from spatial units or sectors).

Even though the impact of public capital investment in the non-manufacturing part of the economy has been examined in more than usual detail (see chapter 6), the great bulk of the analysis undertaken here refers to Greek manufacturing industry. This analysis has been conducted at both regional and sectoral levels. In fact, even the sectoral analysis has been undertaken at different spatial levels - the nation as a whole, the metropolitan area of Athens, and a region composed of the Rest of Greece. (The dataset for this last region was obtained by subtracting the data for the Athens sectors from those of Greece as a whole).

1.3 The Greek economy during the period 1976-1992

The post war economic development of Greece was characterised by remarkable rates of growth up until the seventies. The Gross Domestic Product (GDP) was 350$ per capita in 1953, increasing to 574 $ per capita in 1960, to reach 1133 $ per capita by 1970. However, during the first half of the seventies it became obvious that the economic growth of Greece was being hampered, and an economic crisis of the Greek manufacturing in particular, and the Greek economy in general, began to emerge. Growth rates started to decelerate and after a while investment, demand and production suffered from severe decline. Concurrently, several structural changes took place in the Greek economy, such as the reinforcement of the traditional industrial sectors at the expense of the most advanced ones, the decline of foreign investment, the rise in foreign trade deficit and, after many years, the appearance of unemployment (for a further analysis, as well as some potential explanations for the dramatic drop of the rate of economic growth in Greece, see Georgakopoulos 1995, Gianitsis 1985, pp. 356-383, Katseli 1990, Kintis 1995, Lianos et al. 1995, Sakkas 1994, or Vaitsos et al. 1987).

The Greek economy did not recover during the eighties. As Christodoulakis has argued *"the three salient characteristics of Greek economy during the period 1980-94 was the decrease of the growth rate, the dramatic decline of investment, and the threatening swelling of public debt"* (1998, p. 23). It is characteristic of the problems of the Greek economy that during 1981 and 1982 the increase of the national product was almost zero (ibid.). As Greece had become a member of the European Economic Community during that period the trade deficit almost doubled from 1980 to 1982.

The fiscal austerity programmes previously adopted by the government had not been successful and, thus, by 1985 public spending had reached 43 percent of the Gross Domestic Product (GDP), the inflation rate was over 20 percent, and public investment had fallen to 11 percent of GDP (ibid.). A new austerity package did not change the situation. In 1989, public spending had skyrocketed at 50 percent, and the public deficit reached 15 percent. It general, it can be argued that during the period under examination in this thesis *"Greece has experienced repetitions of fiscal political cycles with pre-electoral expansions giving way to post-electoral stabilizations, and the cycles have been getting wilder at each new turn"* (Thomadakis 1993, p. 363). It is true that during the nineties some of these indicators improved. However, it was certainly the case that Greece failed to meet the Maastricht Treaty criteria in order to be in the first wave of the European Monetary Union.

The problems of Greek economy are not restricted only to the *macro*-economic level. The structural problems at the *micro* level, particularly evident in the secondary (industrial) sector, as mentioned earlier, abound. High transaction costs for all types of economic activity (Papandreou 1988a), an underdeveloped capital stock and capital markets, a black economy of approximately 30 percent of Gross National Product (Pavlopoulos 1987), an agricultural labour force about 28 percent of the total (for year 1986, as cited in Katseli 1990, p. 270), are just some of these problems.[1] It is in this economic context and era that this thesis examines the role of public capital in regional and national development.

[1] Lianos and Lazaris (1995) have argued that although the Greek economy will probably do better in the beginning of the next century, when compared to the last thirty years, a *"potential recovery would be far from spectacular"* (p. 72).

1.4 A digression to methodological problems and research alternatives

The recent resurgence of research about infrastructure has been based on the mainstream approach of neoclassical economics. The emphasis in this approach on empirical research is one of the main reasons for its dominance in current public capital thinking. Yet, this analytical framework is not uncontested. A comprehensive critique (of positivism and empiricism, which underpin this dominant approach) at the methodological level, can be found in Sayer 1992; equally interesting critiques about the underlying assumptions of neoclassical economics exist and one can be found in Dobb 1973.

Even though this thesis utilises mainstream theoretical and statistical tools, it would be interesting to present briefly some of the basic ideas of the radical alternative theorisation for the role of infrastructure capital. A basic summary of this theorisation can be found in Skayannis (1990; 1994), along with a critique of the more mainstream approaches[2]. Some of the most interesting ideas of the radical theorisation draw directly from the work of Marx (despite the fact the he did not address the subject directly). He argued that "*the relative surplus population and surplus production*" must be all the greater if the fixed capital is of large scale, long life and only indirectly related to production – "*thus more to build railways, canals, aqueducts, telegraphs, etc. than to build the machinery*" (Marx 1973, p. 707, cited in Harvey 1982, p. 217)."

As is argued in chapter 2, there is no general agreement of what types of fixed capital should be included in an infrastructure definition within mainstream public capital research. There has been a similar debate in the context of the more radical tradition. Authors like Lojkine (1976) have proposed a broad definition including public works on

[2] Unfortunately, this analysis ignores the (then) emerging literature from the United States (Aschauer, Munnell, etc.). At the same time this study has two additional shortcomings. First, it conflates the critique of the whole neoclassical analytical framework with the critique of particular research project (such as the work of Biehl [1986] for the regional effects of infrastructure in Europe) which really should be judged in its proper context. Secondly, it seems that it lacks a basic understanding of the rudimentary tools of economic analysis (see, for example, the misrepresentation of production function in Skayannis 1994, p. 105), and the standard economic 'jargon' either of Marxist or orthodox approach, at least in Greek. That said, this basic summary has been able in addition to incorporate some of the more obscure pieces of radical research into the debate, which is useful in itself.

social infrastructure. Other authors, for example, Theret (1982), have argued that such a broad definition confounds the actual physical basis of infrastructure with its operation[3].

One of the most interesting recent attempts at theorising the role of public capital following the radical tradition has come from a not unexpected source. Harvey has argued that "*fixed capital formation and in particular the creation of physical infrastructures in the built environment cannot be understood independently of the social processes that regulate distribution*" (1982, p. 69). In his view, fixed capital in general (which includes of course physical infrastructure) is installed to increase labour productivity, which, however, "*becomes, once it is installed, a barrier to further innovation*" (ibid. p. 123). In that sense, infrastructure can either increase or decrease economic development at a particular point in time. Governments can create infrastructure either by direct investment (such as public utilities, transport and communications), or by regulating the private sector which would undertake the investment.

Harvey justifies the public involvement on the basis of the "*scale of investment required and in part because we are dealing with 'natural monopolies' which arise because it is physically impossible to have a large number of competitors operating in the same area*" (ibid. p. 151; see also Harvey 1989b, chapter 7). Other authors have argued that there is an 'oscillation' in the provision of infrastructure between the public and private sectors, which depends mainly on technological and economic (profitability) factors (see Laepple 1973, or Skayannis 1990, 1994).

However, on of the most interesting points raised by Harvey's analysis is the direct relationship between evolving infrastructure fixed capital and the temporal and spatial displacement of resources and excess capital. He argues that "*excess capital and surplus labour can, for example, be absorbed by switching from current consumption to long-term public and private investments in plant, physical and social infrastructures*" (1989, p. 182). Similarly, the over-accumulation problem in a specific space can be solved if the excess resources can be used for the 'production' of new spaces in which capitalist production can continue. The importance of the finance and credit system in

[3] This is a crucial point to the radical debate, which cannot be developed further here due to space limitations. For a more extensive analysis, as well as discussion of the prerequisite conceptual tools refer to Skayannis 1994, chapter 3.

mediating these temporal and spatial displacements has to be noted (see Harvey, 1982 and 1989b).

Those who control excess capital, credit, and the political system can determine the spatial allocation of the new infrastructure investment. This means *"the ability to influence the production of space is an important means to augment social power"* (Harvey 1989b, p. 233). This power to command 'space', the argument continues, "*becomes an even more important weapon in class struggle*" (ibid. p. 294). At the same time the increased mobility of private capital and the different regional endowment of infrastructure capital would lead to "*spatial competition between localities, cities, regions, and nations*" (ibid. p. 295).

Sheppard and Barnes (1990) in a most useful, yet underrated attempt to 'reshape' the radical approach in economic geography, summarised previous arguments of the Marxist literature (Harvey 1982, or Walker 1981). They agreed that infrastructure investment reduces the size of inputs necessary per unit produced for a substantial period in the future. However, they argued that "*such a strategy diminishes the flexibility of future actions, however, since fixed capital investments must be depreciated before they can be economically written off, and because fixed capital from bygone eras may no longer be functional for capital accumulation*" (Sheppard and Barnes p. 192). Even though they did not incorporate explicitly infrastructure capital in the spatial models they developed, their transportation model illustrates how improved transportation investment can ameliorate the production capabilities of a given economy (see Sheppard and Barnes pp. 277-280).

The radical approaches to infrastructure analysis have delineated a general (*macro*) framework in which public capital investment can be theorised. However, they have not yet developed appropriate analytical tools for an empirical analysis and assessment of specific infrastructure projects or policies. For these reasons, and without forgetting the theoretical value of these radical approaches, this thesis has opted to utilise the more conventional analytical framework provided by the neoclassical approach.

1.5 Thesis structure

The chapters of the thesis can be divided to three basic types according to purpose. Chapters 2 and 3 provide the theoretical and data foundations for the empirical analysis. This analysis is then presented in chapters 4, 5, and 6, and the last part (chapter 7) provides a summary of the main conclusions.

More particularly, the first part of chapter 2 contains a compendium of the earlier attempts to theorise and investigate empirically the public capital and economic development relationship. There is also an analysis of the theoretical difficulties that a 'public infrastructure' definition entails, and a synopsis of the main 'empirical tools' upon which the empirical analysis has been based. However, the largest part of this chapter has been used to undertake a comprehensive presentation of the recent resurgence of academic work on infrastructure research. An attempt has been made to offer an account of all sides of the debate, and to do justice even to the very recent (and to, a large extent, tentative) methods of empirical investigation of the problem. Special attention has been given to illustrate the nuances and complexities that the addition of the spatial dimension adds to the problem.

Chapter 3 is a description of the Public Investment Programme (PIPR), which has been the main source for infrastructure investment in Greece. The first sections cover the historical and legal context in which PIPR has evolved. The latter sections present the temporal evolution and regional distribution of PIPR investment in total, and of its basic categories. Several measures have been used in order to gauge the degree of regional inequality.

The empirical investigation starts in chapter 4. The dominant approach in the recent infrastructure research is the use of production function analysis, and more particularly of the Cobb-Douglas variant. This analytical framework has been used in this chapter primarily in order to facilitate a comparison of the Greek results with similar findings from other countries. The centre of the investigation is the Greek manufacturing industry at regional (prefectural) level, and several empirical specifications have been used. There are also several different spatial levels of analysis, as well as temporal and network analysis undertaken in this section of the work.

One recent and promising alternative analytical framework is that of cost function analysis and this constitutes the primary focus of chapter 5. There, in addition to the regional (prefectural) dataset for Greek manufacturing, several sectoral panels of data have been used. The first regards a sectoral dataset for Greece as a whole. The second, which is the only available from the National Statistical Service of Greece at the 'regional' level, is that for the manufacturing industry in the metropolitan area of Athens. The third is the dataset for the manufacturing industry in the Rest of Greece, which has been derived by subtraction. Even though the interpretation of the empirical results is not as straightforward as might be the case for the production function analysis, the cost function analytical framework presents the opportunity for a deeper investigation of the infrastructure impact on the production and cost structure of manufacturing. Thus, several measures have been used to help in this direction. These are the cost elasticities of manufacturing with respect to infrastructure, the private factors of production bias effects, the private input demand elasticities with respect to public capital, and the 'shadow values' of public infrastructure.

The production and cost function approaches are perhaps the standard tools of empirical analysis in infrastructure research, certainly this statement is true of the former lines of study. There are, however, some more recent attempts in economic modelling that have been undertaken with the aim of investigating other more indirect channels by which public capital can affect private sector economic performance. Chapter 6 has used one such model, which takes a simple but comprehensive view of the economy, in order to explore further the infrastructure effects in Greece. The first part of chapter presents this theoretical model. The second is dedicated to the analysis of public capital's impact on the non-manufacturing part of the economy, using again regional data (at the prefectural level), and for this purpose quasi-production functions have been employed. The use of these production functions was dictated by the data limitations regarding the non-manufacturing sectors. The next part of chapter 6 presents the analysis of the potential indirect channels of infrastructure effects on the manufacturing part of the economy. The first of the explored channels concerns the effects of public capital on the preferred scale of production. This point is explored further by analysing the impact of infrastructure on the total output of the manufacturing sector. Another potential channel by which public capital can affect the private sector is by altering the equilibrium number of manufacturing establishments. This and indeed all analysis of these indirect channels has been conducted using once again the four available datasets, that is regional at the prefectural level (for total manufacturing), sectoral for Greece as a whole, sectoral for the metropolitan area of Athens (urban level), and sectoral for the remainder region termed the Rest of Greece.

The final chapter offers a summary of the major empirical findings of the thesis. It also presents a list of theoretical and practical limitations of work of this sort in order to put these findings into context. The last part of this chapter gives a comprehensive list of possible extensions of this research, a potential based on already existing data and analytical frameworks, and proposes some ideas for future research, based on different theoretical premises.

Chapter 2

Evolving Alternative Approaches to Comprehending the Infrastructure-Development Symbiosis

2.1 Introduction

Theoretical and applied research in every discipline usually reflects the problems and needs that a society is faced with at that specific point in time. This is even more the case for the social sciences. The search for a theoretical and empirical understanding of the relationship between public infrastructure capital and development has flourished whenever there was a need for a review and rationalisation of public investment policy. Such needs have occurred immediately after the Second World War, when there were numerous projects for rebuilding the destroyed infrastructure, and during the last two decades. The more recent period has reflected a time in many countries when the dominant economic philosophy has been to reduce the economic role of the public sector. This has been coupled with an imperative need for a more rational allocation of infrastructure investment.

The stabilisation policies followed by many governments have aimed to reduce inflation and public deficits. In many cases, the policies of fiscal austerity have slashed public investment in infrastructure, alongside the other public expenditures. However, even after recent public investment retrenchment, public infrastructure stock remains still a great part of the overall capital stock of almost every country. For instance, in 1987 the non-military public capital stock of the United States was 29 percent (1,887 billion dollars) of the total national capital stock. It could then, of course, be argued that just the sheer volume of the public investment spend begs for a comprehensive investigation of its effects on the economy.

Despite the fact that understanding the relationship between public capital and development is critically important for national economic efficiency, infrastructure investment only really became a political 'buzz' word in the nineties. The issue of public investment had a significant place in the 1992 Clinton electoral programme (Clinton and Gore 1992 and Clinton 1993), while in European Union political agenda infrastructure projects have always had a special place. Electoral programmes and government policies have an infrastructure reference because the physical aspect of public capital stock seems to be construed by the electorate as a visible evidence of the policy efficiency of a government. However, and given the huge amounts spent, it is not always clear that governments know exactly in what type of public capital they should invest, nor what are the short and long-run effects of this investment (for example, if there is a crowding-out of private investment, and so on).

The need for policy guidelines has spawned a new theoretical and empirical interest in infrastructure research. There have been several recent attempts to provide a summary and further clarification of this literature. This by no means implies that there is a lack of previous similar literature reviews of the field. Rietveld's (1989) review or Vickerman's (1991) *Infrastructure and Regional Development* collected volume are excellent examples of the infrastructure effects literature. As regards the new strands of research originating in the US, Gramlich's (1994) review essay, Sturm's (1998) book, and the collected volumes edited by Munnell (1990) and Batten and Karlsson (1996) can also be recommended.

This chapter sets out to present in section 2 a summary of earlier attempts to investigate the infrastructure puzzle, before the resurgence of research in the late eighties, primarily utilising a different method of measuring public capital stock. Section 3 gives a brief presentation of the seminal work of Aschauer on US infrastructure and some key points of the subsequent debate, particularly about production function analysis. Part 4 delineates the main alternative - the cost function analytical framework - and discusses examples of such applied work. Section 5 presents a summary overview of empirical research on infrastructure effects from around the world. The next part addresses the econometric problems and controversies of the debate to date. Part 7 offers a preview of some recent examples of innovatory and alternative methods that have been developed recently for the investigation of the infrastructure-development relationship. The conclusion summarises the main points of this literature survey, tables 2.1, 2.2, and 2.3 providing a concise report of the most important contributions to the field, as well as to some of the main results of this research.

2.2 Early approaches to understanding the public capital – development connection

2.2.1 Definition of public infrastructure capital

The notion of governmental or public provision of infrastructure capital is, of course, not new. Adam Smith (1970) in the *Wealth of Nations* suggested that the state had the duty to erect and maintain certain public works. Historical experience has shown that different countries have chosen different paths for the construction of the infrastructure necessary to underpin the economy. A classic example is the case of railway networks, which in some countries have been set up by private companies (United States), while in others they have been funded (and run) by the public sector, as is (was) the case in many European countries.

However, the exact nature of public infrastructure capital is not always clear. In the search for a definition of the term public capital (or public infrastructure, or just infrastructure, as here these terms are used interchangeably) a helpful departure point could involve the clarification of the term 'capital'. A basic definition of capital[1] includes "*all those man-made aids to further production, such as tools, machinery and factories, which are used up in the process of making other goods and services rather than being consumed for their own sake*" (Lipsey 1989, p. 3). Sometimes the term *financial capital* is employed to describe the money used to start up or maintain a business, and the term *physical capital* (or capital goods) for the tangible factors of production (see Varian 1993).

[1] This is a widely accepted definition for capital, in the neoclassical context of analysis. It has, however, to be reminded that other schools of though view capital differently. The radical (marxist) approach sees capital as "*process rather than a thing*" (Harvey [quoting Marx] 1982, p. 20).

However, even if a proper and acceptable definition of capital can be generated, it still would be a different and, to some extent, a more difficult task to measure it. This measurement is even more problematic if the task is to measure public capital. The treatment, for instance, of military outputs or non-durable goods causes difficulties. Residential housing sometimes is also included in the capital stock. Education, too, is also difficult in terms of its human capital interpretation. It seems that public capital is a problematic and rather elusive term, and in most cases, instead of a well-founded theoretical definition, what has been employed has been a rule of thumb.

As mentioned above, the period just after the second World War brought infrastructure investment under the spotlight. Infrastructure networks, especially in Europe, had been seriously damaged, and also many governments saw investment in public capital as an efficient tool of economic development. One of the first authors dealing with the term 'overhead capital' was Singer who distinguished between 'overhead' and 'directly productive' projects for development (Singer 1951). Nurkse (1961) considered overhead capital to be a crucial factor, which if present could lead a country, especially an underdeveloped one, out of a stagnation phase.

Another key writer, Hirschman (1958) adopted the distinction between 'social overhead capital' (SOC) and 'directly productive activities' (DPA) in his seminal work - *The Strategy of Economic Development*. His concept of SOC includes those basic services without which the productive activities in primary, secondary, and tertiary sectors cannot function. In addition to the conventional understanding of what the physical infrastructure entails, SOC also includes services associated with public health and welfare as well as education and public security.

According to Hirschman, there are three necessary conditions by which an activity can be classified (or not) under the heading SOC. First, it should be able to support a great variety of economic activities. Second, it should be provided by public agencies free of charge or at rates regulated by these agencies. And third, the services that it supports cannot be imported. He also uses a rather complex fourth condition. The investment necessary to provide SOC services should be characterised by technical indivisibility ('lumpiness' as he calls it) and a high capital-output ratio. This condition forms the basis upon which the difference between the wide and narrow definition of SOC is based. If this condition is adopted, then SOC is restricted to 'hard' infrastructure such as highways, airports, power installations, whereas categories such as education and health are excluded.

Further, he was able to identify two sequences of development - development via excess capacity of SOC and the development via shortage of SOC (expansion starts through increases in the supply of DPA). He also argued that regional policies that follow the excess capacity sequence rarely generate the desirable expected results. In his opinion, it was irrational to rely on the ability of the SOC facilities to induce development of other economic activities in backward areas. He also considered that a moderate shortage of SOC is unlikely to do much damage to a dynamic and developing area. On the contrary he argued, if good quality SOC facilities were provided, there would be a tendency for industries to refrain from creating their own facilities.

Some writers such as Rostow (1963) suggested that, in fact, everything that is necessary for economic development can be considered as overhead capital. Hansen (1965a; 1965b) has also used the terms, direct productive capital, and overhead capital. He argued that public capital has different impact on different regions believing that it is the characteristics of the recipient region and the type of public infrastructure that will determine the actual impact. He took the view that it would be better to direct an investment in economic overhead capital to a region developed to an intermediate level, where it would stimulate economic growth. The contrary line is where an investment in overhead capital is directed to a lagging region, which well might need it most. Hansen takes the view that, if economic overhead capital investment is directed to the lagging region, this could well constitute a waste of resources because they are unlikely to be able to compete with the intermediate regions. It is clear for Hansen that the sequence of development policy should be social capital investment in lagging regions, and overhead capital investment in intermediate regions.

Youngson (1967, p.40) proposed another definition suggesting that "*overhead capital is that capital which the government feels itself called upon to provide because private investment is absent or inadequate*". His definition implies that in order to characterise capital as overhead capital it has to be kept in mind that the latter is not a set of things but a set of properties. The two main features are first an ability to create external economies and second a requirement to be built ahead of demand. This definition is in accordance with the concepts invoked by Nurkse discussed earlier.

Diamond and his co-authors (1984) also adopted Hirschman's theoretical approach to infrastructure using this term as synonymous with SOC. Diamond and Spence (1989, p.49) also argued that infrastructure provision is like an intermediate input into production activities in the economy. They also provided a working and workable definition that indicates that "infrastructure is the collective and integrative capital basis for economic activity".

A thorough analysis of the theoretical problems of infrastructure definition has been provided by Diewert (1986). He applied duality theory to a restricted profit function to examine how public services might affect private manufacturing firms. He classified infrastructure investment into four categories: utility, communication and transportation investments, and land development projects, each one of which comprised several subcategories (19 in total). He also provided an extensive presentation of the different approaches to measuring the potential benefits of investments in local public goods or infrastructure services.

The precursor of modern regional infrastructure research can be considered in the work of Mera (1973) on Japan. Using ordinary least squares and covariance analysis he showed[2] that public infrastructure capital was significant in the production process in every economic sector (primary, secondary, and tertiary), with the caveat that the estimations were sensitive to the specification of the relevant equations.

One of the most important research projects yet undertaken attempting to analyse the relationship between public infrastructure and regional development was that of the study group co-ordinated by Biehl (1986) for the European Community.

[2] Recently, Merriman (1990) commenting on the Mera analysis suggested that it would not be correct to transfer his conclusions to other countries, as there are significant differences of the definition of public capital from country to country.

In Biehl's report, infrastructure is defined as a resource that simultaneously displays the properties of both public and capital goods. The study argues that infrastructure cannot be provided efficiently by the market mechanism, and that, in general, it has a longer life cycle and/or capacity compared with private capital. Infrastructure demonstrates simultaneously 'publicness' both in production and consumption (at least in principle). It is usually the case that infrastructure is characterised by non-excludability, immobility, indivisibility, limitationality, and polyvalence, but the degree varies according to infrastructure type. Another type of analytical breakdown used in this report was a consideration whether an infrastructure category represents a 'point' or 'band' or 'network' infrastructure subsystem, with bridges, roads, and the combination of a bridge with a road being respective examples. The group also considered as infrastructure public human capital, such as knowledge, information, planning and organising capabilities as well as basic research.

Biehl's team examined the regional effects of public capital in nine European countries, Belgium, (West) Germany, Denmark, France, Greece, Ireland, Italy, Holland, and Great Britain. Various descriptive statistical tools were used in their analysis as well as the calibration of quasi-production functions[3]. The prime focus was on how income, employment, and other potentiality factors are linked with infrastructure. The general conclusion was that public capital does indeed contribute to regional research, although there has been considerable subsequent discussion about the methods and data used in coming to such a view.

2.2.2 Measurement of public infrastructure capital

Apart from difficulties of definition, a fundamental problem which applied research about public capital has to confront is how to measure it. There are two competing approaches on this subject, together with a third that is something of a compromise. The first employs physical measures of the existing stock in a country or region. The road capacity, for instance, can be measured in terms of length and width

[3] For an implementation of quasi-production functions refer to the UK case in Meadows and Jackson (1984).

(quantitative characteristics), and can be additionally weighted by specific indicators of its features, such as the number of lanes (qualitative characteristics). Such an approach was followed consistently cross-nationally by the research team convened by Biehl mentioned above.

The second approach uses monetary measures, usually by adding up past public investment in infrastructure. This has been extensively used in the recent research in the US and other countries. Both methods appear to have some advantages and disadvantages. The physical approach can measure the existing stock at a certain moment of time with few conceptual problems. However, in practice it is rather difficult to produce such a measurement, not to mention the problems arising from the qualitative characteristics of the physical capital stock. The monetary approach seems more suitable for macro-scale analysis, as it incorporates qualitative characteristics (a better road network would tend cost more than a poor one, for example), but it also has its drawbacks. Estimations of the stock of public capital often assumes that the price of public capital is set in a perfectly competitive capital market, and that the devaluation of the stock can be accurately estimated. These assumptions can rarely be met.

Eberts, in order to avoid these problems, proposed a third hybrid approach, where "*the monetary estimates of public capital could be benchmarked by using the physical quantity and quality measures of public infrastructure*" (1990, p.18). Even though, conceptually, this way of thinking seems most proper, in that it potentially could give the most accurate picture of the infrastructure stock, in practical terms it has the deficiencies associated with both the physical and the monetary approaches.

However, it is the monetary approach, which seems to be dominant in the renewed interest about the effects of infrastructure on productivity and development.

2.3 The resurgence of research on public capital and the production function approach

During the eighties a resurgence in interest about the role of public capital occurred and resulted in considerable research advance. This research is based on the monetary approach to measuring public capital, and uses either a production or a cost function methodology to measure the impact of infrastructure investment on the private sector output and productivity. This renewed interest originates in the work of Aschauer (1987; 1988), and initially was focused in US public capital.

This current strand of research was spawned by the debate about the declining of productivity growth of the American economy during the seventies. Even though the US enjoyed the highest absolute level of real gross domestic product per employed person during the period 1960-1990, it had the smallest rate of increase in comparison to the other economic powers of the world. The output per worker in the United States had gone up by less than 50 percent, when in Japan, probably the most significant economic rival, it had increased by more than four times. More specifically, labour productivity growth in the private non-farm business sector in the US declined significantly (from an average annual rate of 2.5 percent in the period 1948-1969 to 2.0 between 1969-1973, and further to 0.5 percent over 1973-1979). During the eighties a small increase occurred but the average 1.2 is significantly smaller than the average of the period 1948-1969. (For a more detailed and thorough analysis of this context see Munnell (1990a).)

Several explanations have been proposed to explain this productivity slowdown, among which are changes in demographic characteristics and the level of education of the labour force as well as the energy crisis. At the same time as the productivity growth of the US economy declined, a downward trend was observed regarding the nation's public infrastructure capital. The most conspicuous form of the deterioration was that of urban infrastructure and for an analysis of this see, for example, Patton (1984). A possible link between this deterioration and the general level of economic development was advanced in the early eighties. Choate and Walter (1984) suggested that the bad condition of the basic public facilities in the US was an obstacle for its economic growth. Barro (1981) was hinting at the problem when he included government services in a developmental production function, but he did not estimate directly their productivity. Ratner (1983) appears to be the first economist to add public capital to a production function in order to examine whether its marginal product would be positive.

However, to repeat, it was Aschauer who accounted for the productivity slowdown as the direct result of a fall in public capital investment. His findings showed that there was a huge impact of public capital on the productivity of the private sector. These arguments generated a vigorous debate over this relationship in the US, and some of his ideas are regarded today as a common truth, or, at the very least, as an absolutely essential part of the debate on public spending[4].

Aschauer used a neoclassical theoretical framework influenced by that of Arrow and Kurz (1970). The basic idea was to expand a Cobb-Douglas production function by including the stock of public infrastructure capital, a similar kind of analysis to that used by Mera for the Japanese case.

The Cobb-Douglas production function normally has the form:

$$Q = AK^{a}L^{b} \tag{2.3.1}$$

where Q represents output, K is the private capital input, L is the labour input, and A represents, normally, a measure of technological progress. If public capital is considered as another (unpaid) factor of production, the above equation takes the form:

$$Q = AK^{a}L^{b}G^{c} \tag{2.3.2}$$

where G is public capital input. It can be added here that this basic form of equation can be expressed not only in terms of output, but also in terms of capital productivity (Aschauer 1989a):

[4] See, for example, Thurow (1994) *Head to Head* and Krugman (1994) *Peddling Prosperity*.

$$Q / K = AK^{a-1}L^{b}G^{c} \tag{2.3.4}$$

and labour productivity (Munnell 1990a)

$$Q / L = AK^{a}L^{b-1}G^{c} \tag{2.3.5}$$

None of these forms of Cobb-Douglas function can be estimated by standard econometric methods as they are non-linear in the parameters a, b, and c. Equation 2.3.2, for instance, has to be transformed into a *log-linear* form[5], by taking the natural logarithms of variables Q, K, L, and G, and of the constant A, in order to be estimated by conventional econometric methods. The operational form of equation 2.3.2 after the logarithmic transformation and appending an error term (e) becomes:

$$\ln Q = \ln A + a\ln K + b\ln L + c\ln G + e \tag{2.3.6}$$

The parameters a, b, and c measure the elasticity of output with respect to private capital, labour, and public capital respectively. These coefficients are the relative shares of the respective factors of the total product, under the assumption that each production factor (input) is paid by the amount of its marginal product (which implies that there is a perfectly competitive market for each production factor). These shares, in a more rigorous language, measure the elasticities of output in respect to private capital, labour, and public capital[6]. This means that if labour, for instance, is increased one unit then the coefficient b indicates the respective increase in output. The relationship between these

[5] Some econometricians call such a model a *double-log* formulation, reserving the term *log-linear* for models where the dependent variable is in logarithmic form and the independent variables have not been transformed (Ramanathan 1992). Here, however, the more widespread convention is followed, by which the former model is called *log-linear* (the terms *log-log*, and *double-log* sometimes are also used) and the latter *log-lin* (Gujarati 1995).

[6] In a log-linear regression the estimated coefficients measure the elasticity of the dependent variable with respect to the corresponding independent variables, in contrast to simple linear regression where such elasticities have to be calculated. See Gujarati (1995) for an illustrative analysis of this point.

coefficients represents the degree of homogeneity of the equation, or in economic terms the type of returns of scale (see chapter 4, section 4.6, for a more thorough analysis).

As mentioned, Aschauer's initial interest was the examination of the effects of public spending on the US economy. He argued that expansions of public investment spending have a larger stimulative impact on private sector output than equal increases in public consumption expenditure have. Thus, an increase in public investment generates an increase in the rate of return of private capital. This increase, in turn, stimulates private investment (1989a). His empirical analysis showed that an increase in public investment produced four to seven times greater increases in private-sector output than increased public consumption. At the same time, changes in government consumption (salaries of public servants, consumption goods purchased by public sector, etc.) had no effect, or at least only a small positive influence, on private-sector output (Aschauer 1987, 1988).

Further, his empirical analysis for the US economy during the period 1949-1985, showed that different categories of public capital investment affected productivity in different ways. Aschauer used the 'core' infrastructure concept, a subdivision of non-military capital stock which is comprised by the sum of public investment on highways, mass transit, airports, electrical and gas facilities, water, and sewers. Core infrastructure seems to have the greatest impact on productivity, in comparison to other forms of public investment, such as on general public buildings (office buildings, fire and police stations, courthouses, garages, passenger terminals), hospitals, conservation and development, and educational buildings. Military capital stock did not appear to be an explanatory factor at all of the productivity slowdown, despite the fact that it represented one third of the total government stock of equipment and structures (Aschauer 1989a).

Aschauer took the view that there are two main reasons justifying public investment in the public infrastructure. The first is the private market's failure to allocate resources the optimum way. Producers of such goods and services cannot find a practical manner to exclude particular agents from consuming them and, thus, cannot receive the right price in order to get a competitive return. The second reason is because of economies of scale. In the case of the acquisition and distribution of water, for example, there are substantial decreases in cost when the scale of production increases (Aschauer 1989).

One of the most important supporters of these ideas is Munnell. She has justified public provision of goods and services using similar arguments to Aschauer and agreed that the drop in labour productivity was due to a decline in the growth of public infrastructure. She argued that an increase in public capital investment would not only stop the erosion of the existing infrastructure stock, but would also raise the rate of growth in the amount of capital per worker and, thus, labour productivity (Munnell 1990a).

Aschauer and Munnell's ideas were truly influential and generated a vigorous debate with Holtz-Ealkin probably the most prominent and informed opponent. Holtz-Eakin, in series of papers, (1992; 1993a; 1993c) argued that the emphasis on the productivity and competitiveness effects of public capital is misplaced[7]. He did not deny the fact that during the seventies productivity growth fell to unprecedented levels, but he supported the theory of reverse causation with regard to the public infrastructure. His argument is that after the Second World War and until the early seventies, the US economy performed well. As result, substantial investment in the public infrastructure was undertaken, for example the construction of the interstate highway system. However, productivity growth dropped significantly in the seventies and in consequence government budgets were tightened and this, in turn, caused a serious decline in the growth of public capital stock. In other words, it was the decline of productivity that caused the decrease in the rate of infrastructure accumulation and not the converse.

Holtz-Ealkin did not deny also the fact that the large stock of public capital in the US provides benefits for the national economy as a whole. However, he argued that the US already has on average a rather good stock of infrastructure and any additional increase to this stock would be hardly likely to increase the overall productivity of the economy. He pinpointed as the major problem with public capital the fact that it is free to use and that there is no incentive to maintain the existing infrastructure stock.

[7] However, recently Holtz-Eakin argued that public capital does affect positively private sector behaviour via more compex channels of influence and these are discussed later.

What he suggested was not new investment programmes for public capital, but alternative programmes whose goal was to charge users for the services that the infrastructure delivers. These charges could be collected with the assistance of the appropriate sensor-mechanisms and systems (given the recent innovations in electronics and computers). Further, he considered that if such programmes were adopted, instead of new investments in public capital, then the intensity of demand for infrastructure services would be revealed and this, in turn, would lead to the improvement of the planning process. User fees, he argued, could then be directed towards the maintenance and modernisation of the already existing public capital. Basically, he is critical of the post-war Federal policy in the US, which has tended to subsidise new investment in infrastructure rather than maintaining well the already existing stock. If a new philosophy, along the lines he outlines, was adopted by the Federal government then a more efficient use of the infrastructure stock would result. Furthermore, he feels that this would also help to save on resources since this policy would be more cost-effective than new build.

All the aforementioned examples of research on public capital have used a methodology based on the Cobb-Douglas production function. This category of production function is easy to estimate and the interpretation of the results gives some immediate answers about the elasticities of the production inputs. Unfortunately, granted its convenience and ease of use, this approach it is characterised by some restrictive properties. The Cobb-Douglas function is characterised by constant (unitary) elasticity of substitution, which is the measure of how the ratio of factor inputs changes as the slope of an isoquant changes, or alternatively is the measure of the substitution possibilities of the production function. However, this restriction does not represent accurately the dynamic aspect of the real production process, especially in cases where technological innovation affects the intensity of use the production inputs.

A way to relax such a restrictive assumption as the unitary elasticity of substitution, is to adopt a different type of production function, such as the transcendental function (translog). The translog function allows for variable elasticity of substitution, and also has the advantage of being easily estimable. If public infrastructure capital is added to the private capital and labour inputs the basic logarithmic form of the translog is as follows:

$$\begin{aligned}\ln Q = {} & \alpha+\beta_L \ln L+\beta_K \ln K+\beta_G \ln G+\beta_{LL}(\ln L)(\ln L)+\beta_{KK}(\ln K)(\ln K)+\beta_{GG}(\ln G)(\ln G) \\ & +\beta_{LK}(\ln L)(\ln K)+\beta_{LG}(\ln L)(\ln G)+\beta_{KG}(\ln K)(\ln G)+e\end{aligned} \tag{2.3.7}$$

where lnQ, lnL, lnK, and lnG, are, as before, the natural logarithms of output, labour, private, and public capital, respectively, a is the constant term, and e the error term. The drawback of translog production function is that in an applied econometric calibration there is a need for significantly more degrees of freedom for its estimation, certainly in comparison to the Cobb-Douglas function.

There are, nevertheless, several examples of infrastructure research based on translog production functions. One, actually predating Aschauer's work, was that of da Silva Costa et al. (1987) who estimated such a function for the US for the period 1932-1972. Their results showed that public capital and labour were complementary inputs, public capital exhibited diminishing returns, and the ratio of public to private capital was negatively related to the output elasticity of public capital.

Production function analysis, either in Cobb-Douglas or translog guise, has proven popular in infrastructure applied research in the US. This research field is conducted at three, many times intertwined, spatial levels - the national level, regions and/or states, and sub-regionally say at the level of metropolitan areas.

Garcia-Milà and McGuire (1992) estimated a Cobb-Douglas production function using a panel consisting of observations for the 48 contiguous states. As a public infrastructure capital proxy the study used data relating to highway capital and education. An interesting feature of their estimations was that they did not use state dummy variables because they did not want the cyclical variation to dominate the long-run relationship. Instead, they used the state population and a measure of the average industrial mix of every state to capture potential differences across states. Both highway and education public capital was shown to have a positive impact on output.

However, in a more recent attempt, and estimating again a Cobb-Douglas function, these same authors used first differences of the data, and tested for random and fixed regional (state level) effects, nonstationarity, endogeneity of the private inputs, and measurement error. The results showed that here public capital variables were not significant, with the caveat that there are aspects of the problem yet to be explored, such as the use of time lags for the impact of infrastructure, or the networks effects (Garcia-Milà and McGuire 1996).

Pinnoi (1994) estimated a translog production function also using panel data (48 states from 1970 to 1986) an applying various econometric techniques. His findings showed that water and sewer services are complements to private capital and labour in most regions and industries.

Sturm and de Haan (1995) estimated a Cobb-Douglas production function for the same period as Aschauer. However, they used the first differences suggesting that this is necessary because the variables are neither stationary nor cointegrated. They concluded that infrastructure does not affect development, and also stressed that the alternative cost function approach might be helpful.

Dalenberg and Partridge (1995 p. 635) examined the effects of public capital, along with taxes and government spending, on employment in 28 metropolitan areas of the US. Their overall conclusion is that public infrastructure "did not appear to positively influence metropolitan employment".

Evans and Carras (1994a), using panel data from the 48 contiguous states in a production function analysis, concluded that if specific econometric methods (correction for serial correlation, attempt to take endogeneity into account) are used, then government capital, statistically, has negative productivity, with the exception of government educational services.

Moomaw et al (1995) replicated Munnell's regional work for the US, but with one major difference. Instead of using the Cobb-Douglas form, they preferred the translog function. Their basic conclusion was that water and sewage systems have had the biggest contribution (in comparison with other types of public capital) to regional (state) output, especially in the southern states. They also argued that their results supported Hansen's assertion that the economic impact of various types of infrastructure depends on the characteristics of the region.

The results of Baltagi and Pinnoi (1995), for a panel of 48 US states, showed again that water and sewerage capital investments make a significant contribution to private sector productivity, in contrast that is, to the other categories of public capital.

2.4 The cost function (duality theory) approach to infrastructure research[8]

Production function analysis is by no means the only avenue of approach to understanding the role of public capital. One alternative theoretical framework is that of cost function analysis and duality theory. An extensive theoretical presentation of this approach can be found in Diewert (1986) and Chambers (1988). In a nutshell this approach can be described as follows. In the context of a national or regional economy any industry can be assumed to be seeking to minimise its production cost. This can be expressed in terms of a private cost function:

$$C_i = w_i * L_i + r_i * K_i \qquad (2.4.1)$$

where C_i is the private cost of production, w_i is the wage rate, L_i is the labour input, r_i is the user costs of private capital, K_i is the private capital input, and i denotes the industry. This minimisation of this equation is subject to the restriction posed by the production function of the industry:

$$Y_i = f(L_i, K_i, G, t) \qquad (2.4.2)$$

[8] This approach can be equated with the maximization of a profit function (which is achieved by the minimization of the cost function). Sturm (1998) has classified both cost and profit methods under the heading of the '*behavioural approach*' to the analysis of infrastructural effects.

where Y_i is the production of industry i, G is the public capital input, and t denotes time (as a proxy for disembodied[9] technical change).

From the minimisation of the private cost function, subject to the production restriction, a cost function can be derived:

$$C_i = C(w_i, r_i, Y_i, G, t) \tag{2.4.3}$$

This can be considered as the dual cost function to the production function defined above. Then, instead of estimating the primal function (which is the production function), it is possible to estimate its dual (which is the cost function defined above).

This alternative analytical framework has been proposed as superior to the production function approach, either Cobb-Douglas or translog (Berndt and Hansson 1991). Production functions, besides being a restrictive functional form, suffer from potential problems of simultaneous equations bias. As Berndt and Hansson argue, variables such as labour input, capacity utilisation or the unemployment rate should be treated as endogenous, otherwise standard ordinary least squares (OLS) procedures produce inconsistent and biased results. Additionally, production function analysis reveals only the impact of public capital on production and/or productivity; it does not provide information about under or over-provision of public infrastructure. This limitation is overcome by the cost function approach.

Public capital, or more accurately its services, has no market price (the case where public infrastructure services are charged cannot be ruled out, but can be easily incorporated in a more extended model). This means that infrastructure does not enter the cost function directly, but indirectly via the production function. Its shadow value (this concept can be viewed as the opportunity cost using infrastructure resources), as well its

[9] If it is assumed that capital is more or less homogeneous then technological progress would affect all existing production processes. This depiction of technological progress is called disembodied. An alternative view assumes that new technological progress demands an adaptation of the existing processes (thus technological progress is embodied in the capital stocks). For an introduction in this subject see Heathfield et al. (1987). A more advanced presentation is provided by Chambers (1988).

impact on labour, private capital, or total factor productivity can easily derived from equation 2.4.3.

Cost functions provide the opportunity to answer questions such as whether public capital and the other production inputs are complementaries or substitutes, whether public investment is crowding out private capital, what is the shadow price of public capital, and what is its optimal level of provision.

There are some examples of the cost function approach in infrastructure research in the US context, though they are much fewer in number than those using production functions. The main reason for the prevalence of production functions is that, despite the fact that the cost function analytical framework can shed light on more complex areas of the infrastructure and development relationship, it is much more demanding in terms of data requirements and econometric implementation.

Nadiri and Mamuneas (1994) examined the effects of public capital and research and development capital on the productivity of twelve two-digit American manufacturing industries using cost function analysis. Their results showed that public infrastructure has a significant productive effect and that it is a substitute for labour and private capital, as well as complementing intermediate inputs. Lynde and Richmond (1992), using a translog cost function, have also found that public infrastructure has a positive marginal product and is a complement in production to private capital. Morrison and Schwartz 1992), measuring the effect of public capital investment (in highways, water, and sewers) on private sector costs, concluded that infrastructure does provide a significant direct benefit to private manufacturing.

Even though it cannot be classified as cost function analysis, the work of Deno (1988), estimating a translog profit function at the regional level (metropolitan areas in the US), has close affinity to it. Deno discovered that there are large differential effects across regions and categories of infrastructure, and that the greatest impact can be found in declining regions.

2.5 The international research response to the US infrastructure discoveries

The debate spawned by Aschauer's original work is now by no means confined to the US experience. Similar research has been conducted subsequently in several other countries or within an international comparitive framework.

An example of the latter has indeed by provide by Aschauer himself (1989b). He presented a comparative study of the public investment and productivity growth of a group of seven major industrialised countries, concluding that infrastructure has both positive direct and indirect effects on the private sector output and productivity growth of each country.

Ford and Poret (1991) conducted similar research on private-sector productivity for eleven OECD countries. All of their series were differentiated, and corrected for second-order autocorrelation. Their findings were that public capital investment had a large estimated return in the US and four other countries of the sample. However, even though there was some evidence that countries with high public infrastructure investment had high productivity growth, this relationship was not particularly clear.

Another piece of international comparison is the work of Evans and Karras (1994b). They constructed a panel of countries (Belgium, Canada, Finland, Germany, Greece, the UK, and the US) and tried to examine how productive public capital is. Criticising Aschauer's work on econometric grounds, they concluded that if the equations are specified for the country and time effects then there is no evidence that public capital is highly productive and underprovided in the sample countries.

There is also a body of literature from national research on how public infrastructure affects development.

An early paper was by Looney and Frederiksen (1981) who tried to test Hansen's hypothesis, namely whether planned changes in various types of infrastructure have significant regional effects on income levels within a developing country. Their case study was Mexico and they suggested that the results tentatively confirm the truth of Hansen's proposition. Also working on Mexico, Shah (1992) used a restricted equilibrium approach to examine the impact of public infrastructure on private sector profitability. He specified a restricted translog cost function and using data for twenty six three-digit industries for the period 1970-1987 concluded that public capital had a small but positive multiplier effect on output.

Berndt and Hansson (1991) measured the contribution of public capital in Sweden. Using an operational empirical definition for public infrastructure they showed that the growth rates of real private and public capital stocks in Sweden and the US, over the period 1960-1988, were "surprisingly similar", which means that there was a sharp slowdown in public capital investment. They rejected the Cobb-Douglas production function framework as their results produced by such an analysis were incomprehensible. The adoption of the alternative cost function model showed that increases in public capital, ceteris paribus, did reduce private costs.

Using cost function analysis for the UK, Lynde and Richmond (1993) concluded that public infrastructure has played a positive role in enhancing production and reducing costs in the manufacturing sector.

Research results from France also support the positive impact of public capital on regional economic development. Prud'homme (1996), using regional production functions, concluded that infrastructure does indeed contribute to labour productivity. Public capital's elasticity was around 0.08, when private capital's was 0.25. However, as Prud'homme observed, if spillover effects and externalities are also estimated (which was not the case in this particular research) then infrastructure's elasticity will probably exceed that of private capital.

The interest in the effects of public capital has flourished in Spain perhaps due to the excellent data sources that are available. Following Biehl's line of work Cutuna and Paricio (1994) estimated a quasi-production function for Spain as a whole. The results show that infrastructure is an important explanatory factor in accounting for regional income differences. Bajo-Rubio and Sosvilla-Rivero (1993), using the production function framework for the Spanish economy also supported Aschauer's argument. It is interesting to note that because of the joint dependence and non-stationarity of aggregate time-series they argued in favour of cointegrating regression methods. Mas et al. (1996)

conducted similar research for the Spanish regions. They also used a Cobb-Douglas production function and concluded that public capital in Spain had significant positive effects on the productivity of the private sector (with the exception of education and health). They also found that there were spillover (network) effects, as the elasticity of labour productivity to the stock of productive public capital was greater in the estimations where the public capital stock was composed of each particular region and the neighbouring ones. However, it was discovered that the effect of some forms of public capital on the productivity of the Spanish regions has decreased over time.

Public capital also has been demonstrated to display a positive role on the private sector of the Greek economy. That is the basic conclusion from a time series analysis of Dalamagas (1995), and Segoura and Christodoulakis (1997), who used a broad definition of infrastructure working at the national level (both these pieces of research are discussed more extensively in chapters 4, 5 and 7).

Seitz and Licht (1995), using a translog cost function and a panel data set, estimated the impact of public capital for the eleven states of the (former West) Germany. They concluded that public infrastructure formation encouraged private investment and that such a policy instrument can be considered as an efficient instrument to improve the competitiveness of cities, regions, and nations.

Sturm and de Haan (1995) used a Cobb-Douglas production function not only for the US economy (see above), but also for the Netherlands. Their estimations for the Dutch economy gave rather peculiar results (several cases exhibited a negative private capital elasticity and a labour elasticity above one), even though they were estimated in first differences. Toen-Gout and Jongeling (1993, cited in Hakfoort 1996), however, achieved really rather high positive coefficients for their study of the effects of Dutch public capital.

In a context of underdevelopment, Elhance and Lakshmanan (1988) used multi-equation econometric models in which public capital was a quasi-fixed input, to examine infrastructure-production system dynamics in India, both at national and regional levels (six states of the Indian Union). They suggested that there is evidence *"of considerable lagging of infrastructure stock development optimally desired levels, and an emphasis on* *more directly productive economic infrastructures vis-à-vis indirectly productive social infrastructures would seem to support the conceptual formulations by Hirschman*" (p. 529).

A recent attempt to evaluate public capital's role in Japan is that of Miyawaki and Tobita (1992). They argued that fiscal austerity reached even Japan during the eighties and that this has had, as a result, a significant decrease in public investment in infrastructure, for the first time since 1945. Their findings showed that what they called 'industrial infrastructure' (a term covering all public invested capital with the exception housing, water/sewer systems, urban parks, educational facilities, and other social and cultural facilities) made an important, though declining, contribution to national GDP between 1976-1988. These results were corroborated by the work of Ohkawara and Yamano (1997). This research has an accentuated spatial dimension, analysing the effects of the regional allocation of public infrastructure by numerical simulations.

2.6 Considering empirical specifications and technical problems in infrastructure research

Most of the researchers involved in the US debate regarding the effects of public capital on productivity and/or the output of national or regional economies have used the production function approach. However, there is no unanimity about its exact specification and it is certainly the case that the specific form of the production function can affect the results of the research. The range of choice in the final formulation is surprisingly wide, given the rather rigid theoretical model that Cobb-Douglas function seems to be.

A first choice, not of particularly real substance, is that the analysis can be formulated in terms of output, private capital productivity, or labour productivity as dependent variables.

There are, however, significant differences in how the empirical models are formulated in empirical research. For instance, Aschauer (1989a) has employed, in addition to the three factors of production (private capital, labour, and public capital), capacity utilisation as a measure for the influence of the business cycle. He has also used capacity utilisation to assess the argument that the productivity decline in the US was a result of the declining capacity use. Munnell in her national analysis (1990a) also used capacity utilisation. However, in her regional paper (1990b) she used the unemployment rate as this variable can reflect the cyclical nature of productivity. Ford and Poret (1991) argued that the inclusion of this variable is imperative, since in their research residuals from regressions excluding this term were highly auto-correlated.

Another controversial and probably more important problem, is whether the data should be in differentiated form or not (which, in terms of econometrics, can be translated as the question whether the time-series used are stationary or not). Aaron (1990), Hulten and Schwab (1991a), Jorgenson (1991), Tatom (1991b), and Sturm and de Haan (1995) all argue that one of the basic problems of the time series analysis, on which the Aschauer-Munnell arguments are based, is trend which some times produces spectacular fits. There are several econometrics methods dealing with this problem, and one of the most popular is based on the first differences of the variables entering the production equations. It is important to recognise that the aforementioned researchers using such techniques reached results contradicting those of Aschauer and Munnell. The latter, however, rejected the idea of differentiating the data, arguing that such a technique would destroy "any long-term relationship in the data, which is exactly what one is trying to estimate" (Munnell 1992, p. 193). Bajo-Rubio and Sosvilla-Rivero (1993) have used cointegration techniques, rejecting simple OLS methods as invalid, and yet their results still supported the Aschauer argument. Dalenberg and Partridge (1995) argued that first differences over three years intervals would take into account long-run differences, while at the same time check for the spurious regression argument.

Another point of debate is when the empirical work is not confined to the use of time series, but instead panel data analysis is used. This is of great interest for regional analysis as, mostly, infrastructure data do have a spatial dimension. The allocation of investment funds is usually based on the different needs of the smaller geographical units within a larger total, for example the state level of the Federal programme in the US. In other cases, it is the local or regional government that has the responsibility to devise an investment programme for infrastructure. In any event, it is easy and often helpful to use data from a lower spatial level to construct, for instance, a panel data for the higher level. This means that the treatment of these combined data sets (which have both a time series and a cross section dimension) can contain important pieces of information not available from a single time-series or cross-section. However, at the same time, different econometric techniques are needed, as panel data analysis presents some rather special technical difficulties.

One such difficulty is the fact that different geographical units are endowed with different locational characteristics, such climate, labour markets, levels of industrialisation or urbanisation, and the like. These regional differences at the level of the lower spatial unit, which is the base for the analysis panel (a state in the case of the US), will enter into the error term as an unobserved component. One of the most common techniques in panel data analysis is to use the least squares dummy variables model (LSDV), instead of the ordinary least squares model (OLS). In the LSDV model differences across the geographical units can be captured by the use of binary variables representing each one of these units. This fixed effects model can be extended to include time differences for the period of the analysis. An alternative method is the use of a random effects model, especially in the case where the sampled cross-sectional units are drawn from a large population[10].

Munnell (1990b), in her regional analysis for the US, used states as the spatial units in the panel (48 states for the period 1970-86). She estimated the effects of public capital in the production process of the US as a whole and its regions (Northeast, Northcentral, South, West) using the standard OLS procedures. Nevertheless, the employment of simple regression techniques, as Holtz-Eakin observed (1993c), produces biased and inconsistent results. He supported again the argument of reverse causation, this time at regional level. Rich states, in terms of locational endowment, will have greater income and output than poorer ones. That increases their ability to invest in public infrastructure. Holtz-Eakin suggested that research techniques such as those implemented by Munnell present these public investment programmes to produce rich states, when the

[10] For a consideration of these techniques, see Greene (1993): *Econometric Analysis*. A more extensive analysis of the panel data methods can be found in Hsiao (1986) *Analysis of Panel Data* and Baltagi (1995) *Econometric Analysis of Panel Data*.

association is in fact the other way round. Other researchers seem to agree with this point (Eisner 1991). Holtz-Eakin argued of the necessity to include in the production function, and particularly in the specification of the error term, a component that would capture the regional characteristics.

Kelejian and Robinson (1994) specified a panel data Cobb-Douglas production function by OLS for their estimations without using state dummy variables, but taking into account the public capital and output per labour ratio in the bordering states. At a second stage, they offered an account of the problems that such a model may entail, for example, the role of state dummies, autocorrelation, heteroskedasticity, spatial correlation, endogeneity of the production factors, and unit roots. Their overall conclusion was that infrastructure does not play a role in private sector's productivity. They also argued that it is not necessary to use state-specific characteristics as Holtz-Eakin did to obtain this result. They reached similar results in a more resent piece (Kelejian and Robinson 1997) where they also argued that the high coefficients of labour elasticities, which by the way, are the norm in the Cobb-Douglas literature for infrastructure, may be an indication that the labour variable is a proxy for omitted variables. They also explored several aspects of the spatial dimension in infrastructure research, especially addressing the problem of spatial correlation.

The problem in accounting for the lower spatial units of a panel data set has also occurred in another aspect of infrastructure research - international comparisons. Evans and Karras (1994b) criticised Aschauer's (1989b) work in this respect, as in his panel analysis for the group of seven industrialised countries he did not allow for fixed or random effects for time or/and country. As Evans and Karras commented Aschauer did not even take into consideration the fact that capital-output ratios varied over time and between countries. The results Evans and Karras reached for their panel (consisting of different countries) showed that public capital is not productive, which is the exact opposite of Aschauer's findings.

Another problem of regional production function analysis based on panel data, apart from the aforementioned treatment of the regional specific effects, is the simultaneous determination of observed quantities of private and public capital, labour, and output. The proposed remedy by Holtz-Eakin (1992) was the use of instrumental variables[11] estimators by which the simultaneity bias can be circumvented.

In aggregate research studies of the monetary type the aggregation of data *per se* can create some significant conceptual and technical problems, as all aggregation methods have their weak spots. If the output of a country or a region is measured in terms of gross production value, several restrictive assumptions should be adopted in order to treat intermediate goods. One such assumption can be, for instance, that intermediate inputs should have a constant near to unity marginal product. If there are data available for the respective value-added, this problem can be circumvented.

For the calculation of capital stocks, either public or private, different methods can be employed, the most popular being that of perpetual inventory. A relevant difficulty for aggregate studies is the calculation of capital depreciation. If the empirical research applies only to a specific industry there would be no problem (that is, if the depreciation rates and life times of all pieces of fixed assets and machinery were known). However, in many pieces of macro-scale research, it is assumed that all industries of a sector or, even worse, all firms in all industrial sectors in a region or country have the same rate of depreciation. Gramlich (1994), referring especially to the measurement of infrastructure depreciation, argued that as public capital rarely is sold the economic rates of its depreciation are almost never directly measured.

The treatment of aggregate data for labour is not less problematic. Usually, what is used as a proxy for labour input is the average annual employment (most of the time adjusted by worked hours). A frequent assumption is that labour is qualitatively homogeneous or, in other words, that every worker or employee has the same endowment of skills. However, differences in labour force, such as between males and females, educated or not, skilled and unskilled, should be weighted in order to have a more reasonable approximation of the real situation.

[11] The 'instrumental variable' of a variable Y_t, for instance, is a proxy variable, which is highly correlated with Y_t, but uncorrelated with the error term of the regression (see Gujarati 1995). In the specific case, Holtz-Eakin constructed an instrumental variable estimator that used the input levels of some states as the explanatory variables for other states (see section 2.2, in Holtz-Eakin 1992a).

2.7 What does the future hold for research on the infrastructure development relationship?

For sure, production and cost function approaches can reveal some of the complicated aspects of the relation between public capital and development. There are, though, many facets of this relationship that have not yet been analysed thoroughly. This gap has fed some recent attempts to use more complex methods and models in infrastructure research.

A major research project at the London School of Economics has recently investigated the impact of the EU Cohesion Fund on the development of the four recipient countries - Spain, Portugal, Ireland, and Greece. One of the main areas of this study was an exploration of the regional effects of infrastructure investment in the aforementioned countries. Several different and innovative approaches were employed, because, as the final report (ESCL LSE 1996) argues, an "all encompassing model" does not exist and the traditional approaches either are invalid and/or do not have the ability to account for spillovers and dynamic effects. The main analytical tools employed by the research group were vector autoregressive (VAR) techniques[12], and economic modelling (general equilibrium models as well as dynamic models). The principal results of the study were that public capital has a direct positive impact on private investment decisions, that there is no major difference in the impact of transport and other infrastructure capital, and that the regional spillovers are more important in some countries than others.

There are some other examples of VAR analysis for the investigation of public capital's effect on private sector output. Clarida used data from the United States, Britain, France, and Germany (1993), McMillin and Smyth (1994) also examined the US case, and Otto and Voss (1996) applied the methodology to Australia. (For a more extensive analysis for these attempts to utilise the VAR approach can be found in Sturm 1998.) The

[12] Vector autregression (VAR) is a simple method by which the problem of deciding which variable is endogenous and which is exogenous can be circumvented. VAR modelling, however, has been criticised as a-theoretical and "an article of faith" (Greene 1993, p. 553). For introductory presentations of the problems and limitations of the VAR technique see Gujarati (1995) or Greene (1993). For a discussion of VAR models in macroeconomic modelling, see Cooley and LeRoy (1985).

overall result from these VAR analyses is that either public capital has no significant effect on private output, or that the causality of this relationship is not yet clear.

Recently a Spanish team of researchers tried to analyse "*the total and dynamic partial effects of public capital on output, employment and stock of private capital by making use of a structural VARMA*[13] *approach*" (Flores de Frutos et al. 1998, p. 992). Their empirical findings showed that there is a long-term positive effect of public capital investment on the private sector variables. At the same time, however, it is shown that previous values of the private sector variables also affect the current level of public capital.

There have recently been several attempts to construct general models for the economy incorporating public capital, and the above mentioned project is one of them. The general lack of formal economic modelling can be considered as one of the deficiencies of the recent public capital debate. As Holtz-Eakin and Lovely (1996) have argued, the vast majority of the empirical literature has been confined to estimations of the productivity effects of infrastructure, neglecting the mechanism by which public capital affects firms, markets, and equilibrium production in each sector of the economy.

Alogoskoufis and Kalyvitis (1996) have provided a theoretical model for endogenous growth in an open economy with both private and public capital. They model alternative public policies regarding infrastructure investment and they concluded that "*a transition period is required during which the private sector experiences a changing marginal product of public capital. Private investment adjusts gradually until the economy ends in the new steady-state*[14]. *In this sense public capital formation can become the engine of growth as higher public investment generates ongoing growth*" (p. 13).

[13] For an analysis of this method, see Hamilton (1994).
[14] 'Steady state' is the point at which the "*amount of capital per worker remains constant*" (Jones 1998, p. 25; see also Mankiw 1997).

Erenburg (1993) examined the relationship between private sector and public sector investment in the US with the use of a simple rational expectations model, comprised of a two-equation system. It was assumed that public investment is determined by the public investment and public deficit in the previous time period, and private investment from private and public investment and public deficit of the previous period. The results showed that the relation of the investment behaviour of the two sectors was positive.

Holtz-Eakin and Schwartz (1994) presented a neoclassical model of economic growth emphasising the role of infrastructure. Public capital stock is assumed to be a component of the aggregate production function (of the model economy). Then the evolution and characteristics of the steady state of the economy (see above for definition) are analysed. The empirical calibration of the model for the US economy, showed that public sector capital accumulation did not explain the growth patterns of the constituent states.

Another simple, but rather complete model, of a small economy has been offered by Holtz-Eakin and Lovely (1996) who then tested using panel data based on the states of the US. They sketched a simple economy comprised by two commodities (wheat and finished manufactures as they call them), two inputs[15] (labour and capital), and tried to incorporate infrastructure and to formulate its effects on the private sector of the economy. This model assumes that there are also intermediate goods, or components in their terminology, which are used for the production of the finished manufactures. These components are also assumed as unique to their local economies (there is no trade in intermediate goods). The provision of public capital by the government alters the cost structure of the components production, which leads to changes of their preferred levels of production. According to Holtz-Eakin and Lovely, an increase of public capital provision would have, as a result, an increase in the number of component producers and thus would enhance "any external economies of the finished manufactures industry" (1996, p.113).

[15] Holtz-Eakin and Lovely noted that this model can be easily altered to a three inputs model, including mobile capital, and two immobile factors, labour and land (see Holtz-Eakin et al. 1996, footnote 6).

However, there is the possibility that this increase of component producers would not be large enough in order to have an expansion of the manufacturing sector (that is, of course, the sector of finished "manufactures" production). Holtz-Eakin and Lovely concluded that their analysis "suggests that the effects of infrastructure provision are far from direct and clear-cut".

The empirical calibration of this model, again for the American states, gave some interested results. It was assumed that infrastructure does not directly affect non-manufacturing sector, but has an impact on manufacturing, through a number of ways. One such way is by "altering the preferred scale of production for each firm in the manufacturing sector". Their results suggest that infrastructure does not have a significant impact on manufacturing output. Another possible way is by affecting the equilibrium number of firms. Holtz-Eakin and Lovely basic argument is that it is this latter, subtler, way by which public capital affects production. Infrastructure increases the number of manufacturing establishments, and this in turn has a result an increase of the manufacturing output. The increase of the establishments' number creates external returns, which would give, in turn, a rise on manufacturing productivity (ibid., p.122).

2.8 Conclusions

The new infrastructure research paradigm initiated by the work of Aschauer in the late eighties has followed a monetary approach to the measurement of public capital stock. It can be safely argued that this approach has prevailed over the physical measuring alternative, at least for aggregate research at regional, national, and international levels. For both measurement types, however, the problem of an exact measurement of infrastructure utilisation remains, as these methods can only provide a picture of the existing capital stock capacity, but not of the intensity which this stock is used.

In the recent research there are two analytical frameworks which have been extensively used. The first, and more popular, is the use of production function analysis, usually as a Cobb-Douglas or translog form. The second utilises duality theory and cost (or profit) functions. Despite the problem that the empirical implementation of cost function framework is more complex and data demanding, it can shed light on more complex aspects of the infrastructure-productivity relationship. It circumvents potential problems of simultaneous equations bias of the production function approach and can give information about the level of public capital provision.

In this debate over the role of infrastructure in development there are two opposite views of the role of public capital. One supports the argument that public capital is a significant factor in determining private sector production. This school of thought reaches high and significant results for infrastructure's impact on private output when the production function approach is implemented, and concludes that infrastructure provides significant direct benefits to manufacturing costs. This positive role of infrastructure on economic and regional development when viewed in policy terms means that new investment in public capital is necessary where the existing stock is deemed as inadequate or outdated. In short, infrastructure becomes an important and efficient tool of economic planning, either at the regional or national level. There are, however, the sceptics, who believe that these positive results are a product of inappropriate econometric techniques. Even if these results are accepted, this school of thought believes that the direction of causation in the infrastructure-development relationship is not from the former to the latter, but vice-versa. This camp advocates against the commissioning of new infrastructure projects, and has been especially vocal in the US context.

Nevertheless, most empirical research worldwide, as summarised in Tables 2.1, 2.2, and 2.3, seems to find some evidence in favour of the positive role of public capital. Recently, even Holtz-Eakin, who has been one of the most prominent figures in the group which rejects the positive results for infrastructure, identified other, more subtle ways, in which public capital can affect, in a positive way, the private economy.

From the empirical evidence it has also emerged that investment in the productive dimension of public capital[16] (transportation, sewage, energy facilities, etc.) has a positive effect on the economy, certainly in comparison to an equivalent investment in social infrastructure (education, health, housing, administration, etc.) which has a negative or insignificant effect. These results are consistent with what is intuitively

[16] Some authors use the term core infrastructure in this context (Aschauer 1989; Munnell 1990).

expected. However, it must be kept in mind that usually only invested capital in buildings, materials, etc. are used as a proxy of social infrastructure services, when the services in these sectors include a great part of human capital, such as teachers, medical and clerical staff, etc. Future research in these particular categories of public capital will need to include more the human dimension before final judgements are made.

This last point is directly linked to the fact that, until now, a great part of research refers to infrastructure as a total, or perhaps there is just a distinction between productive and social infrastructure. However, there is a great need for analysis for the particular types of public capital (transportation, energy facilities, education, health, etc.). There is an existing literature for some of these categories, especially for transportation (Button 1996), but for others a much deeper investigation is needed.

Another important conclusion is that the spatial dimension does matter in the infrastructure debate. Even though the research presented here is at a more macro scale, there are numerous examples of research on specific infrastructure projects (airports, highways, bridges, etc.). If this is taken as the smallest spatial level then four more levels can be distinguished - urban infrastructure research (effects of public capital on urban centres and land prices, Haughwout 1994; 1996), regional research, national research, and that of international comparisons. The results from the US research have shown that the larger the level of analysis, the larger is the estimated impact of public capital (Aschauer 1993a), or at least for some of the infrastructure categories (Haughwout 1994)[17]. One potential explanation is that a larger scale analysis reveals spillover effects, which otherwise would remain undetectable. It has to be mentioned here that there are examples of work in which the existence of such spillover effects has been specifically investigated (Mas et al. 1996).

One of the weaknesses of the methods described is that there is no thorough investigation of some of the macroeconomic infrastructure effects. Infrastructure investment as a tool of national or regional policy can make possible the diversification of the economy towards new products or sectors, or areas. Consistency of public

[17] However, Boarnet has argued that "*although much effort has been devoted in arguing whether state or national infrastructure stocks are too large or too small, the most important effects are the local*" (1998, p. 398).

infrastructure investment can act as a counterbalance to political or business cycles. Related to this point is the notion that infrastructure investment can be a channel by which there can be a permanent flow of resources from consumption to investment in countries or regions where the market for capital is underdeveloped or distorted. There is potential, for example, of the use of an extensive public infrastructure programme instead of a stabilisation one; usually the latter is used in order to maintain credibility of the public sector. However, there is always the danger that a stabilisation policy can lead to high unemployment and stagnation. Public infrastructure investment could, potentially, be a more reliable long-term alternative to such policies, as in many cases governments tend to loosen fiscal austerity measures before elections, contrary to public investment policies, which are popular with the electorate. There is also the argument that favours the role of public capital investment as a more efficient Keynesian policy tool in comparison with enhanced traditional public spending of other sorts (for a more extensive analysis of these points see for instance Kessides 1996).

The following tables (2.1 to 2.3) presents a summary of most of the important examples of infrastructure research[18]. The first contains empirical research based on the production function approach, the second, research that has utilised the cost function approach, and the last details other pieces of research. Even a cursory examination of these tables shows that most of the cost function analyses have produced results that support the thesis that public capital investment has a beneficial impact on the private sector of the economy. The results for the other approaches tend to be mixed, even though, it can be argued that there is more evidence for a positive infrastructure impact than the converse.

[18] Appendix V presents additional bibliographical references on infrastructure maintenance, management, privatization, and other related topics.

Table 2.1 Production function approach - Selected Studies

Author	Year	Country	Level of Aggregation	Specification	Results for Public Capital
Aschauer	1989a	USA	National	Cobb-Douglas p.f.	high positive
Aschauer	1989b	International Comparison	Panel of Group of Seven Industr. Countries	Cobb-Douglas p.f.	high positive
Bajo-Rubio et al..	1993	Spain	National	Cobb-Douglas p.f. time series (cointegration)	high positive
Baltagi and Pinnoi	1995	USA	Panel of the 48 states	Cobb-Douglas p.f.	some of G categories (water etc.) positive
Bergman and Sun	1996	USA	Regional	Cobb-Douglas p.f.	distinct effects in regions at different develop. levels
Cutanda and Paricio	1994	Spain	National	quasi-production function	high positive
Eisner	1991	USA	National-Regional (States)	Cobb-Douglas p.f. Time series-Cross Section	positive
Evans and Karras	1994	USA	National	Cobb-Douglas p.f. (differenciated) Panel data	negative productivity of public capital (except education)
Evans and Karras	1994	International Comparison	Panel of 7 OECD countries	Cobb-Douglas p.f. (differenciated) Panel data	no evidence that public capital is productive
Ford and Poret	1991	International Comparison	Comparison of 11 OECD countries	Cobb-Douglas p.f. (differenciated) Time Series	ambiguous findings
Garcia-Mila and McGuire	1988	USA	National-Regional (States)	Cobb-Douglas p.f. Time series-Cross Section	positive
Garcia-Mila, et al.	1996	USA	National	Cobb-Douglas p.f. (differenciated) Panel data	not significant
Holtz-Eakin	1992	USA	National-Regional	Cobb-Douglas p.f. Panel data	almost zero
Hulten and Schwab	1991	USA	Regional	Cobb-Douglas p.f. (differenciated) Time Series	does not generate externalities
Kelejian and Robinson	1994	USA	National	Cobb-Douglas p.f. Time series-Cross Section	does not play a role in private sector's productivity
Kelejian and Robinson	1997	USA	Panel comprised by USA states	Cobb-Douglas p.f. Panel data	results sensitive to specification regional G involves spillovers
Mas, et al.	1996	Spain	National-Regional	Cobb-Douglas p.f. Panel data analysis	positive
Mera	1973	Japan	Regional	Cobb-Douglas p.f. Panel data analysis	high positive
Miyawaki and Tobita	1992	Japan	National	Cobb-Douglas p.f.	high positive
Munnell	1990a	USA	National	Cobb-Douglas p.f.	high positive
Munnell	1990b	USA	Regional	Cobb-Douglas p.f. Time series-Cross section	significant positive
Ohkawara and Yamano[a]	1997	Japan	Regional/National	Cobb-Douglas p.f. Simulation of reg allocations	significant positive in the production function
Rrud'homme	1996	France	Regional/National	Cobb-Douglas p.f.	significant positive
Ratner	1983	USA	National	Cobb-Douglas p.f.	small positive
Rovolis and Spence	1998	Greece	Regional/National (Panel data analysis)	Cobb-Douglas p.f.	significant positive
Segoura & Christodoul.	1997	Greece	National (Time series)	Cobb-Douglas p.f.	significant positive
Sturm and deHaan	1995	USA Netherlands	National	Cobb-Douglas p.f. First differenced	does not play a role (both in USA and the Netherlands)
Tatom	1991	USA	National (Business sector)	Cobb-Douglas pf. (differenciated)	Insignificant
Toen-Gout & Jongeling	1993	Netherlands	National	Cobb-Douglas p.f.	significant positive

G = infrastructure
p.f. = production function
[a] See there for the results of other research teams

Table 2.2 Cost (and profit) function approach - Selected Studies

Author	Year	Country	Level of Aggregation	Specification	Results for Public Capital
Berndt and Hansson	1991	Sweden	National	Variable Cost function	increases in private capital reduce private costs
Conrad and Seitz	1994	Germany	National	Cost function	public capital contributes to total factor productivity
Lynde	1992	USA	National	Profit rate function	Increasing G may help to restore profit rate and increase output
Lynde and Ricnmond	1992	USA	National	Cost function (translog)	high positive
Lynde and Ricnmond	1993	USA	National	Profit function (translog)	G is an important part of production process
Lynde and Ricnmond	1993	United Kingdom	National	Cost function (translog)	high positive
Morrison & Schwartz	1992	USA	Regional	Variable Cost function	public capital augments productivity growth
Morrison & Schwartz	1996	USA	Regional (New England manufacturing sector)	Variable Cost function	G has cost-saving benefits (in the short-run)
Nadiri and Mamuneas	1991	USA	Manufacturing (12 2-digit Industries)	Translog Cost function	significant productive effects
Seitz	1993	Germany	National (Public roads)	Leontief Generalized c.f. Panel data analysis	K & G complementary L & G substitutes
Seitz	1994	Germany	National (Core public capital)	Leontief Generalized c.f. Panel data analysis	K & G complementary L & G substitutes
Seitz and Light	1995	Germany	Regional	Translog Cost function Panel data analysis	strongly encourages private invest. & reg. competitiveness
Shah	1992	Mexico	Manufacturing (23 3-digit Industries)	Translog Cost function Restricted Equilibrium appr.	small positive multiplier effect on output

c.f. = cost function
K = private capital, L = labour, G = public capital

Table 2.3 Other approaches for infrastructure research - Selected Studies

Author	Year	Country	Level of Aggregation	Specification	Results for Public Capital*
Duffy-Deno and Eberts	1991	USA	Regional (28 standard metropolitan statis. areas)	Simultaneous equations system	significant positive
Eberts	1991	USA	Regional (40 standard metropolitan statis. areas)	Correlation and Regression analysis	positive
Eberts and Fogarty	1987	USA	Urban areas	Correlation and Regression analysis	positive
Elhance and Lakshmanan	1988	India	National-Regional (6 States)	Multiequation model	-
Erenburg	1993	USA	Nationale	Rational expectations model	positive significant relationhip between priv.& public investm.
Flores, Gracia and Pérez	1998	Spain	National	Structural (VARMA) approach	positive long-term effects of public capital on private sector variables
Holtz-Eakin and Lovely	1996	USA	National	General equilibrium model	affecting manufacturing productivity via indirect channels
Holtz-Eakin and Schwartz	1994	USA	National	Neoclassical growth model	negligible impact on annual productivity growth
Neill	1996	USA	National	Neoclassical Growth Model	An increase of public capital should lead to an output increase

*Where there is a direct estimation

Chapter 3

The Evolution of the Public Investment Programme in Greece: 1976-1992

3.1 Introduction

The first step for the assessment of the role of public infrastructure in national and regional economic development is to compile the relevant data, preferably at the lowest possible spatial level. The powerful role that the central state has played in Greek economic life has been an advantage for the completion of this task, as the great bulk of infrastructure capital has been centrally invested. The data for the regional breakdown of the state's Public Investment Programme (PIPR) have provided the opportunity to have an analytical dimension for the role of such investment at the prefectural (*nomos*) level.

This chapter provides a detailed analysis of the PIPR. Section 3.2 outlines a general description of the PIPR, and section 3.3 presents the historical and legal framework under which it was created and developed. Section 3.4 examines the basic categories of infrastructure that constitute the PIPR investment expenditure, as well as those aggregate categories that will be used in the subsequent chapters for the empirical analysis. This section has a sub-component in which the PIPR is compared to other macroeconomic variables. The regional distribution of public infrastructure investment has also been analysed with a particular emphasis on the regional inequalities of this distribution. Section 3.5 contains a brief discussion of the method that has been followed for the construction of the public capital stocks, which are again used subsequently in the analytical phases of the study. The final part summarises the PIPR presentation.

It has to be noted that there are some aspects of the PIPR which have not been analysed here, mainly due to space limitations. Questions concerning the finance dimension of the PIPR, and especially its relation to public borrowing and EU (former

EEC) funding, are of great importance generally within Greece. The interested reader can find an exhaustive analysis in Psyharis (1990).

3.2 The PIPR as an estimate of the Public Capital in Greece

There are several empirical ways through which it is possible to investigate the relationship between infrastructure and regional development. In this research, the PIPR has been used as the basic source of information on the public infrastructure capacity in Greece and its regions. This programme was, and still is, the main channel by which the state is investing in the public infrastructure.

Empirical estimation of public investment in infrastructure has long been problematic and a number of difficulties usually have to be overcome. For instance, the estimation of infrastructure investment in terms of physical capacity (roads, airports, ports, etc.) has the inherent difficulty of an adequate description of the qualitative features of the infrastructure stock. There are several methods for the estimation of these qualitative parameters, for example weighting the length of a highway by the number of lanes. However, here it was decided to use actual investment flows and these can be calibrated using the PIPR expenditure. This is the *monetary* approach of measurement of public capital, which has been the dominant method in recent examples of infrastructure research (for a more extensive presentation of the physical and monetary approach, as well as a hybrid method, see chapter 2, section 2.2.2). Its major advantage is that it makes inter-temporal and inter-regional comparisons possible, with care.

The use of the PIPR as an estimate of the public infrastructure capacity, nevertheless, is not unproblematic. Using the PIPR exclusively, the level of the actual investment is underestimated because in Greece there are some alternative sources of public investment. Their contribution to the public capital formation is not captured by the exclusive use of the PIPR. These alternative sources of infrastructure investment are via the Public Companies and Corporations (DEKO) and Local Governments (OTA)[1]. Table 3.1 gives an estimation of the percentage of each source of Gross Investment in Fixed Capital during the period 1976-1987:

[1] There is a complex relationship between PIPR and DEKO. Indeed part of DEKO's investment has been financed by the PIPR. For an extensive analysis of the subject, see Psyharis (1990), Part II, Chapter 2.

Table 3.1 Source of gross investment in fixed capital in Greece, 1976-1987

(in percentages)

Year	PIPR	DEKO (Public Enterprises)	OTA (Local Government)
1976	60.36	33.88	5.76
1977	59.95	31.41	8.65
1978	51.05	41.43	7.51
1979	44.75	48.60	6.65
1980	34.10	59.49	6.41
1981	39.29	52.54	8.17
1982	33.78	57.88	8.34
1983	37.41	53.33	9.26
1984	40.59	48.72	10.69
1985	38.79	51.01	10.20
1986	42.59	46.81	10.60
1987	43.34	47.10	9.56

Source: Psyharis 1990

This underestimation will inevitably subsequently lead to the underestimation of the magnitude of the actual infrastructure stock and its effects on regional productivity.

However, there is a rationale justifying the exclusive use of the PIPR. Even though the magnitude of the investment of public companies and enterprises is substantial, there are several reasons why it makes sense not to take it into account. First, in other countries most of these companies belong to the private sector - water or electric power companies for example in the United States, telecommunication companies in the United Kingdom, etc. In Greece, however, they are owned by the public sector for various economic and historical reasons[2]. Their inclusion would make the comparison with similar research carried out in other countries difficult. Secondly, these companies have their own agenda for investment, especially in terms of the spatial distribution of investment projects, dictated by the particular aims of the company. For instance, DEH (Public Company for Electricity) and OTE (Greek Telecommunication Enterprise) have on many occasions invested in a specific prefecture or region, because of the existence of raw materials. More specifically it is the case that DEH allocates much of its investment to regions with lignite deposits.

[2] In Greece, it has been the responsibility of the public sector to accomplish the necessary investment projects in telecommunications, electric power, or water supply. The main reason for this has been that the private sector would be unable to manage and undertake such public works, simply given its small size in comparison with the sector elsewhere. Concurrently, constant international difficulties with neighboring countries made it necessary (for reasons of national safety) for the control of telecommunications and electric power to remain in the hands of the public sector.

More generally, while investigating the role of public capital in regional development, there is always the problem of spreading the benefits of an infrastructure investment located specifically in one region over other regions which receive the resultant service. This problem would be magnified if public companies were included in the calculations. It is in the nature of a public telecommunications or an electricity company, for example, to produce their goods in a specific location and distribute them in other regions. In Greece the public companies that produce electric power, utilise oil deposits, exploit the railway services or mail services, as well as telecommunications, operate on a national scale only and have no regional public or private competitors. In order to estimate the regional effects of such infrastructure investment, it would be necessary to use proxies, for example the number of telephone lines in a region. This would have made for extreme difficulties in making these data compatible with those of the PIPR.

The case of the OTA (Local Governments) infrastructure investment is different. They invest in many of the PIPR categories. However, the data for their investments are simply not available. Instead, what is available are figures relating to the central government aid[3] to the local state for their investment projects (since this aid is given via the PIPR) and especially the prefectural expenditures (a more extensive analysis of this category will follow shortly).

Another problem arising from the use of PIPR is that not all amounts included represent real investment projects. Some PIPR categories reflect operational costs, or other costs, such as interest to be paid, as the public sector has been sometimes forced to borrow money in order to finance the PIPR. Nevertheless, as the PIPR is divided into categories of expenditure, it has been possible to exclude the amounts that do not represent real investment in infrastructure (as will be demonstrated later in this chapter).

[3] For a more extensive analysis, see Greek Company for the Local Development and Government (1989), chapter 4. It must be emphasised that the works financed and completed solely by local government in Greece are limited to the development of common spaces, construction of sports centers, building infrastructure for the needs of local government, etc.

3.3 The Origins of the Public Investment Programme

3.3.1 The historical background of public capital in Greece

The Greek public sector became the dominant actor in the economic life of the new state shortly after the war of independence against the Ottoman rule. For whatever the reasons[4], the fact remains that during the nineteenth century the Greek public sector expanded significantly, as table 3.2 indicates.

Even though the public sector was relatively large, public works and infrastructure investment was not a high priority in this early economic history of the modern state. According to Svoronos (1972) there were only 450 kilometres of public roads until 1864, and the remaining public works were insignificant (cited in Tsoukalas 1989, p. 65). In 1864, 853 kilometres of roads were added to the existing road system, as the Ionian Islands were annexed to Greece[5]. Subsequently, the policy implemented by the Prime Minister Trikoupis, who considered the construction of the necessary infrastructure as a prerequisite for the economic development of Greece, resulted in 2750 kilometres of roads, a railway network, various ports, and the Korinthian canal being added.

Table 3.2 Public expenditure per capita in selected nations

(in golden francs)

	1830	1840	1850	1870	1881
Great Britain	57.5	50	50	56.2	58.7
France	31.2	42.5	43.7	62.5	85
Germany	15	18.7	21.2	31.2	50
Russia	11.2	12.5	16.2	23.7	25
Italy	18.7	25	38.7	42.5	50
Sweden	12.5	12.5	12.5	21.2	27.5
Spain	20	22.5	25	50	50
USA	5	7.5	8.7	37.5	26.2
Portugal	13.7	21.2	25	30	45
Belgium	22.5	31.2	33.7	35	52.5
Greece	25	25	25	42.5	56.2

Source: Mulhall (1886), cited in Tsoukalas (1989) p.45

[4] See Tsoukalas (1989).

[5] The road network of these islands was constructed by the British.

The first half of the twentieth century was characterised by the (successful) efforts of the Greek state to expand its borders to Macedonia, and less successfully to Minor Asia. During this period, the national objective was to absorb the great influx of Greek refugees from Minor Asia after 1922, and to create the necessary industrial and social infrastructure at the same time. During the Second World War the public infrastructure stock was severely damaged. It can be argued, then, for most contemporary economic analytical purposes that the real history of the existing stock of public capital in Greece begins after 1950.

3.3.2 The creation of the Public Investment Programme

By the end of the war the network of roads was extremely restricted. Most of the roads and bridges were destroyed by the German army during its retreat from Greece. Ports and railways were only partially in operation, and only two or three of the major Greek cities had a water and sewerage network. The first attempt to build anew the infrastructure capacity was the Programme for the Reconstruction of Greek Economy, initiated in 1947. This programme was implemented by several ministries, but it was set up by the ministry of Co-ordination (Decree 1125/1949 and Law 2540/1950).

The Public Investment Programme (PIPR) itself commenced in 1952, regulated under the Law 2212/1952. In 1954, the Decree 2957 awarded the responsibility for the implementation of this programme to the Ministry of Co-ordination[6] (which in contemporary times has been renamed as the Ministry of National Economy). This Decree made clear five crucial points for the subsequent history of PIPR. First, the terms under which public works are included in the PIPR were determined. Second, the way by which the total budget for the PIPR is assessed was clarified. Third, the expenditure on those public works requiring more than one fiscal year's finance was reallocated into successive fiscal years. Fourth, special programmes were set up for a) alterations and extensions to already approved works, which were not possible to be included in the initial budget, and b) minor public works. The fifth, and probably the most important

[6] For a more extensive analysis of the legal framework, and especially of the changes with regard to ministerial responsibility, see: Greek Company for the Local Development and Government (1989): *Local Government and the Programme of Public Investment.*

point, was an operational definition of public investment. This definition is of great importance as it still regulates whether a project will be classified as a public investment or not. According to this definition, a public investment is considered to be a public expenditure of the Greek state, or of the public enterprises[7], or the local state in the following cases: (i) permanent or semi-permanent constructions (buildings are included in this category); (ii) capital assets and machinery procurements as long as they are needed for the previous category; (iii) research expenditures concerning the previous categories. The Decrees 120 and 498/1960, and 4355/1964 introduced further modifications, especially with regard to ministerial responsibilities.

The Law 1235/1982 significantly changed the legal framework of the PIPR and shaped its present form. The current formulation of the annual budget for public investment is, in brief, as follows: each year the Ministry of National Economy sends instructions to every responsible agent (government ministries, prefectures, and local governments) for the proposals of potential works which will be financed by the PIPR during the following fiscal year. The Ministry of National Economy also assesses the maximum limit for the finance of each particular agent. These bodies gather data and develop a budget for their potential works. The next step is to send the proposals to the Divisions of Public Investment in the Ministry of National Economy where a draft of the PIPR is drawn up (they sketch a general proposal for every particular Ministry). The draft is next sent to the General Accounts Office, which is responsible for the formation of the details of PIPR. The Budget Division of the General Accounts Office will form these details and forward individual budgets to each agent.

The annual PIPR is determined and approved by special ministerial decisions called Collective Decisions (*Syllogikes Apofases*). They are classified into four general categories: i) *Collective Decisions for Works* (SAE). This category includes constructions, procurements, and special programmes, ii) *Collective Decisions for Research* (SAM). These include the expenditure for the necessary research for the works of the PIPR, iii) *Collective Decisions for Prefectural Funds* (SANT). These are the decisions for the works, research, and other expenditure at the prefectural level - meaning that there is a specific SANT for every particular nomos in Greece, iv) *Collective Decisions for*

[7] Such as OTE, DEH, ELTA, EYDAP, etc.

Administrative Expenditure (SAD). This final category involves approvals for administrative expenditure in regard to the implementation of the PIPR. The decisions of this category also need the approval of the Minister of Finance.

Collective Decisions are also divided into different PIPR sub-sectors (a detailed analysis will follow). For instance, there are several Collective Decisions for ports, roads, civil aviation etc., under the heading Transportation. The number of Collective Decisions varies every year depending on the division of sectors but the average is approximately two hundred Collective Decisions per year. Each Decision always embodies similar works, and research and administrative expenditure of the same Ministry.

3.4 The Public Investment Programme in aggregate

3.4.1 The basic categories of the Public Investment Programme

Three different breakdowns of the PIPR data are available from the Ministry of National Economy in Greece. The first presents investment expenditure in a particular year for every ministry in each prefecture. In the second, each project is classified under the respective ministry. The problem with this breakdown, unfortunately, is that it does not have a spatial dimension. The third is the one selected for use in this research that supplies the investment expenditure for every investment category in every prefecture in every region of Greece. This breakdown was chosen because all investments are classified under an investment category or sector (that is the particular type of infrastructure) and there are detailed data for every single prefecture in Greece.

The data that will be used in the present analysis cover the period from 1976 to 1992. A matrix of statistics has been created for every year. In this matrix each row shows investment expenditure per prefecture (*nomos*), while columns show investment expenditure per infrastructure category.

The prefecture vector contains all Greek prefectures with the exception of the semi-autonomous region of Agion Oros (*Holly Mountain*), inhabited only by monks, but with the addition of some extra categories. Each prefecture is assessed together with other neighbouring prefectures forming a region. However, this taxonomy does not correspond to the nine official regions in use until 1988, nor to the new thirteen official regions formed in 1988 (which are still in use). As table 3.3 shows, there are nine 'real' regions in use in the PIPR (in the sense that they correspond to a geographical area) and one 'account' region (category 'Rest' in table 3.3) that includes expenditures for investment that cannot be classified to a single region. In this latter category, investment projects, which have not been materialised in a specific spatial unit, have been grouped together.

Table 3.3 Spatial units in use in the Public Investment Programme of Greece

Sterea	**Ionian Islands**	**Macedonia**	**Aegean Islands**
More than one Pref.	More than one Pref.	More than one Pref.	More than one Pref.
Aitoloakarnania	Zakynthos	Drama	Dodecanissos
Attica	Kerkyra	Imathia	Kyclades
Viotia	Kephalonia	Thessaloniki	Lesvos
Evia	Lefkada	Kavala	Samos
Evritania		Kastoria	Chios
Fthiotis	**Epirus**	Kilkis	
Fokida	More than one Pref.	Kozani	**Crete**
Athens	Arta	Pella	More than one Pref.
East Attika	Thesprotia	Pieria	Iraklio
West Attika	Ioannina	Serres	Lasithi
Piraeus	Preveza	Florina	Rethimno
		Halkidiki	Chania
Peloponnese	**Thessaly**	Grevena	
More than one Pref.	More than one Pref.		**Rest**
Argolida	Karditsa	**Thrace**	Other
Arcadia	Larissa	More than one Pref.	More than one Region
Achaia	Magnisia	Evros	Whole Greece
Ilia	Trikala	Xanthi	Abroad
Korinthia		Rodopi	
Laconia			
Messinia			

Source: Ministry of National Economy

The Rest category is constituted of four sub-categories: a) 'Other' - where projects that cannot be classified under any other category have been included. b) 'More than one Region' - which includes projects which have been materialised as the name would indicate, and in this way they cannot be classified under the inter-prefectural category in each region. c) 'Whole Greece' - which covers investment projects planned for the entire country. However, a large part of the PIPR expenditure classified under this heading does not constitute real investment activity, but is much more concerned with the operational costs of the programme. For example, the 'Miscellaneous' and 'Administrative' sub-categories of the PIPR, which are accounting categories and not true physical investment (see following section), cover the great bulk of the Whole Greece category. d) 'Abroad' - which deals with the financing of the construction, purchase, etc., of buildings, machinery, and materials for Greek embassies, consulates and Greek schools abroad. There is also an additional 'account' entry – 'More than one Prefecture' - in every region, in which investment programmes are materialised in that particular region and in more than one prefecture are classified.

The different categories of infrastructure investment are shown in Table 3.4 and Table 3.5. After 1981 some categories have been merged into broader categories (for example Forest and Fishery to Forest/Fishery, and Roads-Bridges, Ports, Civil Aviation, Urban Transportation, Athens Works all to Transportation). For the purpose of this research, infrastructure categories for the period 1976-1980 have been added together in order to correspond with the broader categories of the period 1981-1992[8]. Thus, inter-temporal comparisons (between the two periods) are made possible. There was, however, an additional reason for which the pre-1981 categories should correspond to those of the second period, and that is the need to estimate the public capital stocks, the construction of which are considered later in this chapter.

Monetary values for all the data available have been deflated using the GDP (Gross Domestic Product) deflators. There existed the alternative possibility of using different deflators for every single category of infrastructure investment. In this way, however, the deflators would have been estimated arbitrarily, as in many cases the composition of every category is not absolutely clear. For instance, in transportation, it is not always possible to estimate what was the percentage of materials used for the construction of a highway, especially at the regional level. It was decided that the use of the aggregate GDP deflators formed a good approximation, as the differences between the particular deflators for every single category would be at the third or fourth decimal level. The deflators of GDP (and generally most of the deflators in use by the ESYE National Statistical Service of Greece), have taken 1970 as the base year (which is also the base year for the deflation of the Public Investment Programme data).

[8] For a detailed description of the how the 1976-1980 categories have been added to correspond to those of the subsequent period 1981-1992, see Appendix II.

Table 3.4 Investment categories of the Public Investment Programme of Greece, 1976-1980

Agriculture	Rest Education
Forest	Housing
Fishery	Health
Irrigation Programme Ministry of Agriculture	Welfare
Irrigation Programme Ministry of Public Works	Water/Sewage
Mines etc.	Public Administration
Industry/Energy/Handicraft	Technical Co-operation
Roads-Bridges	Research Institutions
Ports	Greek Committee Atomic Energy
Aviation (Civil)	Prefectural works
Urban Transportation	Borderline Programmes
Athens Works	Special Programme for Evros Prefecture
Railways	Miscellaneous
Tourism	Special Works
Museums	Administrative Expenditures
Higher Education	Special works Athens/Thessaloniki
School Buildings	Prefectural Programmes

Table 3.5 Investment categories of the Public Investment Programme of Greece, 1981-1992

Agriculture	Public Administration
Forest/Fishery	Research and Technology
Irrigation	Prefectural works
Industry/Energy/Handicraft	Miscellaneous
Transportation	Special works Athens/Thessaloniki
Railways	Administrative Expenditures
Tourism/Museums/Monuments	Special Works
Education	Prefectural Programmes
Housing	Prefectural Programme financed by the MIP*
Health/Welfare	OTA(Local Government) Programmes
Water/Sewage	

*Mediterranean Integrated Programmes

3.4.2 Temporal evolution of the PIPR and its aggregate categories

The subsequent three chapters present the empirical analysis based on the infrastructure data of PIPR. However, it could never be possible to use all the aforementioned categories due to the space limitations that the thesis necessarily has to work to. Thus, it was deemed necessary to impose a meaningful aggregation of all of these categories. The most obvious, and frequently used, classification in empirical research on public capital is the one based on whether an infrastructure category aims to facilitate directly production activities or to satisfy social needs. Hence, the sub-categories presented in table 3.5 have been classified under three major headings. The first is productive infrastructure, which consists of the categories of Agriculture, Forestry and Fishery, Industry, Energy and Handicrafts, Irrigation, Research and Technology, Special Works (plus those of Athens/Thessaloniki), Transportation (plus those for Railways), Water/Sewage Works, and Prefectural Works/Programmes[9]. The second is social infrastructure which includes Education, Health and Welfare, Housing, Public Administration, and Tourism sub-categories. Finally, there are Miscellaneous and Administrative Expenditures sub-categories that refer to the operational expenditures of the PIPR. It has to be stressed that in the subsequent analysis total infrastructure investment (denoted by *G*) is the sum of productive and social infrastructures (denoted by *P(G)* and *S(G)* respectively). This means that the Miscellaneous and Administrative Expenditures sub-categories have been subtracted from the total PIPR expenditures in order to have the 'real' investment, purged of accounting expenditures. The evolution over time of these categories is presented in tables 3.6 and 3.7. To repeat, all data have been deflated using 1970 as base.

Table 3.6 shows that the total PIPR expenditure fell between 1977 and 1983 from its 1976 level. This tendency was reversed during the eighties as the total PIPR expenditure regained the 1976 level. It can be argued that the PIPR has been a reliable source of investment when compared to the significant decline of private investment during the eighties (discussed later). Regarding the composition of the PIPR, it is obvious from table 3.7 that real infrastructure investment (*G*) and especially the productive categories (column 4) dropped during the early eighties only to increase significantly after 1983. The exact opposite was the case in the trend for Miscellaneous and Administrative Expenditures categories (the non-investment operational part of PIPR). From an 11 percent share of the overall Programme budget in 1976, it peaked at 31 in 1982, only to fall back to 5 percent by 1992).

[9] This category includes the Border (mainly in the Evros prefecture) Programmes.

Table 3.6 Evolution of public investment in Greece, 1976-1992

(1976 as base year; constant prices)

Year	PIPR (3+4+5)	G (4+5)	Misc. and Adm. Exp.	P(G) (Productive)	S(G) (Social)
	(1)	(2)	(3)	(4)	(5)
1976	100	100	100	100	100
1977	88	86	103	88	80
1978	86	84	102	83	86
1979	90	75	206	75	76
1980	75	66	147	70	54
1981	91	67	283	70	59
1982	93	72	261	76	61
1983	107	88	262	98	60
1984	115	101	228	111	73
1985	120	106	232	116	78
1986	108	100	170	113	67
1987	98	93	135	104	64
1988	99	96	117	107	68
1989	99	104	61	116	71
1990	94	95	81	109	58
1991	102	107	61	123	61
1992	110	118	49	132	78

Source of original data: Ministry of National Economy

Table 3.7 Composition of public investment in Greece, 1976-1992

(1976 as base year; constant prices)

Year	PIPR (3+4+5)	G (4+5)	Misc. and Adm. Exp.	P(G) (Productive)	S(G) (Social)
	(1)	(2)	(3)	(4)	(5)
1976	100	89	11	65	24
1977	100	87	13	65	22
1978	100	87	13	63	24
1979	100	75	25	55	20
1980	100	79	21	61	18
1981	100	66	34	51	16
1982	100	69	31	53	16
1983	100	73	27	60	14
1984	100	78	22	63	15
1985	100	79	21	63	16
1986	100	83	17	68	15
1987	100	85	15	69	16
1988	100	87	13	71	16
1989	100	93	7	76	17
1990	100	91	9	76	15
1991	100	93	7	79	14
1992	100	95	5	78	17

Source of original data: Ministry of National Economy

3.4.3 The PIPR compared to other macroeconomic indicators

It is interesting to examine the relationship of the PIPR to two other macroeconomic variables in Greece, the Gross Domestic Product (GDP) and the private fixed asset formation. Table 3.8 gives the total PIPR expenditure (both investment and administrative-operational expenditures) as a percentage of GDP. It is evident from these data that the PIPR fluctuated between 3.576 percent of GDP in 1980 (minimum) to 5.560 in 1976 (maximum). The fluctuation may, at first glance, seem not to have a discernible pattern. However, it could be the case that the years 1981 and 1990, being election years of great importance, are an indication that the fluctuation is the result of the political business cycle[10]. It is possible that Greek governments in years just before elections decide to decrease levels of public investment, which of course are likely to stimulate results in the long run, in favour of more general public spending having an immediate return. This is a point that probably begs further future research in the field of government.

Table 3.8 Basic infrastructure categories as percentage[+] of GDP in Greece

YEAR	PIPR	Productive	Social
1976	5.560	3.617	1.339
1977	4.745	3.105	1.038
1978	4.345	2.730	1.049
1979	4.391	2.403	0.892
1980	3.576	2.184	0.627
1981	4.352	2.198	0.677
1982	4.405	2.348	0.704
1983	5.053	3.015	0.686
1984	5.288	3.332	0.814
1985	5.333	3.367	0.842
1986	4.726	3.210	0.709
1987	4.306	2.985	0.676
1988	4.140	2.923	0.683
1989	4.018	3.052	0.696
1990	3.838	2.910	0.568
1991	4.038	3.192	0.582
1992	4.298	3.359	0.732

[+]The percentage is based on deflated (1970) prices
Source of original data: National Statistical Service of Greece

[10] For the concept of political business (or trade) cycles, see Lipsey (1989) or Mankiw (1998).

Table 3.8 also presents details of investment in Productive and Social public capital respectively (note that the Productive and Social percentages do not add to the total PIPR percentage, the difference being the percentage of Miscellaneous and Administrative expenditures). The share of the Productive category as a percentage of GDP has followed, as might be expected, the fluctuations of the total PIPR spending. In the early eighties, it showed its lowest levels, falling in 1980 to its minimum (2.184 percent). For the remainder of the period, it has oscillated around three percent. The picture for the Social category is, however, different. Social infrastructure as a percentage of GDP was around one during the seventies, and this fell to an average of around seven tenths of a percent for the period 1980-1992.

As far as public infrastructure as a percentage of the total fixed asset formation is concerned, table 3.9 gives the relative temporal changes. The National Statistical Service of Greece (NSSG) classifies as 'total fixed asset formation' the sum of 'asset formation in dwellings, other buildings constructions and works, transport and other types of equipment' (as described in the statistical yearbooks of the NSSG).

Table 3.9 Basic infrastructure categories as percentage+ of total fixed asset formation in Greece

YEAR	PIPR	Productive	Social
1976	25.127	16.347	6.049
1977	20.483	13.403	4.479
1978	18.830	11.832	4.548
1979	18.125	9.918	3.680
1980	16.107	9.836	2.826
1981	21.177	10.695	3.293
1982	22.045	11.751	3.523
1983	25.724	15.348	3.493
1984	29.365	18.505	4.518
1985	29.101	18.374	4.595
1986	27.979	19.002	4.198
1987	26.721	18.525	4.195
1988	24.745	17.469	4.083
1989	22.630	17.191	3.923
1990	19.510	14.792	2.888
1991	22.193	17.546	3.201
1992	23.702	18.521	4.036

+The percentage is based on deflated (1970) prices
Source of original data: National Statistical Service of Greece

The PIPR investment as percentage of the total fixed asset formation dropped in the late seventies from around 25 percent in 1976 fell to about 13 in 1980. However, in the following years, it has recovered reaching its highest value in 1984 (29.365 percent). It has since never again fallen below twenty percent (with the single exception of 1990 when it dipped to 19.510 percent). The trends for the Productive and Social categories of the PIPR are similar. It is notable, in terms of a low point, that in 1980 the Productive and Social percentages were just 9.836 and 2.826 (respectively) of the total fixed asset formation in Greece.

3.4.4 Temporal evolution of the basic PIPR categories

Even though the basic categories of the PIPR have not been used in the subsequent analysis, save for those aggregated as Productive and Social infrastructure (and the Miscellaneous and Administrative Expenditure) classifications, it is useful here, by way of context, to give a brief description of the evolution of such spending (table 3.10).

Five categories consistently seem to account for the lion's share of the spending at around ten percent or more. These are Prefectural Works (19.05 percent on average), Miscellaneous (15.77 percent on average, and if the Administrative Expenditures are added this reaches 16.9 percent on average), Transportation (14.58 percent on average), Industry-Energy-Handicraft (11.62 percent on average), and Education (9.17 percent on average).

The temporal evolution for the Administrative and Miscellaneous Expenditures has already been presented (as a sum). Agriculture has had a rather erratic spending history. The Border Programme was a scheme that stopped by 1980 (targeted to develop the border prefectures and especially Evros). The investment in Educational infrastructure has declined slowly, from a share of around 15 percent in the seventies, to almost the half this amount for the eighties. Forestry and Fishery is one of the categories that retains almost the same share for the whole of the period. Health and Welfare has increased modestly its share from 1.5 percent in the seventies to almost 4 in the eighties. Housing infrastructure investment has remained stable with an average 1.15 percent.

Table 3.10 The evolution of public capital spending in Greece by categories, 1976-1992

Constant 1970 prices

Years	Administ. Expend iture	Agriculture	Borderline Program.*	Education	Forest-Fishery	Health-Welfare
1976	0.87	3.77	1.26	14.33	1.86	1.57
1977	1.14	2.30	0.96	13.82	2.12	1.61
1978	1.32	10.01	1.27	15.39	2.86	1.90
1979	1.64	3.78	1.12	12.89	1.79	1.91
1980	1.42	3.33	1.75	10.22	1.88	2.04
1981	1.36	1.84	0.00	8.17	1.67	3.22
1982	2.16	1.87	0.00	8.73	1.59	2.14
1983	2.47	0.98	0.00	6.65	2.33	2.56
1984	2.33	0.99	0.00	8.23	2.70	2.93
1985	2.10	1.01	0.00	6.69	2.95	4.07
1986	0.47	0.68	0.00	7.08	2.16	3.98
1987	0.43	0.85	0.00	7.98	2.30	4.10
1988	0.35	1.04	0.00	8.52	2.29	4.10
1989	0.38	2.90	0.00	8.12	2.48	3.08
1990	0.42	0.74	0.00	7.03	2.02	2.55
1991	0.16	1.01	0.00	7.35	2.31	2.80
1992	0.06	1.22	0.00	7.59	2.66	3.66
Average	**1.13**	**2.13**	**0.33**	**9.17**	**2.26**	**2.90**

*For the composition of this category see Appendix II
Source of Original Data: Ministry of National Economy

One of the categories illustrating interesting changes in its percentage share is that of Industry, Energy, and Handicraft. Up until mid eighties (1985) its share was around 6 percent. In 1986, however, it was launched to 15.67, to reach 22.97 by 1989. In the early nineties this has now dropped to around 15 percent. Thus, the Industry, Energy, and Handicraft category has become over the years one of the most significant components of (aggregate) Productive public capital spending. In contrast, Irrigation's role in public investment has been diminished over the years, from a high 11.54 percent in 1976, to a low of 3.72 in 1988 (there was a small recovery of the percentage of this category reaching 6.75 by 1992).

Table 3.10 The evolution of public capital spending in Greece by categories, 1976-1992 (Continued)

Constant 1970 prices

Years	Housing	Industry-Energy-Handicraft	Irrigation	Miscellaneous*	Prefectural Works*	Public Administration
1976	1.19	5.32	11.54	10.00	9.69	1.89
1977	1.25	6.52	10.26	11.56	8.17	1.48
1978	1.09	4.77	8.76	11.69	7.85	1.55
1979	1.86	5.57	7.76	23.33	9.91	1.08
1980	0.96	7.67	8.75	19.96	13.12	1.22
1981	0.80	4.83	5.13	32.59	15.15	1.00
1982	1.80	4.70	6.69	28.55	15.47	1.09
1983	1.24	6.96	5.22	24.29	23.88	1.23
1984	1.29	8.83	3.99	19.27	25.71	1.14
1985	1.44	7.42	4.66	18.98	26.64	1.36
1986	1.17	15.67	4.81	16.61	25.11	1.01
1987	1.03	22.22	3.99	14.54	19.59	0.84
1988	0.98	19.15	3.72	12.55	20.23	0.69
1989	1.59	22.97	4.60	6.32	21.88	0.63
1990	0.70	22.82	4.55	8.96	21.12	0.47
1991	0.75	15.58	4.88	6.36	24.43	0.35
1992	0.45	14.23	6.75	4.78	26.10	1.06
Average	**1.15**	**11.62**	**6.11**	**15.77**	**19.05**	**1.06**

*For the composition of these categories see Appendix II

Source of Original Data: Ministry of National Economy

The Prefectural Works category, which incorporates the 'Prefectural Programmes', 'Prefectural Works', 'Prefectural MOP' and 'OTA Programmes' sub-categories, is one of the most important components of the PIPR. As argued earlier in this section, it is clearly the largest category of public capital spending. It is also important, however, from another point of view. The decisions for the actual investment projects that can be materialised for this category are not taken directly by the central state, as is the case for the other categories of PIPR, but instead are decided at prefectural level, after consultation with local governments[11]. As it is evident from table 3.10 the percentage of the Prefectural Works component has increased significantly during the eighties, and especially after 1982[12].

[11] For an analysis of this point, see Psyharis (1990).

[12] This is the starting year of the Socialist administration.

Table 3.10 The evolution of public capital spending in Greece by categories, 1976-1992 (Continued)

Constant 1970 prices

Years	Research & Technology	Special Works*	Tourism-Museums-Monuments	Transportation*	Water-Sewage	PIPR (Total)
1976	0.07	0.00	5.10	23.83	7.70	**100**
1977	0.09	0.00	3.72	27.53	7.49	**100**
1978	0.11	0.00	4.22	18.59	8.62	**100**
1979	0.45	0.00	2.56	16.24	8.11	**100**
1980	4.43	3.57	3.10	13.94	2.63	**100**
1981	3.93	6.75	2.35	10.21	1.01	**100**
1982	2.91	6.35	2.22	11.65	2.08	**100**
1983	2.32	4.53	1.91	11.20	2.25	**100**
1984	2.60	4.42	1.80	10.47	3.29	**100**
1985	2.10	3.28	2.22	12.18	2.90	**100**
1986	2.62	3.31	1.76	10.55	3.01	**100**
1987	2.02	3.04	1.75	10.85	4.47	**100**
1988	2.99	3.44	2.22	13.78	3.96	**100**
1989	3.13	3.34	3.91	10.68	3.99	**100**
1990	1.99	2.54	4.06	14.56	5.48	**100**
1991	3.31	2.17	3.17	18.56	6.82	**100**
1992	3.27	1.92	4.27	15.83	6.17	**100**
Average	**2.26**	**2.90**	**2.93**	**14.58**	**4.65**	**100**

*For the composition of these categories see Appendix II
Source of Original Data: Ministry of National Economy

The percentage for the Public Administration category has been, more or less, stable around one percent. Investment in the Research and Technology element has two separate phases. Before 1979 the share is less than half of one percent. From 1980 onwards, however, this varies from 1.99 to 4.43 percent. The Special Works scheme (which incorporates Special Works for Athens-Thessaloniki) starts in 1980 and has since varied around a 2.9 average. Public investment in Tourism, Museums, and Monuments has been rather stable, fluctuating modestly around 2.93 percent.

One of the most significant categories, at least the one for which the theoretical and empirical research has paid special attention, is Transportation. This is the third largest category of PIPR for the whole period of analysis and was the largest, by far, in the mid-seventies (peaking to a staggering 27.53 percent in 1977). In the early eighties it has dropped to around 11 percent, but in the nineties there has been a recovery of its share reaching 18.56 percent by 1991. Another crucial category is that of Water and Sewage public capital. In the eighties there was a drop of its percentage (from around eight percent in the seventies), but, as for Transportation, there has been a substantial recovery in the late eighties and early nineties.

3.4.5 Regional distribution of the public infrastructure categories

The estimation of the regional infrastructure capital in Greece is not as simple as might be expected given the fact that most of the PIPR works have a specific spatial designation. This difficulty stems from the fact that a part of the PIPR investment expenditure is allocated to a larger spatial unit than a prefecture (normally to a NUTS II level region, instead the NUTS III region level that a prefecture represents)[13]. Table 3.11 elucidates the problems involved in deriving an adequate estimation of regional (prefectural) public capital. Column (1) presents the percentage of infrastructure investment at a higher than prefectural regional level. It is apparent that with the exception of the first year (1986) this percentage is rather low.

The 'non-spatial' category in column (2) gives the percentage of investment projects that either have materialised in more than two regions of NUTS II level, or have not been classified for accounting reasons in a specific area. The percentage of this category is high, its average for the examined period being around 40 percent of the total PIPR. If to this category is added the non-prefectural amounts in column (1), then the total part of the Programme, which cannot be estimated at prefectural level is generated and shown in column (3). However, it has to be noted that a significant part of this sum corresponds to the Miscellaneous and Administrative categories, which do not constitute real investment. Column (5) provides the percentage of the PIPR that cannot be estimated at prefectural level after the deduction of the Miscellaneous and Administrative categories given in column (4). This means that the final percentage of PIPR unaccountable at prefectural level averages around 28 percent and thus constitutes a significant part of the PIPR. This has important implications for the data panels based on the prefectural estimation of public capital stocks in that the regional infrastructure is underestimated.

[13] A potential alternative would be to estimate the regional infrastructure capital at NUTS II level. However, the adoption of this higher spatial level would mean that valuable information about the variation of infrastructure at the prefectural level would have been lost. Additionally and from a statistical point of view, this lost information would be translated into a reduction of the number of degrees of freedom in the econometric analysis in the subsequent chapters.

However, this is not a problem in the case of the sectoral panels (for a detailed analysis of these panels, see chapter 5).

Table 3.11 Non-spatially allocatable percentages of the Public Investment Programme of Greece

Years	Non-Prefectural	Non-Spatial	Total Non-Prefectural	Miscel. & Adminstr.	Non-Prefect. minus Misc.
	(1)	(2)	(3)	(4)	(5)
1976	13.30	36.20	49.50	10.87	38.63
1977	5.54	33.83	39.37	12.70	26.68
1978	4.53	40.85	45.39	13.01	32.38
1979	4.51	40.33	44.84	24.97	19.87
1980	5.69	41.17	46.86	21.39	25.47
1981	5.18	50.64	55.81	33.95	21.87
1982	5.37	50.25	55.62	30.71	24.91
1983	4.57	41.45	46.02	26.76	19.26
1984	3.77	36.48	40.26	21.60	18.66
1985	3.62	36.32	39.94	21.07	18.87
1986	2.94	36.99	39.93	17.08	22.85
1987	2.88	44.61	47.49	14.97	32.52
1988	3.20	42.21	45.41	12.90	32.50
1989	4.26	41.73	45.98	6.70	39.28
1990	4.53	43.37	47.90	9.38	38.52
1991	4.43	35.63	40.06	6.52	33.55
1992	5.28	37.98	43.26	4.83	38.43
Average	**4.88**	**40.39**	**45.27**	**16.90**	**28.37**

Source of Original Data: Ministry of National Economy

Public infrastructure investment is rarely distributed evenly in space. In most countries the spatial distribution of infrastructure is influenced by the existing dispersion of the economic activity and population. Greece is no exception. Some prefectures have concentrated the lion's share of the overall infrastructure spending allocated at prefectural level. Table 3.12 gives the relevant information about the regional (prefectural) distribution of the total investment in the overall public capital. The term 'total' means that the comparison between the prefectures is made based on the total sum of public infrastructure spent in each prefecture. The term 'overall' refers to the fact that table 3.12 is based on the figures for all public spending in infrastructure (for both productive and social public capital), having excluded the administrative and operational costs.

This table, as well as those to come, was constructed as follows. First, the investment for each year was deflated to constant prices (with a base year 1970). Then, all the years were added. Finally, the prefectures were ranked according to their performance. The table presents the percentage over the average prefectural investment for the study period for every prefecture, as this comparison may be more meaningful than one based on the 'real' amounts. In any case, the real total investment can be easily recovered as the base section of the table provides details of average prefectural investment (in constant 1970 prices in thousands of drachmas).

An examination of table 3.12 shows some interesting characteristics of the regional distribution of infrastructure. The prefectures of the major urban centres of the country have received the great bulk of the nation's public capital investment. The first two prefectures Attiki and Thessaloniki, which have achieved percentages well above the average, contain the two most significant metropolitan areas of Greece. Viotia, which is in seventh position, is a prefecture adjacent to Attiki, and it can be argued that here the investment pattern is influenced by the proximity to Athens. Achaia, in fourth place, contains the third major urban centre, Patra. Ioannina and Iraklio, at fifth and sixth positions respectively, contain also the largest cities in their wider areas. The only exception in this pattern is Evros, which was ranked as the third prefecture. However, this is a rather special area, as it is on the border with Turkey. For both political and economic reasons all Greek administrations have paid special attention to the infrastructure needs of this prefecture.

The base of table 3.12 (as well of the following tables in this section) details some overall statistics based on the real total amounts (in constant 1970 prices) spent for each prefecture. The average in this table, as mentioned earlier, is the average total prefectural investment. The maximum and minimum total prefectural investment values refer to the Attiki and Lefkada prefectures respectively. The maximum - minimum ratio, variance and standard deviation are the standard statistics of the variation in the data[14]. However, the most interesting statistic[15] seems to be the coefficient of variation (*CV*). This measure is equal to:

[14] For a useful evaluation of these measures in the context of regional analysis, see Molle et al. (1980), appendix 2.

[15] As Molle et al. have argued, "the coefficient of variation has the advantage over variance" (1980, p. 258).

$$CV = \frac{\sigma}{\bar{x}} \qquad (3.4.3.1)$$

where, σ, is the standard deviation, and $\bar{x}$, is the average.

The coefficient of variation will be used latter to compare inequalities in regional distributions between the different types of public capital.

However, analysis such as that presented in table 3.12 cannot reveal potential regional clustering of public capital at a regional level higher than that of prefectures. For this reason the data from this table have been also presented as map 3.1. This map illustrates some of the points made earlier. It is obvious that there is a clustering of infrastructure investment around the three major urban poles, of Athens, Thessaloniki, and Patras (darker shaded areas correspond to higher infrastructure investment in all maps presented here).

Table 3.12 Prefectural total (overall) infrastructure spending in Greece, 1976-1992

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	15.53	Kavala	18	0.71	Imathia	35	0.44
Thessalon.	2	3.47	Karditsa	19	0.69	Korinthia	36	0.42
Evros	3	1.55	Kyclades	20	0.64	Laconia	37	0.42
Achaia	4	1.47	Drama	21	0.60	Arta	38	0.40
Ioannina	5	1.42	Kozani	22	0.58	Pieria	39	0.40
Iraklio	6	1.23	Rethimno	23	0.57	Evritania	40	0.39
Viotia	7	1.22	Lesvos	24	0.57	Chios	41	0.39
Messinia	8	1.13	Halkidiki	25	0.56	Samos	42	0.38
Serres	9	1.09	Fthiotis	26	0.56	Kastoria	43	0.38
Aitoloakar.	10	1.09	Rodopi	27	0.56	Fokida	44	0.35
Dodecan.	11	1.04	Xanthi	28	0.53	Thesprotia	45	0.34
Larissa	12	0.95	Lasithi	29	0.53	Kilkis	46	0.34
Chania	13	0.92	Trikala	30	0.52	Kephalonia	47	0.33
Evia	14	0.91	Argolida	31	0.50	Grevena	48	0.33
Ilia	15	0.84	Arcadia	32	0.46	Florina	49	0.32
Pella	16	0.84	Preveza	33	0.46	Zakynthos	50	0.19
Magnisia	17	0.80	Kerkyra	34	0.44	Lefkada	51	0.18
Average		3,592,369				Variance		6.E+13
Maximum		55,800,106	Max-Min	Ratio	84	Stand. Deviation		7,685,373
Minimum		660,673				Coef. Of Variation		2.139

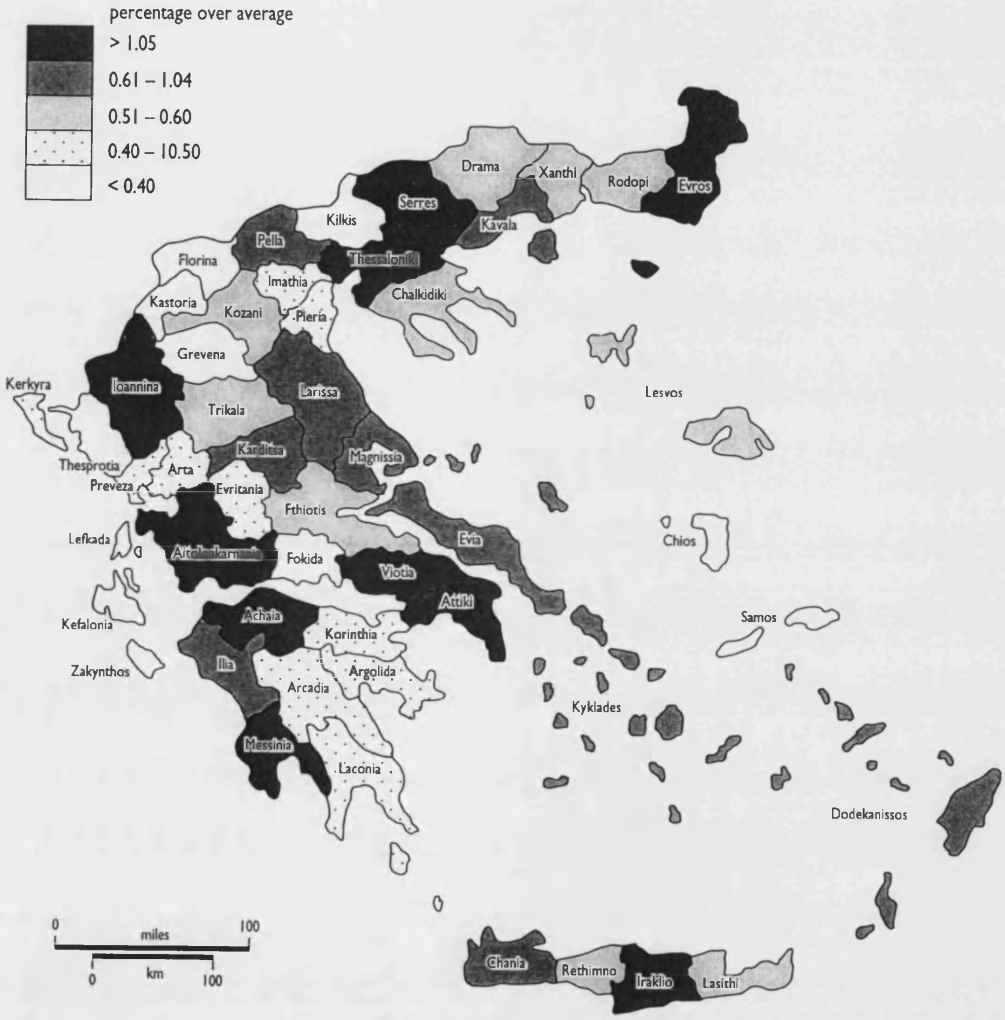
The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

Source of Original Data: Ministry of National Economy

Map 3.1 shows also the higher investment for Ioannina and Iraklio prefectures. There are, nevertheless, some points which can be seen best in the map. For instance, the

Map 3.1 Total overall infrastructure spending, 1976-1992

Constant 1970 prices



western part of the Peloponnese (Achaia, Ilia, and Messinia prefectures) seems to have received a much higher percentage of infrastructure investment than the eastern part (Korinthia, Argolida, Arcadia, Laconia). It is also apparent that the west-central prefectures of mainland Greece have received a lower percentage than the prefectures having the bigger urban centres.

In tables 3.13 and 3.14 the overall infrastructure investment has been disaggregated into the productive and social categories respectively. The prefectural ranking for the productive category is almost identical to that of table 3.12. The only notable exception is that Iraklio is not one of the high ranking prefectures, dropping to twelfth position. Two prefectures of the central and eastern Peloponnese - Arcadia and Argolida - appear to have a relatively better percentage of productive infrastructure in comparison to the overall public capital spending. The same is true for the eastern Aegean prefecture of Dodekanissos. These differences can again being seen graphically in map 3.2.

Table 3.13 Total productive infrastructure spending by nomos in Greece, 1976-1992

Constant 1970 prices

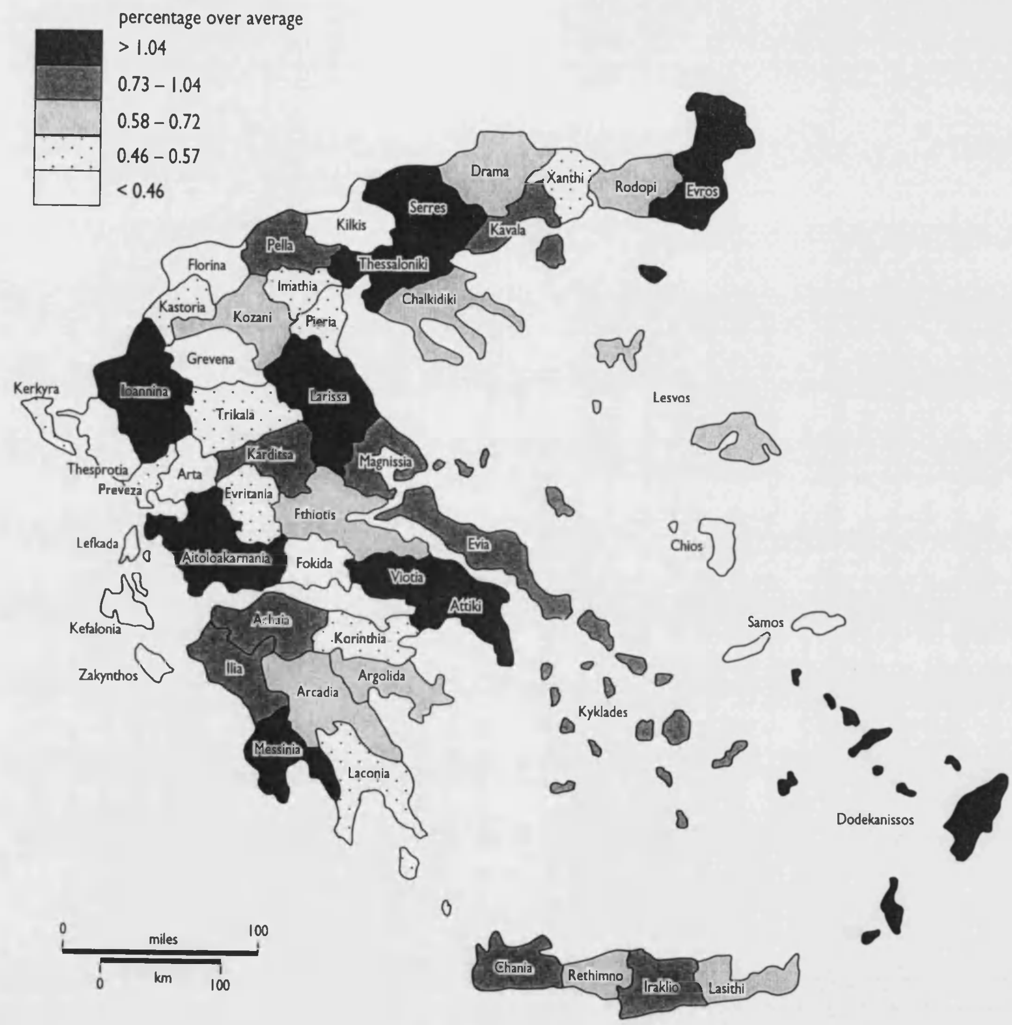
NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	12.24	Kyclades	18	0.81	Korinthia	35	0.51
Thessalon.	2	3.06	Karditsa	19	0.76	Imathia	36	0.51
Evros	3	1.90	Kavala	20	0.74	Kerkyra	37	0.49
Viotia	4	1.55	Drama	21	0.72	Kastoria	38	0.47
Serres	5	1.37	Lesvos	22	0.70	Evritania	39	0.46
Aitoloakar.	6	1.31	Kozani	23	0.65	Pieria	40	0.46
Ioannina	7	1.25	Rethimno	24	0.63	Samos	41	0.46
Messinia	8	1.24	Fthiotis	25	0.62	Chios	42	0.45
Dodecan.	9	1.17	Halkidiki	26	0.62	Thesprotia	43	0.44
Larissa	10	1.06	Argolida	27	0.61	Kilkis	44	0.43
Achaia	11	1.04	Rodopi	28	0.60	Fokida	45	0.43
Iraklio	12	1.02	Lasithi	29	0.59	Grevena	46	0.42
Ilia	13	1.00	Arcadia	30	0.58	Kephalonia	47	0.41
Chania	14	0.98	Trikala	31	0.57	Florina	48	0.40
Pella	15	0.97	Xanthi	32	0.56	Arta	49	0.39
Evia	16	0.96	Preveza	33	0.56	Zakynthos	50	0.24
Magnisia	17	0.84	Laconia	34	0.52	Lefkada	51	0.02
Average		2,608,264				Variance		2.E+13
Maximum		31,913,834	Max-Min	Ratio	53.504	Stand. Deviation		4,366,128
Minimum		596,472				Coef. Of Variation		1.674

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

Source of Original Data: Ministry of National Economy

Map 3.2 Total productive infrastructure spending, 1976-1992

Constant 1970 prices



The case of total social infrastructure is analysed in table 3.14 and illustrated in map 3.3. It can be seen that prefectures with large urban centres and higher percentage of population have achieved the higher percentages (above the average) of social capital investment. An inspection of map 3.3 shows that the general picture is not dramatically different than that of productive infrastructure distribution. The most important feature of table 3.14, however, is presented in the statistics at the foot of the table. It is obvious from both the max-min ratio, and the coefficient of variation (*CV*) that the investment in social capital is more unequally distributed among the prefectures than in the case of productive capital. The CV_{social} is equal to 3.069, while the $CV_{productive}$ is much smaller (1.674).

Table 3.14 Total social infrastructure spending by nomos in Greece, 1976-1992

Constant 1970 prices

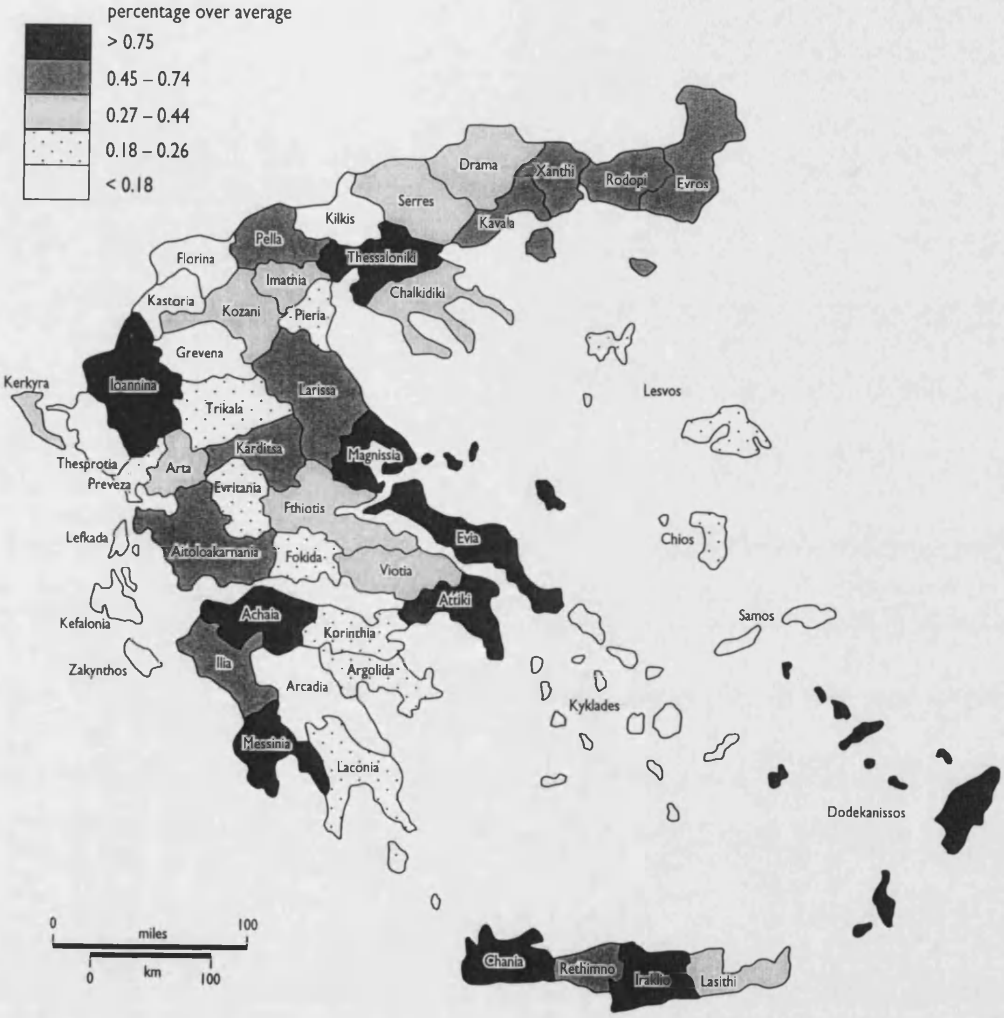
NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	21.73	Rethimno	18	0.50	Evritania	35	0.20
Thessalon.	2	4.44	Ilia	19	0.49	Laconia	36	0.19
Achaia	3	3.19	Karditsa	20	0.49	Korinthia	37	0.19
Ioannina	4	2.40	Kozani	21	0.44	Preveza	38	0.18
Iraklio	5	2.23	Fthiotis	22	0.43	Trikala	39	0.18
Messinia	6	0.93	Lasithi	23	0.43	Fokida	40	0.17
Chania	7	0.85	Serres	24	0.41	Kyclades	41	0.17
Evia	8	0.83	Viotia	25	0.39	Kephalonia	42	0.17
Dodecan.	9	0.80	Kerkyra	26	0.37	Samos	43	0.16
Magnisia	10	0.78	Drama	27	0.36	Florina	44	0.13
Larissa	11	0.74	Imathia	28	0.29	Kastoria	45	0.11
Kavala	12	0.74	Halkidiki	29	0.27	Kilkis	46	0.11
Pella	13	0.61	Arta	30	0.27	Arcadia	47	0.11
Aitoloakar.	14	0.59	Lesvos	31	0.26	Thesprotia	48	0.09
Xanthi	15	0.59	Chios	32	0.24	Lefkada	49	0.08
Rodopi	16	0.51	Pieria	33	0.24	Zakynthos	50	0.08
Evros	17	0.51	Argolida	34	0.23	Grevena	51	0.07
Average		741,060				Variance		5.E+12
Maximum		16,102,983	Max-Min	Ratio	329.094	Stand. Deviation		2,273,951
Minimum		48,931				Coef. Of Variation		3.069

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

Source of Original Data: Ministry of National Economy

Map 3.3 Total social infrastructure spending, 1976-1992

Constant 1970 prices



Next, table 3.15 and map 3.4 do not present the allocation of an actual investment category, but provide, in a manner similar to previously, information about regional differences in the total miscellaneous and administrative expenditures of the PIPR. Only Attiki, Thessaloniki, and Trikala (only just) are above the average. It has to be pointed out again that a great part of the miscellaneous and administrative expenditures does not correspond to a specific prefecture but it is accounted for at the national level (approximately 70 percent).

Table 3.15 Total miscellaneous and administrative expenditure of the Public Investment Programme by nomos in Greece, 1976-1992

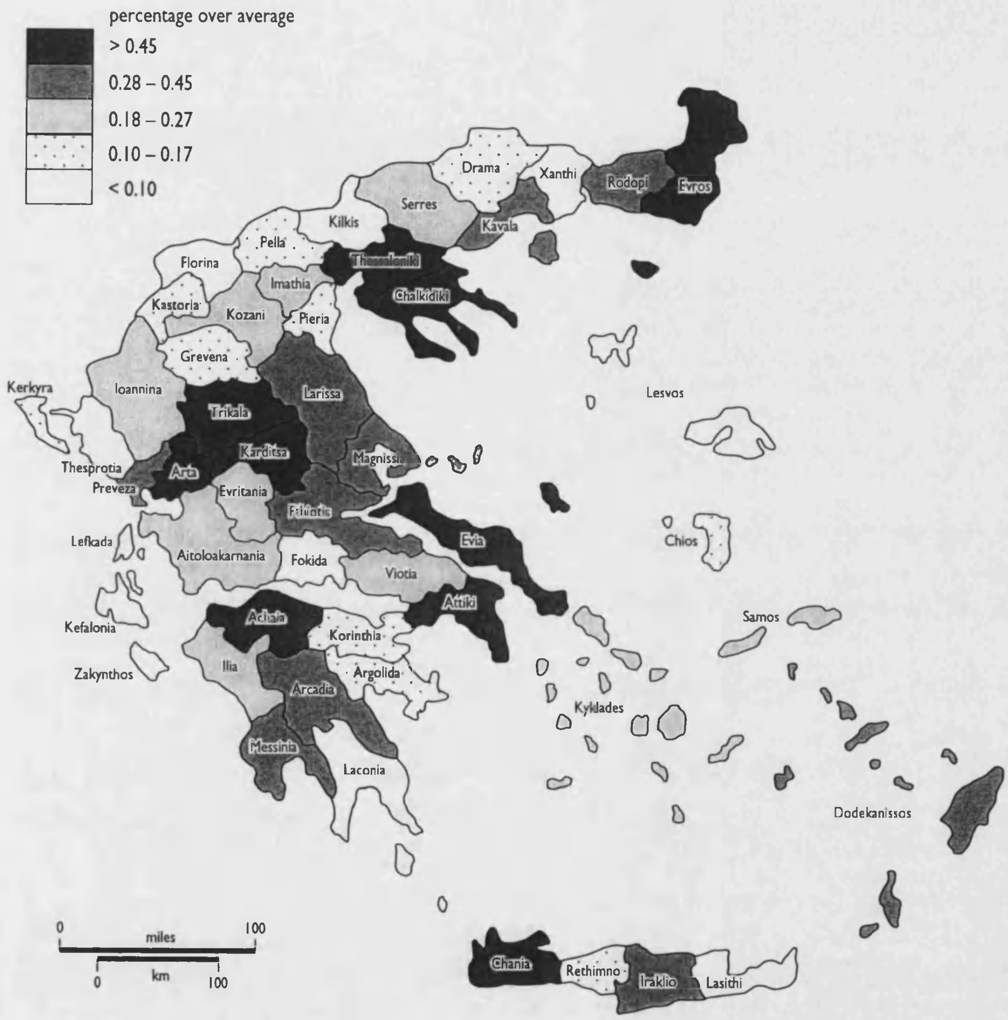
Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	32.02	Preveza	18	0.32	Pella	35	0.13
Thessalon.	2	4.92	Kavala	19	0.31	Drama	36	0.13
Trikala	3	1.02	Rodopi	20	0.28	Grevena	37	0.12
Halkidiki	4	0.91	Ioannina	21	0.27	Kastoria	38	0.12
Evros	5	0.90	Ilia	22	0.25	Korinthia	39	0.12
Arta	6	0.89	Serres	23	0.24	Argolida	40	0.12
Achaia	7	0.81	Evritania	24	0.24	Lesvos	41	0.10
Evia	8	0.69	Kyclades	25	0.21	Lasithi	42	0.09
Karditsa	9	0.52	Samos	26	0.20	Thesprotia	43	0.09
Chania	10	0.50	Imathia	27	0.19	Fokida	44	0.08
Messinia	11	0.45	Kozani	28	0.19	Kephalonia	45	0.06
Iraklio	12	0.45	Viotia	29	0.18	Kilkis	46	0.05
Magnisia	13	0.42	Aitoloakar.	30	0.18	Laconia	47	0.05
Larissa	14	0.38	Pieria	31	0.18	Zakynthos	48	0.04
Arcadia	15	0.35	Chios	32	0.18	Xanthi	49	0.04
Fthiotis	16	0.34	Rethimno	33	0.17	Florina	50	0.04
Dodecan.	17	0.33	Kerkyra	34	0.15	Lefkada	51	0.02
Average		243,045				Variance		1.E+12
Maximum		7,783,289	Max-Min	Ratio	1670.918	Stand. Deviation		1,090,151
Minimum		4,658				Coef. Of Variation		4.485

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages
Source of Original Data: Ministry of National Economy

Map 3.4 Total miscellaneous and administrative expenditure of PIPR, 1976-1992

Constant 1970 prices



A totally different picture is apparent for the regional distribution of infrastructure if the spending per inhabitant[16] is considered. Table 3.16 shows that Evritania is, in this case, the prefecture with the highest total infrastructure spending per head in Greece. The borderline prefecture of Evros occupies the second position, the island prefecture of Kephalonia is in the third place, and Viotia comes fourth. This last prefecture is adjacent to Attiki (with the metropolitan area of Athens). Regional inequality, as measured by the coefficient of variation, is much smaller in the per inhabitant infrastructure case compared to the absolute spending picture (0.383 and 2.139 respectively).

Table 3.16 Total (overall) infrastructure spending per inhabitant by nomos in Greece, 1976-1992

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Evritania	1	2.50	Messinia	18	1.10	Aitoloakar.	35	0.78
Evros	2	1.70	Dodecan.	19	1.08	Iraklio	36	0.78
Kephalonia	3	1.68	Halkidiki	20	1.05	Evia	37	0.74
Viotia	4	1.55	Drama	21	1.01	Attiki	38	0.72
Ioannina	5	1.49	Zakynthos	22	1.00	Laconia	39	0.71
Samos	6	1.48	Pella	23	0.99	Arcadia	40	0.70
Grevena	7	1.44	Florina	24	0.97	Kerkyra	41	0.69
Rethimno	8	1.38	Xanthi	25	0.95	Magnisia	42	0.67
Lefkada	9	1.37	Serres	26	0.90	Kilkis	43	0.66
Preveza	10	1.29	Karditsa	27	0.87	Kozani	44	0.62
Thesprotia	11	1.28	Lesvos	28	0.87	Thessalon.	45	0.61
Fokida	12	1.27	Rodopi	29	0.85	Trikala	46	0.61
Chios	13	1.23	Argolida	30	0.84	Larissa	47	0.58
Lasithi	14	1.19	Kavala	31	0.84	Pieria	48	0.57
Chania	15	1.14	Achaia	32	0.82	Fthiotis	49	0.54
Kastoria	16	1.14	Arta	33	0.81	Imathia	50	0.52
Kyclades	17	1.12	Ilia	34	0.80	Korinthia	51	0.51
Average		22,416				Variance		7.E+07
Maximum		55,970	Max-Min	Ratio	4.932	Stand. Deviation		8,577
Minimum		11,348				Coef. Of Variation		0.383

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

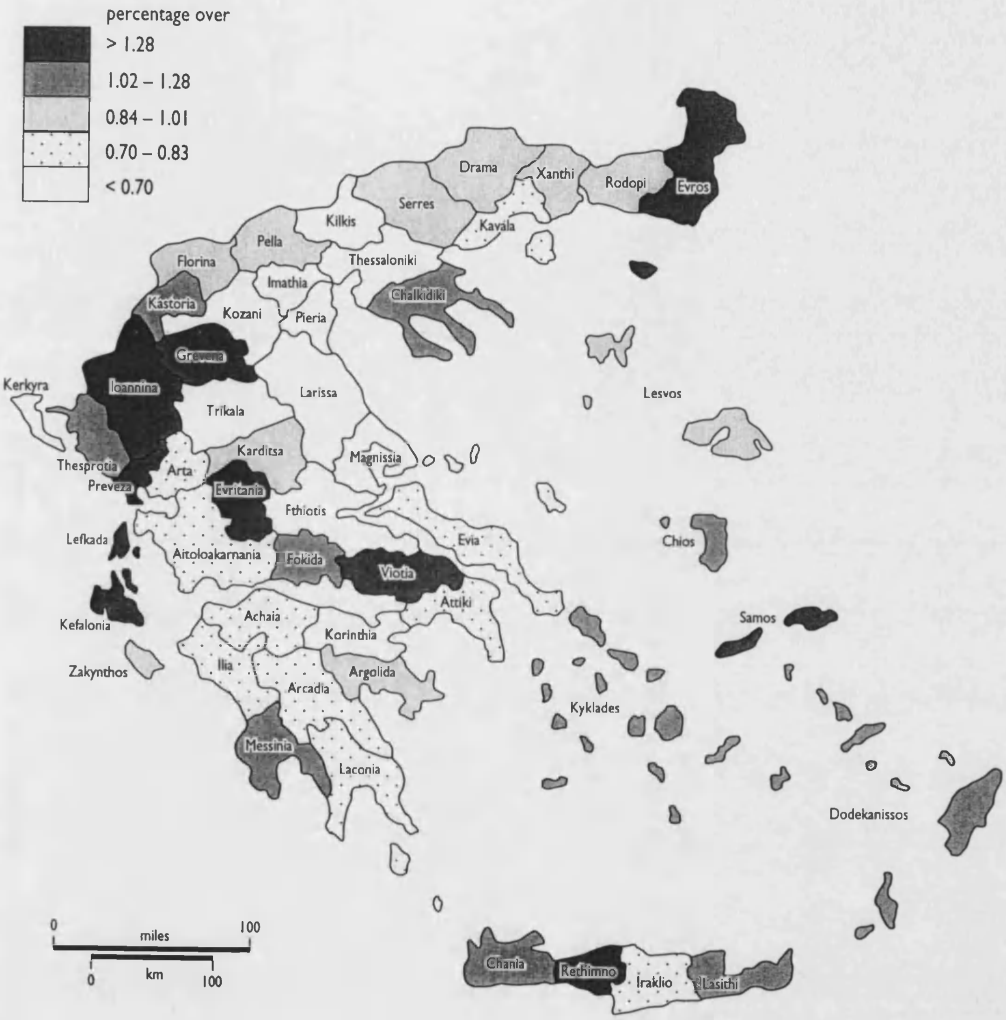
Source of Original Data: Ministry of National Economy

An examination of map 3.5 shows that the peripheral prefectures in Greece obtain the higher percentages of per inhabitant infrastructure spending, with the exception of Viotia, Evritania, Fokida, and Messinia.

[16] The total infrastructure spending (for each category) has been divided by the prefectural population. The latter is the average of the population given in the censuses of 1981 and 1991, given in table 3.22.

Map 3.5 Total overall infrastructure spending per inhabitant, 1976-1992

Constant 1970 prices



The per inhabitant productive infrastructure investment is reproduced in table 3.17. Again Evritania, Evros, Kephalonia, and Viotia are the prefectures with the highest percentages. However, the most interesting fact here is that the prefectures with the three major centres, Attiki, Thessaloniki, and Achaia, and which together concentrate half of the Greek population, receive the lowest per capita spending percentage of the productive public capital component.

Table 3.17 Total productive infrastructure spending per inhabitant by nomos in Greece, 1976-1992

Constant 1970 prices

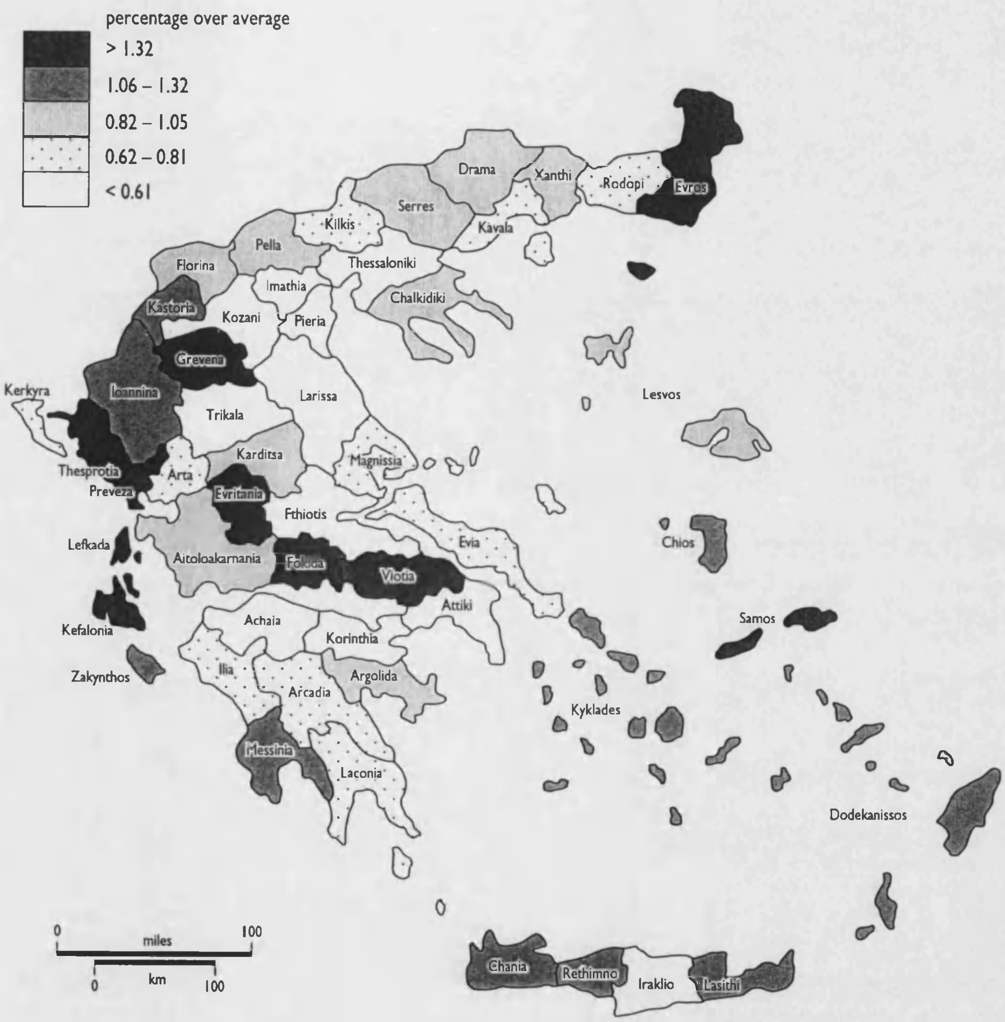
NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Evritania	1	2.57	Messinia	18	1.06	Arcadia	35	0.76
Evros	2	1.82	Dodecan.	19	1.06	Kilkis	36	0.74
Kephalonia	3	1.79	Chania	20	1.06	Arta	37	0.69
Viotia	4	1.72	Florina	21	1.05	Evia	38	0.68
Grevena	5	1.61	Drama	22	1.05	Kerkyra	39	0.66
Samos	6	1.56	Pella	23	1.00	Magnisia	40	0.62
Lefkada	7	1.49	Halkidiki	24	1.00	Kozani	41	0.61
Thesprotia	8	1.43	Serres	25	0.98	Trikala	42	0.58
Preveza	9	1.36	Lesvos	26	0.94	Pieria	43	0.58
Fokida	10	1.35	Argolida	27	0.90	Larissa	44	0.56
Rethimno	11	1.32	Xanthi	28	0.88	Iraklio	45	0.56
Kastoria	12	1.25	Karditsa	29	0.84	Korinthia	46	0.54
Kyclades	13	1.24	Aitoloakar.	30	0.82	Imathia	47	0.52
Chios	14	1.24	Ilia	31	0.82	Fthiotis	48	0.52
Lasithi	15	1.17	Rodopi	32	0.79	Achaia	49	0.50
Ioannina	16	1.15	Laconia	33	0.76	Attiki	50	0.50
Zakynthos	17	1.08	Kavala	34	0.76	Thessalon.	51	0.47
Average		18,667				Variance		6.E+07
Maximum		47,932	Max-Min	Ratio	5.464	Stand. Deviation		8,012
Minimum		8,772				Coef. Of Variation		0.429

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages
Source of Original Data: Ministry of National Economy

This important fact is illustrated in map 3.6 where it can be seen that prefectures with high population density are well below the average per inhabitant investment in productive infrastructure (the non-shaded areas of the map).

Map 3.6 Total productive infrastructure spending per inhabitant, 1976-1992

Constant 1970 prices



The pattern of overall and productive total investment per inhabitant is more or less the same. The regional distribution of social investment per inhabitant, presented in table 3.18 and map 3.7, is, however, significantly different. The first ten to fifteen of the highest ranked prefectures include some of the most significant urban areas of the country, when for the overall and productive components the first places in rank are occupied generally by less populated areas. As table 3.18 shows, Attiki, Thessaloniki, Achaia, Iraklio, and Ioannina, (prefectures of greater population density) are in the upper one third of the classification. A comparison of maps 3.6 and 3.7 well illustrates the difference between the spatial distribution of productive and social public capital.

Table 3.18 Total social infrastructure spending per inhabitant by nomos in Greece, 1976-1992

Constant 1970 prices

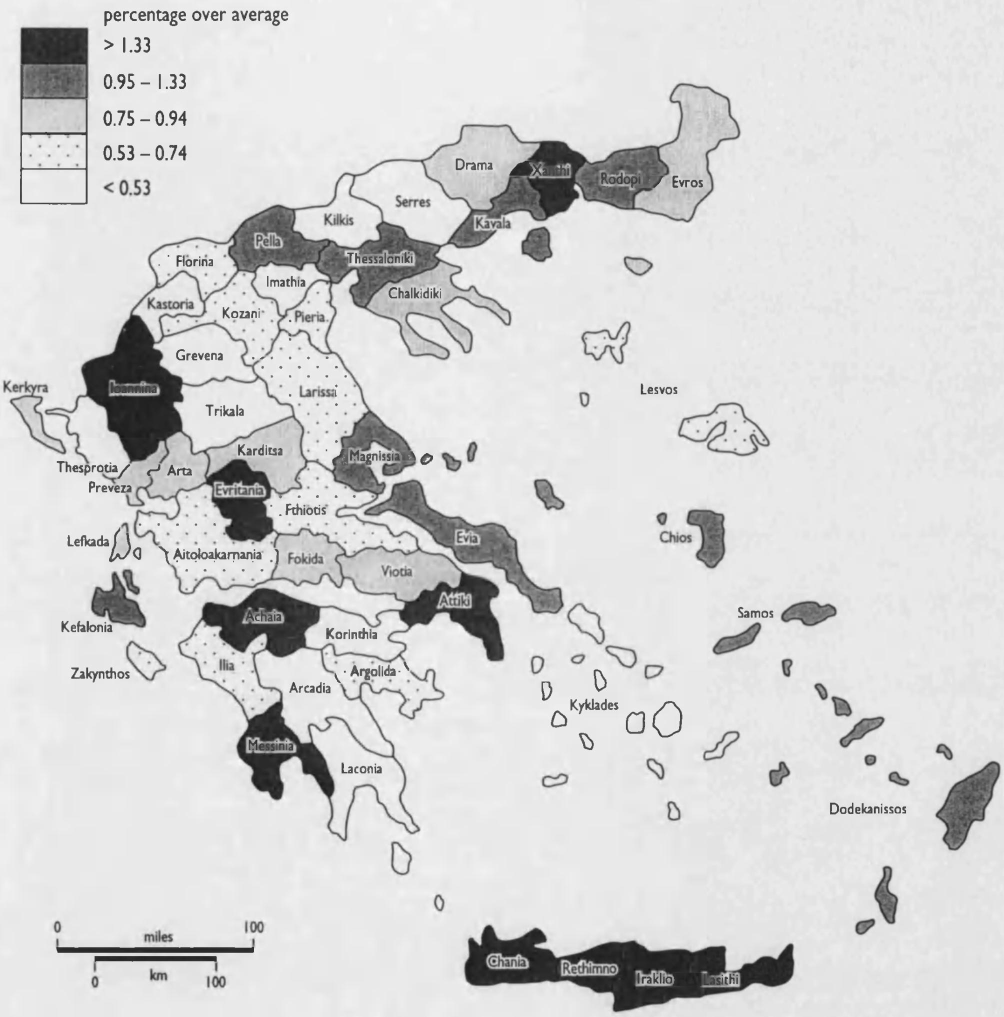
NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Ioannina	1	3.82	Evia	18	1.02	Fthiotis	35	0.63
Achaia	2	2.70	Magnisia	19	1.00	Florina	36	0.61
Iraklio	3	2.14	Samos	20	0.95	Zakynthos	37	0.61
Evritania	4	1.89	Fokida	21	0.95	Lesvos	38	0.59
Rethimno	5	1.84	Karditsa	22	0.94	Argolida	39	0.59
Xanthi	6	1.61	Drama	23	0.92	Pieria	40	0.53
Chania	7	1.60	Lefkada	24	0.91	Imathia	41	0.52
Attiki	8	1.53	Kerkyra	25	0.86	Serres	42	0.52
Lasithi	9	1.47	Evros	26	0.85	Kastoria	43	0.52
Messinia	10	1.38	Arta	27	0.82	Thesprotia	44	0.52
Kavala	11	1.33	Halkidiki	28	0.77	Laconia	45	0.48
Kephalonia	12	1.26	Viotia	29	0.76	Kyclades	46	0.45
Dodecan.	13	1.26	Preveza	30	0.75	Grevena	47	0.44
Thessalon.	14	1.19	Kozani	31	0.72	Korinthia	48	0.34
Rodopi	15	1.18	Ilia	32	0.71	Kilkis	49	0.34
Chios	16	1.17	Larissa	33	0.69	Trikala	50	0.31
Pella	17	1.09	Aitoloakar.	34	0.65	Arcadia	51	0.25
Average		3,046				Variance		4.E+06
Maximum		11,621	Max-Min	Ratio	15.121	Stand. Deviation		1,960
Minimum		768				Coef. Of Variation		0.643

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

Source of Original Data: Ministry of National Economy

Map 3.7 Total social infrastructure spending per inhabitant, 1976-1992

Constant 1970 prices



A comparison between the coefficient of variation of the per inhabitant infrastructure categories (tables 3.16 to 3.18) with the respective statistics for the absolute spending (tables 3.12 to 3.14) shows that the per inhabitant regional distribution is considerably less unequal than for absolute spending.

The final set of tables 3.19 to 3.21 provide the prefectural ranking according to per unit of area (per square kilometre, given in table 3.22) investment for each of the public capital categories. As might be expected, the Attiki and Thessaloniki prefectures have been ranked first and second for all three categories of public capital (overall, productive, and social). This is a result of the fact that Greek prefectures are more of less of the same size, with the possible exception of some of the island prefectures (see table 3.22 for details of prefectural size). Table 3.19 shows that from the list of prefectures ranked first to tenth, more than half are islands. Similar is the case for productive infrastructure per unit area (table 3.20). However, it is somewhat different for social public capital because, as table 3.21 reveals, the most endowed prefectures are those with large urban centres.

Table 3.19 Total (overall) infrastructure spending per unit area by nomos in Greece, 1976-1992

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	10.85	Kavala	18	0.89	Rodopi	35	0.58
Thessalon.	2	2.51	Pella	19	0.89	Kastoria	36	0.58
Kerkyra	3	1.84	Ilia	20	0.86	Evritania	37	0.56
Lefkada	4	1.37	Magnisia	21	0.81	Aitoloakar.	38	0.53
Samos	5	1.31	Xanthi	22	0.79	Halkidiki	39	0.51
Zakynthos	6	1.27	Lasithi	23	0.77	Korinthia	40	0.49
Iraklio	7	1.24	Ioannina	24	0.76	Larissa	41	0.47
Achaia	8	1.19	Serres	25	0.73	Drama	42	0.46
Preveza	9	1.18	Lesvos	26	0.70	Florina	43	0.44
Chios	10	1.15	Pieria	27	0.70	Fokida	44	0.44
Viotia	11	1.10	Karditsa	28	0.69	Kozani	45	0.44
Chania	12	1.03	Imathia	29	0.69	Trikala	46	0.41
Dodecan.	13	1.02	Kyclades	30	0.66	Grevena	47	0.38
Rethimno	14	1.01	Arta	31	0.64	Kilkis	48	0.36
Messinia	15	1.00	Argolida	32	0.62	Fthiotis	49	0.34
Kephalonia	16	0.99	Thesprotia	33	0.60	Laconia	50	0.30
Evros	17	0.97	Evia	34	0.58	Arcadia	51	0.28
Average		1,350,412				Variance		4.E+12
Maximum		14,653,389	Max-Min	Ratio	38.766	Stand. Deviation		1,977,835
Minimum		377,995				Coef. Of Variation		1.465

The statistics at the foot of the table refer to the actual (deflated and in absolute numbers) data and not their percentages

Source of Original Data: Ministry of National Economy

Table 3.20 shows that the prefectural allocation (per unit area) of the productive category is similar to that of the overall infrastructure investment. The first four prefectures are the same for overall and productive investment. However, the regional disparities of productive investment are smaller compared to total infrastructure, as shown by the coefficients of variation (1.095 and 1.465 respectively).

Table 3.20 Total productive infrastructure spending per unit area by nomos in Greece, 1976-1992

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	8.15	Ilia	18	0.97	Aitoloakar.	35	0.61
Thessalon.	2	2.11	Kavala	19	0.89	Arta	36	0.60
Kerkyra	3	1.95	Serres	20	0.87	Rodopi	37	0.59
Lefkada	4	1.63	Lesvos	21	0.83	Evia	38	0.58
Zakynthos	5	1.51	Lasithi	22	0.83	Korinthia	39	0.57
Samos	6	1.51	Magnisia	23	0.81	Halkidiki	40	0.54
Preveza	7	1.36	Achaia	24	0.80	Drama	41	0.52
Viotia	8	1.33	Kyclades	25	0.80	Florina	42	0.52
Chios	9	1.27	Xanthi	26	0.80	Fokida	43	0.51
Kephalonia	10	1.15	Pieria	27	0.78	Larissa	44	0.50
Evros	11	1.14	Imathia	28	0.76	Kozani	45	0.47
Dodecan.	12	1.10	Thesprotia	29	0.73	Grevena	46	0.47
Rethimno	13	1.06	Karditsa	30	0.73	Kilkis	47	0.43
Messinia	14	1.06	Argolida	31	0.72	Trikala	48	0.43
Chania	15	1.05	Kastoria	32	0.70	Laconia	49	0.36
Pella	16	0.98	Ioannina	33	0.64	Fthiotis	50	0.35
Iraklio	17	0.98	Evritania	34	0.63	Arcadia	51	0.33
Average		1,027,870				Variance		1.E+12
Maximum		8,380,734	Max-Min	Ratio	24.627	Stand. Deviation		1,126,007
Minimum		340,303				Coef. Of Variation		1.095

The statistics at the foot of the table refer to the actual (deflated and in absolute numbers) data and not their percentages

Source of Original Data: Ministry of National Economy

The situation is slightly different for public investment per area regarding the social category. Here, all of the top prefectures are the most densely populated ones. For instance, the small island of Samos, ranked fifth in the overall classification per area, has a below average percentage social spending (placed at 18 in the list). Also, in this case, regional inequalities are higher (the coefficient of variation for the spending per area on social infrastructure is 2.397).

Table 3.21 Total social infrastructure spending per unit area by nomos in Greece, 1976-1992

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	17.07	Samos	18	0.62	Argolida	35	0.32
Thessalon.	2	3.61	Rodopi	19	0.60	Evritania	36	0.31
Achaia	3	2.92	Evia	20	0.60	Serres	37	0.31
Iraklio	4	2.53	Zakynthos	21	0.58	Drama	38	0.31
Kerkyra	5	1.71	Ilia	22	0.56	Fthiotis	39	0.29
Ioannina	6	1.44	Karditsa	23	0.55	Halkidiki	40	0.28
Chania	7	1.08	Kephalonia	24	0.55	Korinthia	41	0.24
Kavala	8	1.05	Imathia	25	0.51	Fokida	42	0.24
Rethimno	9	1.01	Preveza	26	0.51	Florina	43	0.21
Xanthi	10	0.99	Arta	27	0.48	Kyclades	44	0.20
Messinia	11	0.93	Pieria	28	0.48	Kastoria	45	0.20
Magnisia	12	0.89	Larissa	29	0.41	Thesprotia	46	0.18
Dodecan.	13	0.88	Viotia	30	0.40	Trikala	47	0.16
Chios	14	0.81	Kozani	31	0.38	Laconia	48	0.15
Pella	15	0.73	Evros	32	0.36	Kilkis	49	0.13
Lasithi	16	0.70	Lesvos	33	0.35	Grevena	50	0.09
Lefkada	17	0.68	Aitoloakar.	34	0.33	Arcadia	51	0.07
Average		247,672				Variance		4.E+11
Maximum		4,228,725	Max-Min	Ratio	228.061	Stand. Deviation		593,766
Minimum		18,542				Coef. Of Variation		2.397

The statistics at the foot of the table refer to the actual (deflated and in absolute numbers) data and not their percentages

Source of Original Data: Ministry of National Economy

Table 3.22 Population+ and size of Greek prefectures

Millions and square kilometres respectively

NOMOS	Population	Area in sq.km	NOMOS	Population	Area in sq.km	NOMOS	Population	Area in sq.km
Achaia	287,636	3,271	Halkidiki	86,345	2,918	Lefkada	21,487	356
Aitoloakarnania	223,972	5,461	Ilia	169,867	2,618	Lesvos	104,851	2,154
Arcadia	106,621	4,419	Imathia	136,842	1,701	Magnisia	190,328	2,636
Argolida	95,328	2,154	Ioannina	152,749	4,990	Messinia	163,391	2,991
Arta	79,382	1,662	Iraklio	254,264	2,641	Pella	135,574	2,506
Attiki	3,446,416	3,808	Karditsa	125,892	2,636	Pieria	111,811	1,516
Chania	129,815	2,376	Kastoria	52,927	1,720	Preveza	57,272	1,036
Chios	51,025	904	Kavala	135,578	2,111	Rethimno	66,365	1,496
Dodecanissos	154,274	2,714	Kephalonia	31,886	904	Rodopi	105,574	2,543
Drama	95,663	3,468	Kerkyra	103,535	641	Samos	41,242	778
Evia	198,409	4,167	Kilkis	81,636	2,519	Serres	194,538	3,968
Evritania	25,245	1,869	Korinthia	132,433	2,290	Thesprotia	42,733	1,515
Evros	146,119	4,242	Kozani	148,719	3,516	Thessaloniki	909,222	3,683
Florina	52,789	1,924	Kyclades	91,232	2,572	Trikala	136,577	3,384
Fokida	44,203	2,120	Laconia	94,457	3,636	Viotia	125,642	2,952
Fthiotis	166,635	4,441	Larissa	262,454	5,381	Xanthi	89,920	1,793
Grevena	36,609	2,291	Lasithi	70,666	1,823	Zakynthos	31,286	406
						Average	**196,067**	**2,581**

+Average of the population given in the censuses of 1981 and 1991

Source: National Statistical Service of Greece

3.5 Estimation of the public capital stocks

The original data of the Public Investment Programme utilised here can provide a reliable source of information for the study of infrastructure capacity in Greece, both at a national and a regional level. The next step is to use these data for the estimation of the national and regional capital infrastructure stocks. There are no such existing estimations, but Greece is by no means unusual in this respect.

It can be safely argued that one of the contributions of the recent resurgence in research into public infrastructure is the construction of reliable estimations of such capital stocks, as the following examples illustrate. Munnell has estimated the public capital stocks for the United States at 'state-by-state' level (1990b, Appendix A). Holtz-Eakin, also for the United States, extended Munnell's work for the capital stocks at a local government level (1993b). Mas and her team have calculated the infrastructure stocks at autonomous community (regional) level for Spain (Mas et al. 1995).

The dominant approach for the estimation of the public capital stocks in the infrastructure literature is the *perpetual inventory accounting method.* This approach uses the flow of infrastructure investment for the estimation of stocks, assuming that a percentage of the existing stock has been depreciated. The formula for the estimation of the capital stocks to be used here is:

$$G_t = (1-\delta)G_{t-1} + I_t \qquad (4.5.1)$$

where,
G_t is the end of year public capital stock in year t,
δ is the geometric rate of depreciation,
and I_t is real investment in public capital during years t
(For more details on this fairly standard method of capital stock construction see for example Holtz-Eakin 1993b).

It is apparent from equation (4.5.1) that three pieces of information are necessary for the estimation of public capital stocks. The real investment in infrastructure (I_t) can be approximated by the monetary sums paid by the PIPR. Regarding the geometric rate of depreciation (δ), it was assumed that the rate remained constant for all of the examined period, and that it equals 0.05. This is similar to the depreciation rate used by Bajo-Rubio and Sosvilla-Rivero for the estimation of the Spanish infrastructure stocks (1993, Appendix 1). This figure is arbitrary, but it has chosen assuming that Greek infrastructure capital is not much different from the Spanish, and that in addition the depreciation rate for fixed assets (buildings) given by the NSSG (see Xenaki 1997) is not dissimilar. Finally, as there were no existing stock estimates at regional level, it was decided to build on the first year of the available data[17].

This process has been used for the estimation of total public capital, as well as for the productive and social categories. The next table (3.23) outlines regional inequalities in the estimated prefectural infrastructure capacity (at the middle year -1984 - of the period examined, so that a meaningful comparison with the previous tables, where the averages for the 1976-1992 period were used, is feasible).

Table 3.23 Prefectural total (overall) infrastructure capital stock in Greece, 1984

Constant 1970 prices

NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average	NOMOS	Rank	Perc. Over the Average
Attiki	1	15.88	Kyklades	18	0.64	Laconia	35	0.42
Thessalon.	2	3.76	Kozani	19	0.58	Preveza	36	0.41
Evros	3	2.06	Lesvos	20	0.57	Evritania	37	0.40
Achaia	4	1.48	Argolida	21	0.56	Kastoria	38	0.40
Ioannina	5	1.42	Halkidiki	22	0.55	Samos	39	0.37
Ilia	6	1.23	Rodopi	23	0.55	Serres	40	0.37
Aitoloakar.	7	1.19	Karditsa	24	0.54	Kilkis	41	0.36
Iraklio	8	1.16	Fthiotis	25	0.51	Kephalonia	42	0.35
Pella	9	1.12	Lasithi	26	0.51	Kerkyra	43	0.35
Viotia	10	1.06	Korinthia	27	0.49	Chios	44	0.35
Dodekan.	11	1.00	Rethimno	28	0.48	Grevena	45	0.34
Larisa	12	0.94	Drama	29	0.48	Thesprotia	46	0.34
Messinia	13	0.91	Arcadia	30	0.47	Arta	47	0.33
Magnisia	14	0.89	Xanthi	31	0.47	Florina	48	0.32
Evia	15	0.85	Imathia	32	0.47	Fokida	49	0.28
Chania	16	0.84	Pieria	33	0.44	Zakynthos	50	0.19
Kavala	17	0.69	Trikala	34	0.44	Lefkada	51	0.18
Average		1,319,947				Variance		8.5E+12
Maximum		20,966,494	Max-Min	Ratio	86.070	Stand. Deviation		2,907,097
Minimum		243,599				Coef. Of Variation		2.202

The statistics at the foot of the table refer to the actual (deflated and in thousands) data and not their percentages

Source of Original Data: Ministry of National Economy

17 This is a common practice in the estimation of capital stocks. See for instance Corrales and Taguas (1991).

The prefectural classification and the overall statistics are similar to those of table 3.12, where the total (overall) infrastructure spending was presented for the whole of the period examined (1976-1992). Thus, the Attiki, Thessaloniki, and Evros prefectures are again in the three top places of the classification, while Zakynthos and Fokida occupy the bottom two. Even though there are some differences in the other places of the classification, these can be attributed to the fact that the statistics for them are based on the mid-year (1984) capital stocks. The overall conclusion is that the regional distribution of capital stock depends, as would be expected, on the levels of prefectural spending (as the capital stocks reflect accumulated investment flows). This is also true for the classifications of the productive and social public capital stocks, which are not present here due to space limitations.

3.6 Conclusions

The main provider of public infrastructure investment in Greece is to all intents (for all the post-Second World War period) the Public Investment Programme. Even though it is not the only source for public capital investment, it is by far the most important. The PIPR data provides not only valuable information for the estimation of public capital stocks at the national level, but also have made possible the construction of infrastructure stocks at the (never before available) regional or prefectural level.

If the spatial allocation of public investment is one dimension given by the data of PIPR, another available dimension is the type of infrastructure in which this investment has been materialised. The PIPR is divided to several categories, but in order to simplify the empirical analysis undertaken in the next three chapters, these basic categories have been grouped under two major headings - productive and social infrastructure investment. If these two categories are added, then total (overall) infrastructure investment can be obtained. This overall public capital investment is smaller than the total PIPR expenditure, as the Miscellaneous and Administrative expenditures categories have been subtracted. The exclusion of these categories is necessary, as they do not represent actual investment in fixed capital, but do in fact constitute the operational costs of the Programme.

The share of these Miscellaneous and Administrative expenditures in the eighties became extremely high and this meant that the percentage, and unfortunately the absolute level, of 'real' (fixed capital) investment fell. In the late eighties and early nineties the upward trend of these operational costs was reversed and, thus, the percentage and absolute level of productive infrastructure investment has significantly increased. However, this is not also the case for social infrastructure investment, which has not regained its seventies level.

One of the problems concerning the assessment of the role of public infrastructure in regional economic development and productivity is the fact that a significant part of the PIPR is not allocated at prefectural level (NUTS III), but instead at a higher spatial level. This means that some investment projects have been materialised in more than one prefecture (inter-prefectural level), some at prefectures belonging in more than one NUTS II region (inter-regional level), and some are public expenditure at the national level. However, a significant part of the PIPR expenditure that cannot be allocated at prefectural level does not relate to actual investment, but to Miscellaneous and Administrative operational expenditure. Thus it can be argued that the constructed regional stocks are an underestimation of the existing public infrastructure. However, in the estimation of infrastructure stocks at national level (used for the assessment of the effects of public capital on the manufacturing sectors) all 'real' investment expenditures at the NUTS II regional or national level have been included.

It has been demonstrated that the regional distribution of public investment in infrastructure capital is far for equal. Some prefectures have received a significantly higher percentage of public capital than others. Prefectures with high population density, that is those containing the large urban centres of the country, are the main beneficiaries of total infrastructure investment. The unequal allocation of total infrastructure is also reflected in the regional distribution of the productive and social categories. If, however, instead of the absolute amount of infrastructure, the per capita prefectural spending is examined, the situation is totally different. Peripheral and low population density prefectures have had the highest per inhabitant infrastructure investment, for total and productive categories. But the per capita social public capital distribution is different. For this category prefectures with significant urban centres have higher social capital endowment.

Despite these regional inequalities in the spatial distribution of public capital, the fact remains that the PIPR has been for the most recent decades the most important and most reliable source of investment at both the national and the regional level.

Chapter 4

Public Infrastructure Investment and National and Regional Economic Growth in Greece: A Production Function Analysis

4.1 Introduction

The renewed interest for the relationship between public infrastructure capital and economic development has already produced a substantial body of empirical research in the United States and in many other countries. The majority of this work has been based on the use of an analytical framework based on production functions, and more particularly the Cobb-Douglas production function variant.

This chapter attempts to assess the impact of public infrastructure on national and regional economic development in Greece, and more specifically on the manufacturing sector of the economy, utilising such an analytical framework. The analysis conducted here has used relatively recent developments of econometric theory, and especially the contemporary understanding of estimating production functions using time series - cross section data analysis.

Section 4.2 presents the theoretical framework, as well as an inquiry into the origin of the production functions in general and the Cobb-Douglas specification in particular. Some of the relevant recent empirical findings from other countries are also presented. A concise presentation of the Greek industrial sector is offered in the next section (4.3). The development of a number of the key characteristics of this sector is analysed here and a picture of the regional distribution of the industry presented. Section 4.4 sets out the econometric calibration of the Cobb-Douglas production function, which is to be used later for the empirical research on the Greek case. This section also contains a description of several statistical and econometric tests to be used in the aforementioned analysis.

Section 4.5 introduces the presentation of the empirical results for the Greek case. This section contains the findings at the national level, along with the results for several different econometric specifications. The analysis is not restricted to the aggregate estimates of infrastructure stocks, but also includes consideration of the two major categories of public capital - productive and social infrastructure. The following section (4.6) investigates the possibilities for different types of returns to scale. Such an analysis is deemed necessary here, as these can reveal whether the market operates under perfect competition (as the neoclassical theory would require for the long run) or not. Section 4.7 shifts the spatial level from the national to the regional. Different levels of spatial aggregation, as well as some aggregations based on the level of industrial performance of the Greek prefectures, have been used. The last empirical section (4.8) is an excursion into the role of infrastructure networks. The difference compared to the previous analysis is that in this section the effects of the infrastructure endowment in adjacent spatial units have been taken under consideration.

The last section summarises the empirical findings of this chapter. The overall conclusion is that public infrastructure appears to play a strong positive role in industrial development, at least at national level. It seems that the larger the spatial scale of analysis the larger is the impact of public capital. This is in accordance to the empirical findings from other countries. The probable reason why this might be so is that the analysis of larger spatial units captures the potentially important spillover effects of public infrastructure capital.

4.2 The production function analytical framework

The majority of the recent research on the role of public infrastructure on economic and regional development is based on the production function analytical framework. The Cobb-Douglas specification of the production function appears to be especially popular. In chapter 2 an introductory review of the production function approach has been presented, as well as a discussion of the recent empirical findings. For a concise presentation of the dimensions of this type of research reference should be made to table 2.1. All of this work begs the question why production functions and why the popularity of the Cobb-Douglas form? The answers probably lie in the concept of the production function *per se*.

The production function concept is, probably, the basic building block for the orthodox (neoclassical) economic theory of production. A production function which is "*the simplest and most common way to describe the technology of a firm*" (Varian 1992, p. 1), is "*the set of possible efficient relations between inputs and outputs given the current state of technological knowledge*" (Heathfield et al. 1987, p. 12). For a more formal definition see Takayama 1996, Varian 1992, or Chambers 1988. Chambers also provides an excellent, concise, but formal, analysis of the theoretical properties of the production function (1988).

The development of the production function concept is one of the most interesting in the history of economic theory. An excellent overview of this development can be found in Berndt 1991, section 9.1. The idea of the production function has been central to an economic analysis of production even during the time of Alfred Marshall (see his seminal work *Principles of Economics* 1961, first published in 1870). However, it was Douglas and Cobb[1] who developed one of the most celebrated (and most frequently used in empirical research at both at micro and macro levels of analysis) forms of production function.

Paul Douglas, who was not only an eminent economist but also a politician[2], worked on labour economics. One of the questions he tried to answer was the relationship between movements of labour productivity and real wages over a long period of time, and more particularly if labour was receiving the value of its marginal product. This query was of great importance given the political and economic context of the era (the late 1920s). Douglas wanted to test the marginal productivity theory for this question, but probably felt that an enhanced mathematical aptitude was required for the task. Thus, he enlisted the help of one of his colleagues at Amherst College - an applied mathematician

[1] Wicksell has used this type of equation earlier on. However, it was Douglas who made it popular (for this point see Heathfield et al. 1987).
[2] He was US senator for Illinois from 1949 to 1966 (cited in Mankiw 1998; this reference provides also a presentation of the use of Cobb-Douglas production function in macroeconomics).

called Charles Cobb. Together they published one of the most seminal papers in economics (1928) testing the marginal productivity theory empirically. They concluded that the shares of private capital and labour of national income had remained, for the US economy, more or less constant over a long period of time[3]. The interpretation of this result is that "*as the economy grew more prosperous over time, the income of workers and the income of capital owners grew at almost the same rate*" (Mankiw 1998, p. 76). The formulation that they used was the celebrated Cobb-Douglas equation. This is a theoretical construction that gives constant factor shares if the production factors obtain their marginal product.

As this equation is used extensively in the public capital literature and also in this empirical chapter, it will be useful to present some of its basic properties. The generic Cobb-Douglas production function has the form[4] (see equation 2.3.1 in chapter 2):

$$Q = AK^{a}L^{b} \tag{4.2.1}$$

where:
Q is output,
K is the private capital input,
L is the labour input,
and A is a measure of technological progress

As was mentioned in section 2.3, the parameters a and b measure the elasticities of output with respect to private capital and labour. It is assumed that these parameters are constant and their value is between zero and unity. The Cobb-Douglas function is

[3] They formulated the Cobb-Douglas equation, and estimated the coefficients for private capital and labour, which were 0.25 and 0.75 respectively. (It has to be noted that these shares for the US economy for the period 1946 to 1994 were 0.3 and 0.7 respectively, as it cited in Mankiw 1998, pp. 77-78). The R square for their regression was 0.97. It has to be mentioned, however, that an alternative formulation they used, which was inconsistent to the usual theory of production, as it did not permit diminishing returns, 'achieved' a similar high R square of 0.97 (for these points see Berndt 1991, chapter 9).
[4] This equation can be alternatively expressed in terms of capital or labour productivity (see equations 2.3.4 and 2.3.5 respectively in chapter 2).

homogeneous of degree $(a+b)$, and if it is assumed that $a+b=1$ (constant returns of scale), then is linearly homogeneous[5].

The marginal product[6] of private capital (*MPK*) will be:

$$\frac{\partial Q}{\partial K} = aAK^{a-1}L^{b} = a\frac{Q}{K} \tag{4.2.2}$$

and the marginal product of labour (*MPL*) will be:

$$\frac{\partial Q}{\partial L} = bAK^{a}L^{b-1} = b\frac{Q}{L} \tag{4.2.3}$$

As mentioned previously, it is assumed that parameters a and b take values between zero and unity. That means that the quantities $a-1$ and $b-1$ are both negatives, and, thus, the second terms of expressions 4.2.2 and 4.2.3 are diminishing. This, in turn, means that both *MPK* and *MPL* are diminishing as the relevant input (K, or L) increases.

Another crucial feature of the Cobb-Douglas production function is that its elasticity of substitution is constant and equal to one (a formal proof of this characteristic of Cobb-Douglas can be found in Heathfield et al. 1987, pp. 80-81). The constant elasticity of substitution implies that a k percent change in the ratio of production factor prices would lead, in turn, to a k percent change in quantity terms in the opposite direction. For example, a k percent increase of the price of private capital (relative to the price of labour), would lead to k percent decrease in the quantity of private capital input relative to labour.

The Cobb-Douglas production function is related to Cobb-Douglas isoquants, factor demand functions, and cost functions. Due to space limitations it will suffice to say at this point that in Heathfield et al. 1987 a whole chapter can be found devoted to the Cobb-Douglas function, where these relations are analysed. Also to be found here is an

[5] For an analysis of the terms 'homogeneous' and 'linearly homogeneous' see section 4.6 of this chapter, where there is an attempt to investigate empirically types of returns of scale.

[6] The marginal products presented in equations (4.2.2) and (4.2.3) refer to a homogeneous Cobb-Douglas function. For the marginal products in the case where the Cobb-Douglas is not just homogeneous, but linearly homogeneous (the case of constant returns of scale) see Chiang 1984, pp. 414-417.

analysis of the aggregation of Cobb-Douglas functions. Another useful treatment of the empirical problems in the aggregation and estimation of production functions can be found in Thomas (1993).

As noted in chapter 2, the Cobb-Douglas is not the only type of production function available. There are others, perhaps more sophisticated types, such as the Constant Elasticity of Substitution (*CES*) production function, or the Transcendental Logarithmic (*translog*) production function. Berndt (1991), Heathfield et al. (1987), Thomas (1993), and Varian (1992) all offer excellent introductory presentations of these types of production functions, as well as, in some, examples of empirical research utilising them. Chambers (1988) has also been responsible for putting these forms of production function into a more theoretical framework. Section 2.3 offers some examples of recent public infrastructure research based on *translog* production functions, in addition to its basic formulation.

Chapter 2 also provides an explanation of why the Cobb-Douglas specification has been the dominant form of production function in empirical public capital research. The reasons seem to stem less from a fundamental conceptual advantage of the Cobb-Douglas function, and more to rather mundane issues. The Cobb-Douglas can be formulated and estimated rather easily, it is less data demanding, and the results give immediately a direct picture of infrastructure impact on private sector production activity (in comparison with, say, the more complicate ways of estimation using the cost function approach[7]).

To be more specific, the operational form of the Cobb-Douglas production function where public capital has also been added would be:

$$\ln Q = \ln A + a\ln K + b\ln L + c\ln G + e \qquad (4.2.4)$$

The coefficients for the independent variables in equation 4.2.4 - *a*, *b*, and *c* - as argued earlier are the elasticities of output with respect to private capital, labour, and public capital respectively. This empirical calibration of the Cobb-Douglas equation is called in

[7] See next chapter.

econometrics *log-linear*[8] and has the interesting feature that the slope and elasticity coefficients estimated are the same, something which is not the case in the linear model (see for this point, Gujarati 1995). The fact that these coefficients measure the elasticity of output with respect to the production inputs makes the interpretation of the empirical simple. If, for instance, the estimated coefficients were 0.30, 0.50, and 0.20 for private capital, labour, and infrastructure capital respectively this means that an increase of the infrastructure stock by one percent would have a subsequent increase on the production output by 20 percent. It is clear that this feature of the *log-linear* form of the Cobb-Douglas allows for an immediate comparison of the impact of public capital to that of the private factors of the production (private capital, and labour).

These advantages constitute the main reasons explaining the fact that the majority of the existing research on infrastructure effects has used the Cobb-Douglas production function. More than half of the reported studies in table 2.1 have used the Cobb-Douglas approach. It is true to say, however, that the actual calibration of the Cobb-Douglas varies significantly among researchers. This fact has the implication that a direct comparison of the actual estimates of the effects of the infrastructure variable in these studies could be misleading[9]. With this caveat in mind, table 4.1 presents some of the estimated infrastructure coefficients in some of the most frequently cited pieces of research. Table 4.1 shows that the estimated elasticities for public infrastructure range from a 'sky-high' 0.39 estimated by Aschauer (1989a) to zero or near zero coefficients obtained by Holtz-Eakin (1992a) and Tatom (1991b). What it is not immediately obvious from such a table are the underlying difficulties of comparison. Every study can have a slightly different empirical calibration of the Cobb-Douglas equation and sometimes a significantly different definition of public capital.

[8] Sometimes the terms, *log-log*, or *double-log* are used alternatively (see, for instance, Gujarati 1995). It has to be mentioned, however, that some authors reserve the term *log-linear* just for the *semilog* models (see Ramanathan 1992), where only the dependent variable is in logarithmic form.

[9] See, however, the interesting *meta-analysis* of public capital investment studies developed by Button (1998).

Table 4.1 Estimated Output Elasticities of Public Infrastructure Capital from Selected Studies

Author	Year	Country	Level of Aggregation	Elasticity of Public capital*
Aschauer	1989a	US	National	0.39
Baltagi and Pinnoi	1995	US	Panel of the 48 contiguous states	0.16-0.39+
Eisner	1991	US	National-Regional (States)	0.165
Garcia-Mila and McGuire	1992	US	National-Regional (States)	0.045-0.165+
Garcia-Mila, McGuire, Porter	1996	US	National	no significant effect
Holtz-Eakin	1992a	US	National-Regional	almost zero
Mera	1973	Japan	Regional	0.20
Munnell	1990a	US	National	0.15
Tatom	1991b	US	National (Business sector)	almost zero

+ Range depending on the specification and the infrastructure aggregation

Switching the discussion next to the empirical context of the present research, the only previous works on this topic for Greece are due to Dalamagas (1995), and Segoura and Christodoulakis (1997). Both these pieces of research use time-series data at the national level[10] and an all-encompassing definition of public capital. Dalamagas used a translog production function, adding Energy into the explanatory variables. Thus, his research findings are not directly comparable with those from this thesis. Infrastructure in Segoura and Christodoulakis' research comprises the public capital in transportation, telecommunications, and the energy sector. It is obvious that this definition is very different from the one used in the present study (see chapter 3). The problem with such a broad measure of infrastructure capital is that the telecommunications and energy sectors are already in the process of privatisation and also that the vast majority of the public capital literature only refers to a much narrower band of public investment. Thus, useful though this research is, it is difficult to make detailed comparisons with other research if somewhat different definitions are adopted. The infrastructure elasticity obtained by the Cobb-Douglas equation used by Segoura and Christodoulakis (0.42) is, as might be gathered from Table 4.1, extremely high indeed.

[10] However, the time-series dataset of Segoura and Christodoulakis, is not complete as some intermediate observations are missing (see Segoura et al. 1997, footnote 13).

These different guises of the Cobb-Douglas production function may constitute one of its principal disadvantages, as sometimes it makes for severe difficulties in comparing the results from different studies. The Cobb-Douglas function has several other theoretical restrictions, already addressed in section 2.3. Despite its shortcomings, however, it may be regarded as 'almost compulsory' to at least explore this theoretical and empirical tool in any research of this sort and a consequence it will form the basis of the rest of this chapter. In the following two chapters, however, some more up-to-date, and in many ways more 'sophisticated', methods of analysing role of public capital on the development of the economy will be considered.

4.3 The Greek secondary sector: regional distribution and temporal growth

The temporal evolution and regional distribution of the Public Investment Programme of Greece (PIPR) have been extensively analysed in chapter 3. It would be helpful to offer at this point a similar, although concise, presentation of the temporal performance and regional distribution of the manufacturing industry of Greece.

The data on manufacturing used in this analysis refer to large-scale industry and, more particularly, to establishments with average annual employment of twenty persons and over. This definition of 'large-scale industry' is the official one, used by the National Statistical Service of Greece (NSSG), which has provided the data. It has to be noted, however, that this scale of industry cannot be considered large-scale even in the Greek context. But, overall, it is true to say that this scale of manufacturing amounts to almost 90 percent[11] of all secondary activity in Greece.

Data for capital investment, as well as employment and value-added, together with other variables, are collected via the census questionnaire survey. Data for smaller establishments (which are not available at the regional level and therefore not used here) are collected via a sample. As a result, it can be stated that the regional manufacturing data, which have been used here, are as accurate as can be obtained.

[11] This is true (on average) for the whole of the examined period, irrespectively of which indicator (total employment, remuneration of employment, gross production value, or added value) is chosen.

However, there is a crucial difference between these data and the official data published by the National Statistical Service. In the published data and for reasons of confidentiality, in cases where there is only one firm in a prefecture, this prefecture is then added to an adjacent one. However, it has been possible to use here the original unpublished data, thus circumventing this problem. The use of these data was, in a sense, obligatory, as there were no other data available for private sector investment activity at a regional level. This most certainly was needed in order to construct a panel. Other data, which were available, did not have a sufficient time dimension for the proper estimation of capital stocks.

Table 4.2 shows the evolution of some basic indicators of Greek industrial performance from 1976-1991, using 1976 as a base year of deflation. The principal problem of Greek industry, and the Greek economy generally, has clearly been the decline of private investment. This tendency was accentuated in the second half of the eighties, reaching a low in 1987, when the gross asset formation of Greek industry represented only the 76 percent that of 1976. It is interesting to compare this trend with an opposite one, that of productive infrastructure capital, shown in table 3.6, column 4 (in chapter 3), which increases significantly from the early eighties and by 1991 was 32 percent above the 1976 level.

It is also evident that since 1980 average annual employment has been decreasing, but in fact the remuneration of employment, in real terms, has actually increased and this is problematic, in terms of production costs. The product of Greek industry, either in the form of gross production value or as added value (the form used here later), exhibits a significant increase after 1979, followed by a modest fallback in the early eighties and subsequent recovery and more growth by the end of the decade. The nineties have seen modest upward progress for value-added but declines in gross production value.

Table 4.2 Employment, labour remuneration, industrial production, and gross asset formation in the private industrial sector in Greece (establishments with 20 persons and over), 1976-1992

Year	Average Annual Employment	Remuneration of Employment+	Gross Production Value	Value Added	Gross Asset Formation
	(1)	(2)	(3)	(4)	(5)
1976	100.00	100.00	100.00	100.00	100.00
1977	101.60	108.59	102.03	103.32	87.09
1978	101.51	116.56	90.18	++	77.62
1979	101.37	119.10	97.41	++	95.63
1980	107.76	128.71	131.49	123.21	103.70
1981	107.05	130.02	137.24	121.40	119.10
1982	102.94	133.63	123.79	110.62	98.15
1983	99.64	130.20	128.28	114.09	113.61
1984	99.84	136.92	136.57	118.15	85.49
1985	98.64	136.17	141.37	119.11	87.78
1986	96.29	129.84	133.15	124.67	79.29
1987	98.12	129.94	127.64	124.00	76.05
1988	97.04	134.22	127.67	127.90	79.33
1989	96.85	143.70	130.77	131.23	84.53
1990	94.62	143.63	128.49	129.89	89.16
1991	88.37	138.52	122.06	130.20	79.05
1992	84.77	134.11	116.44	133.27	77.10

Source of original data: National Statistical Service
+ In real (deflated with year base 1970) terms. ++ No data available

Table 4.3 develops a classification of prefectures according to development levels that are defined in terms of average yearly absolute manufacturing value-added (deflated to 1970 prices).

Table 4.3 Classification of prefectures in Greece based on value-added performance, 1976-1992

High Output+	Intermediate Output++	Low Output+++
Attiki	Kozani	Zaky.-Kepha.
Thessaloniki	Iraklio	Thesprotia
Viotia	Aitoloakarnania	Arcadia
Achaia	Serres	Arta
Magnisia	Argolida	Evritania
Evia	Evros	Kastoria
Korinthia	Pieria	Lesvos
Larissa	Ioannina	Samos
Imathia	Kyclades	Fokida
Fthiotis	Ilia	Kerkyra
Kavala	Halkidiki	Chios
Pella	Trikala	Lasithi
Xanthi	Rodopi	Laconia
Kilkis	Preveza	Florina
Messinia	Chania	Rethimno
Drama	Dodecanissos	Grevena
	Karditsa	

+ Output greater than 450 million drachmas (average value for the period 1976-1992, in constant 1970 prices)
++ Output greater than 100 million drachmas (average value for the period 1976-1992, in constant 1970 prices)
+++ Output under 100 million drachmas (average value for the period 1976-1992, in constant 1970 prices)

There are three levels - high output (greater than 450 million drachma - the value for Drama was 493 million), intermediate output (greater than 100 million drachmas - Karditsa's value is 123 million drachma) and low output (under 100 million drachmas). As it is expected, Attiki and Thessaloniki dominate the rankings. This classification will be helpful in later analysis.

Private capital stocks for prefectural manufacturing have been used as a proxy for the quantity of private capital input (K), in the calibration of the Cobb-Douglas function for the Greek case in the following sections. The estimation method is again (see chapter 3 for the case of public capital) via the method of perpetual inventory accounting:

$$K_{it} = (1 - \delta_p)K_{it-1} + IP_{it} \tag{4.3.1}$$

where:

K_{it} is the end-of-year private capital stock in year t in prefecture i,

δ_p is the geometric rate of depreciation,

and IP_{it} is real investment in private capital during years t in prefecture i.

As there were no available estimates of the previous capacity of private capital (for the spatial levels used here) the method used by Corrales and Taguas (cited in Appendix 1 in Bajo-Rubio and Sosvilla-Rivero 1993, p.185) was employed. With this method the initial year is considered as a basis[12], and the stock of the subsequent years is built upon it, with the help of the perpetual inventory method.

4.4 Model specification of links between private production and public capital in Greece

The general analytical framework used here is similar to that developed by US researchers - Aschauer, Munnell, and Holtz-Eakin. To repeat, the adoption of the Cobb-Douglas vis-a-vis other forms of production or cost function can be justified in two ways. First, it is straightforward to estimate, as it does not require the vast amount of information needed, for example, by the cost function approach, and because fewer degrees of freedom are lost in comparison with, say, the translog production function. Second, it makes for convenient inter-study, often cross-national, comparison as the overwhelming majority of infrastructure research projects have used this approach to date.

A Cobb-Douglas production function was estimated for Greece as a whole, and its spatial components - the two large regions of the North and the South, and then for the ten regions approximating to the NUTS II level (see table 4.10). Aschauer (1989a) expressed his Cobb-Douglas function in terms of capital productivity, while Munnell (1990a) preferred a calibration in terms of labour productivity for her research on the US as a whole. However, here another slightly modified specification of the Cobb-Douglas function has been selected, one in which changes in the production output are explained

[12] This initial year can be multiplied by a number k (e.g. $k = 3, 5,$ or 10) for the approximation of the *level* of public capital (in this case the multiplication by 10 gave the highest coefficients for public capital). It has to be noted that the private capital stocks for the several spatial levels of sectoral industrial panels, which have been used in subsequent chapters, such a problem does not occur, as the data for private sectoral investment are sourced many years back in time.

by changes in the production inputs. Such a specification was used by Munnell (1990b) in her regional analysis of US infrastructure.

The general idea in using a Cobb-Douglas production function in the examination of public infrastructure capital is to extend it, adding the public capital variable as follows:

$$Q_{it} = AL_{it}^{a}K_{it}^{b}G_{it}^{c} \tag{4.4.1}$$

where:
A = an efficiency parameter (which can be regarded as an a indicator of the technology level),
Q_{it} = total value added of the private industrial sector in prefecture i at year t,
L_{it} = average annual employment in the private industrial sector in prefecture i at year t,
K_{it} = private capital input to the industrial sector in prefecture i at year t,
G_{it} = public capital input to the industrial sector in prefecture i at year t-1[13].

It is assumed that private and public capital inputs are proportionate to private and public capital stock respectively. In order to have a linear relationship capable of econometric estimation equation (4.4.1) is expressed in logarithmic form:

$$\ln Q_{it} = A_o + a \ln K_{it} + b \ln L_{it} + c\, G_{it} + u_{it} \tag{4.4.2}$$

In the Cobb-Douglas function, the exponents a, b, and c of equation (4.4.1) are the relative shares of the respective factors of the total product, under the assumption that each production factor is paid by the amount of its marginal product. (In other words it is assumed that there is a perfectly competitive market for each production factor). This means that the estimation of the coefficients of equation (4.4.2*)* provides these shares, or put it differently, the partial elasticity of output for the respective inputs of production.

The exact specification of equation (4.4.2) in the subsequent analysis has the form:

$$\ln Q_{it} = A + a \ln K_{it} + b \ln L_{it} + c\, G_{it} + dt + e \ln CU + u_{it} \tag{4.4.3}$$

where:
A = the constant term,
t = a time trend
CU = the capacity utilisation of capital stock,
u_{it} = the error term, and the other parameters are as above.

The capacity utilisation rate is used to control the influence of the business cycle. The values for this variable were obtained from the Organisation of Economic Co-operation and Development (OECD), and refer to national industrial averages. Unfortunately regional capacity utilisation rate estimates are not available. This is a similar formulation to that of Aschauer (1989a). An alternative proxy for the latter could be the unemployment rate (Munnell 1990b), but in the Greek case it seems to be less reliable. In addition, Ford and Poret (1991) have emphasised the importance of the inclusion of a capacity utilisation term, as the residuals from regressions excluding this term were highly auto-correlated in their study. The desired use of capacity utilisation was one of the time-constraints of the panel as there are no available data prior to 1982.

The use of panel data analysis in the infrastructure literature is widespread. It provides considerable advantages, such as lower collinearity among the variables, more degrees of freedom and more efficiency, controlling for individual heterogeneity to name but a few. For a more extensive analysis of these advantages see Appendix I, or Baltagi (1995). However, there is a continuing controversy, especially in the regional infrastructure literature, as to the choice of panel model. In particular, Holtz-Eakin has argued that the standard OLS procedures used by Munnell produce biased and inconsistent results. He suggested that it is necessary to include in the specification of the error term a component that would capture the regional characteristics of the spatial panel units (Holtz-Eakin, 1992a). This argument has been supported by Evans and Karras

[13] Public capital enters as an 'instrument', which is lagged one year. The reasoning for this is that in this way is safeguarded that all infrastructure investment has been materialised into fixed public capital providing services for the production process.

(1994b), who have criticised Aschauer's international comparative research, arguing that in his panel analysis he did not allow for fixed or random effects for country or time.

Here, a least squares dummy variable model (LSDV) is used in which a number of dummy variables has been added to the simple ordinary least squares (OLS) version. The former differs from the latter in that the error term has been specified as follows:

$$u_{it} = m_i + v_{it} \tag{4.4.4}$$

where:
μ_i is the unobservable regional specific effect, and v_{it} is the remainder disturbance.

Alternatively, expression (5) can be written as:

$$u = M_\mu \mu + v \tag{4.4.5}$$

where:
$u' = (u_{11},\ldots, u_{1t}, u_{21},\ldots, u_{2t},\ldots, u_{i1},\ldots, u_{it})$, with the observations stacked in such way that the first index is over regions, and the second over time.

$M_\mu = I_i \otimes \iota_t$, where M_μ is an identity matrix of dimension i, $\otimes$ is Kronecker product, and ι_t is a vector of ones dimension t.

In other words, it has been assumed that μ_i are fixed parameters, and a number of dummy variables equal to the number of regions has been used to estimate these effects. $\mu' = (\mu_{11},\ldots, \mu_{1t}, \mu_{21},\ldots, \mu_{2t},\ldots, \mu_{i1},\ldots, \mu_{it})$, and $v' = (v_{11},\ldots, v_{1t}, v_{21},\ldots, v_{2t},\ldots, v_{i1},\ldots, v_{it})$. For a more formal presentation of the structure of error term see, for instance, Baltagi (1995) or Judge et al. (1985).

These binary variables are expected to capture differences between the spatial units - differences due to the different endowment of the spatial units in location, climate, raw materials, industrial and economic structure, etc[14]. The results for these dummy variables are not reported on here (due to space limitations). The results for the OLS regressions are also not reported on as there are several hundred sets (including the specifications for testing the type of returns of scale). However, it has to be noted that a

[14] There has been an extended debate in the infrastructure literature regarding the formulation of locational characteristics using a panel dataset and a Cobb-Douglas production function (Holtz-Eakin 1992a; 1993c and Kelejian et. al. 1997).

simple Chow test (*F-test*) was used to discriminate between the OLS and LSDV models. This test is based on the residual sum of squares[15]:

$$F = \frac{(\bar{e}'\bar{e} - \hat{e}'\hat{e})/(N-1)}{(\hat{e}'\hat{e})/(NT-N-K')}, \tag{4.4.6}$$

where:
$(\bar{e}'\bar{e})$ = the residual sum of squares from the OLS model,
$(\hat{e}'\hat{e})$ = the residual sum of squares from the LSDV model,
N-1 = the number of linear restrictions,
NT-N-K' = degrees of freedom in the LSDV model

In all cases this *F*-test rejected the OLS formulation in favour of the LSDV model. An interesting point here is that there are two different formulations of the LSDV model available. One is without a constant term and with as many dummy variables as the number of the spatial units. The alternative, which is adopted here, includes a constant term, but drops one of the dummy variables. Even though the interpretation of the dummy variable coefficients is different, the results for the other coefficients are the same whichever formulation is chosen[16].

Although the Cobb-Douglas is the dominant form of production function in the infrastructure literature, there are no *a priori* theoretical reasons for its selection over the

[15] It would be the same if the R squares instead of sum of squares residuals and a slightly different formulation were used.
[16] There are some cases, not only in the infrastructure literature, where the results for such dummy variables are reported without mention of the following caveats. In the formulation without a constant term, every α_i dummy variable coefficient shows the unobservable regional specific effects in region *i*. However, this coefficient represents a separate intercept for the respective region and not a deviation from average behaviour. In the alternative case where a constant term has been included in the regression (and one dummy has been dropped), each dummy variable coefficient is an estimate of α_i - α_1. This means that one region (the one for which the respective dummy has been omitted) has been used as a benchmark from which the behaviour of the other regions has been measured. In both cases the presentation of the estimated regional dummies cannot be useful without a previous transformation of the coefficients. Such a transformation can be achieved by adding a chosen constant to each of the coefficients. It has also to be said that in logarithmic regressions these constants should be selected in such a manner that the antilogs of the dummy coefficients are forced to equal unity. (For a more extensive analysis of these points, see Suits 1984).
Another misconception about these dummy variables is to exclude insignificant t-values associated with individual coefficients. Judge et al. (1985, p.521) argue that it is better to use the conventional F-test (as used here) for testing the joint significance of these dummy variables, as "two different parameterizations of the same problem can lead to different dummy variables being omitted".

translog or, indeed, any other form. It must be kept in mind that the Cobb-Douglas form has some restrictive properties - its returns to scale are the same for all levels of output, and its elasticity of substitution is constant and equal to unity. Its supremacy in public capital research has more to do with the fact that it is relatively straightforward to estimate and understand rather than its theoretical superiority. It is possible, however, that the functional form of the Cobb-Douglas specification to be inconsistent with the empirical data. The functional assumption can be tested with the use of the RESET test suggested by Ramsey and Schmidt (1976). It can be generalised for multiple regression as follows, although for a more extensive presentation see Stewart (1991) or Thomas (1993). If the original equation to compute is of the form:

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}_1 X_{1i} + \hat{\beta}_2 X_{2i} \tag{4.4.7}$$

then, if the squares of the predicted values of this equation ($\hat{Y}_i^2$) are included as an additional regressor in the previous equation, then it is possible to test the significance of the parameter of this variable. If more than one power of $\hat{Y}_i^2$ is added, a χ test or an F test can be used. If one power of $\hat{Y}_i^2$ is used, equation (4.4.7) will take the form:

$$Y_i = \beta_0 + \beta_1' X_{1i} + \beta_2' X_{2i} + \beta_4 \hat{Y}_i^2 + \varepsilon_i \tag{4.4.8}$$

and in this case the F test is equivalent to the square of the simple t test of the added $\hat{Y}_i^2$ parameter (the t test of β_4 in equation 4.4.8). One limitation of the RESET test is that even in the case where the statistic of the test is significant, it provides no indication of an alternative appropriate form. It is for this reason that RESET is considered "a test of general misspecification, as opposed to a test of specification" (Stewart, 1991, p.71).

It has to be noted that the following analysis does not include the Durbin-Watson test for autocorrelation. As Kelejian and Robinson have argued "*the test is not valid in the presence of current or lagged endogenous variables... Furthermore, the test should not be* *applied in panel data framework unless very strong assumptions are made*" (Kelejian et al. 1997, p. 128).

4.5 Measuring the contribution of public infrastructure capital in Greece: the impact at the national level and alternative specifications

This section is presented in two parts. In the first (tables 4.4 to 4.6), the LSDV model is compared to alternative models. In the second (table 4.7), the data set has been partitioned temporally. The following key will be convenient for the interpretation of these tables.

Constant	=	constant term of regression
lnQ	=	natural logarithm of output
lnK	=	natural logarithm of private capital
lnL	=	natural logarithm of labour input
lnG	=	natural logarithm of public capital
lnPG	=	natural logarithm of productive public capital
lnSG	=	natural logarithm of social public capital
$\hat{Y}_i^2$	=	predicted values of the dependant variable
time trend	=	a simple time trend
lnCU	=	natural logarithm of capacity utilisation
$\bar{R}^2$	=	adjusted R square for degrees of freedom
SSR	=	error sum of squares
SE	=	standard error

The results of tables 4.4 to 4.6 compare the LSDV model with the OLS alternative, present an equation by which the RESET test is conducted, and the LSDV model estimated in first differences. The results concern the unconstrained Cobb-Douglas function (for the constrained versions, see section 4.6, in this chapter). Three sets of equations are compared, all referring to the results for Greece as a whole. These findings are based on panel of 49 prefectures for eleven years. The first model (table 4.4, 1a) is the fixed-effects formulation with labour input, private capital, a time trend, and the capacity utilisation. The elasticities of both private capital and labour are highly statistically significant. The share of labour input in the production process is much larger at 0.828, while private capital elasticity is only 0.093. This means that say a one-percent increase in the labour input factor would result in an approximately 0·8 ~~80~~ percent increase in the industrial output. On the other hand, a similar increase of public capital input would only increase output by around 0·1 ~~ten~~ percent. Thus, an increase of labour input is eight times more 'productive' than the respective increase of private capital input.

This is a rather unsurprising result given that during the eighties private investment had sharply declined. These results are not much different from the OLS formulation (2a), which, however, is rejected with a simple Chow test (even at the 1 percent level). The third variant (3a) is not comparable with either the LSDV or OLS formulations, and is the formulation in which the squares of the predicted values of the dependent variable ($\hat{Y}_i^2$) from the fixed effects variant (1a) have been used as a regressor ($\hat{Y}_i^2$), in order to perform the RESET test. As it is clear from the *t*-statistic of ($\hat{Y}_i^2$), or its equivalent *F*-test in last column, that the null hypothesis of linear specification (in this case specification 1a) cannot be rejected. Specification (4a) is exactly the same as (1a), but here the data are in first differences (note that first-differencing reduces the number of observations). The labour input coefficient becomes smaller, and that for private capital becomes slightly higher. However, the overall fitness of the specification, as measured by the adjusted R^2, is extremely low. In all cases the private sector inputs coefficients are statistically significant.

Table 4.4 Industrial output as a function of private capital stock (lnK) and labour (lnL), 1982-1992

Equation for Output (lnQ)

Specification	Constant	lnK	lnL	Time trend	lnCU	$\hat{Y}_i^2$	$\bar{R}^2$	SSE	SE	F-test
LSDV	20.019	0.093	0.828	0.028	-1.870		0.985	23.784	0.221	
(1a)	(5.057)***	(2.125)**	(16.800)***	(5.020)***	(-2.068)**					
OLS	17.692	0.177	0.865	0.029	-1.906		0.966	57.994	0.330	14.563
(2a)	(3.054)***	(9.592)***	(40.143)***	(3.477)***	(-1.417)					
RESET EQ.	16.051	0.067	0.555	0.018	-1.192	0.009	0.985	23.775	0.221	0.179
(3a)	(1.575)	(0.864)	(0.854)	(0.763)	(-0.648)	(0.423)				
FD LSDV	0.054	0.169	0.557		-0.950		0.061	27.745	0.252	
(4a)	(0.677)	(2.298)**	(6.525)***		(-1.299)					

Note: *t*-statistics in parentheses (and henceforth in all tables)

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

In the next set of comparisons (table 4.5, 1b to 4b), the public capital variable has been introduced into every equation. Thus, specification (1b) is the LSDV model with public capital[17]. Here, the coefficient for public capital is high relative to that of private capital (the introduction of public capital makes little difference to the private input coefficients, reducing them both marginally, and all are statistically significant). Again the OLS variant (2b) has been rejected with the use of a Chow *F*-test. The linear specification cannot be rejected, as the RESET test shows in equation (3b). Finally, the LSDV estimation of the first-differences (variant 4b) gives a high coefficient for public infrastructure, when at the same time the labour coefficient appears to be relatively low.

Table 4.5 Industrial output as a function of private capital stock (lnK), labour (lnL), and infrastructure capital stock (lnG), 1982-1992

Equation for Output (lnQ)

Specification	Constant	lnK	lnL	lnG	Time trend	lnCU	$\hat{Y}_i^2$	$\bar{R}^2$	SSE	SE	F-test
LSDV	14.131	0.088	0.811	0.202	0.004	-1.385		0.985	23.473	0.220	
(1b)	(3.091)***	(1.999)**	(16.387)***	(2.534)**	(0.353)	(-1.507)					
OLS	16.151	0.178	0.849	0.052	0.023	-1.771		0.966	57.588	0.329	14.685
(2b)	(2.769)***	(9.692)***	(36.679)***	(1.938)*	(2.515)**	(-1.318)					
RESET EQ.	12.836	0.071	0.631	0.155	0.003	-1.045	0.006	0.985	23.469	0.220	0.085
(3b)	(2.014)***	(1.010)	(1.021)	(0.864)	(0.257)	(-0.704)	(0.292)				
FD LSDV	-0.008	0.166	0.531	0.451		-0.752		0.072	27.366	0.250	
(4b)	(-0.090)	(2.265)***	(6.210)***	(2.462)***		(-1.028)					

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

[17] A possible problem for time-series analysis is the potential collinearity between these variables. The simple correlations between them (as well the infrastructure variables used in the following set of equations) were low. However, such a measure of multicollinearity is weak and cannot reveal more complex interrelationships between the independent variables. For this reason, a matrix decomposition (variance-decomposition proportions) of the independent variables matrix was conducted. Again there was no evidence that there is linear dependency between the variables (for both the matrix with the total public capital, and for that where infrastructure is divided into its productive and social parts). Nevertheless, even with matrix decomposition, it can be difficult to separate linear relations. (For a full presentation of these problems refer to Judge et al. (1985)). In any case, panel data sets naturally seem to exhibit less collinearity, as the cross-section dimension adds considerable variability between the spatial unit of the analysis (Baltagi 1995).

In the third set of equations (table 4.6), instead of the total public infrastructure, its two components - productive and social public capital - are introduced. In equation (1c), which is the LSDV variant, the results are according with expectations. The productive part of infrastructure appears to have a positive and significant impact on private sector production processes, whereas its social counterpart is statistically insignificant. As in the previous sets of equations, the fixed effects variant is superior to the OLS specification, the latter being rejected by the *F*-test. Also the RESET test shows that the Cobb-Douglas specification cannot be rejected (variant 3c). Finally, in the fixed-effects version of the first-differences (4c), the social component of infrastructure appears to have an extremely high coefficient, but again the adjusted R^2 is low.

Table 4.6 Industrial output as a function of private capital stock (lnK), labour (lnL), productive (lnPG) and social infrastructure capital stock (and lnSG), 1982-1992

Equation for Output (lnQ)

Specification	Constant	lnK	lnL	lnP(G)	lnS(G)	Time trend	lnCU	$\hat{Y}^2$	$\bar{R}^2$	SSE	SE	F-test
LSDV	13.481	0.089	0.806	0.170	0.060	0.002	0.304		0.985	23.402	0.220	
(1c)	(2.942)***	(2.035)**	(16.188)***	(2.526)**	(0.942)	(0.180)	(-1.445)					
OLS	16.145	0.178	0.847	0.037	0.018	0.023	-1.773		0.966	57.482	0.329	14.684
(2c)	(2.756)***	(9.660)***	(36.447)***	(1.010)	(0.841)	(2.416)**	(-1.317)					
RESET EQ.	11.882	0.067	0.563	0.116	0.043	0.001	-0.883	0.008	0.985	23.395	0.220	0.157
(3c)	(1.946)*	(0.938)	(0.912)	(0.760)	(0.573)	(0.109)	(-0.607)	(0.397)				
FD LSDV	-0.016	0.172	0.532	0.278	0.400		-0.883		0.079	27.091	0.249	
(4c)	(-0.194)	(2.362)**	(6.256)***	(1.787)*	(2.528)**		(-1.204)					

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

A first tentative conclusion from these comparisons is that the fixed-effects formulation (LSDV) must be favoured and in the following analysis (tables 4.7 to 4.14) only the fixed effects model has been used. A second conclusion is that the labour coefficient[18] is higher than that obtained by time-series analysis (see Segoura and Christodoulakis, 1997), while the private and public capital coefficients are much lower. However, and given that the time period of the analysis of these authors is almost three times longer than that used here, such differences can be attributed to two main reasons.

[18] The high labour share is similar to the findings of Holtz-Eakin (1992a), and Kelejian and Robinson (1997, p128) who argue that "the coefficient of the labor variable is, in many cases, too high and so one expects that it may be at least partially, a proxy for some omitted factors".

Segoura and Christodoulakis incorporate totally different stages of Greek economic development, namely those of the sixties and early seventies[19], where, arguably, public capital has played a greater role than in the later period. Also, as pointed out earlier in this chapter, their definition of infrastructure capital is much broader than the one used here. A third conclusion is that when public capital is disaggregated into its productive and social parts, it seems that the results accord with expectations. Productive infrastructure has a positive and significant impact on private production, while the social component is not significant. Finally, if the results obtained, and more particularly public capital's elasticity generated by the LSDV version (0.202 in table 4.5) is compared to empirical findings from other countries (see table 4.1), it seems that this coefficient is close to the norm, for the studies where positive results have reported.

Table 4.7 presents a comparison of the two different periods constituting the overall time dimension of this analysis. The first is from 1982 to 1987 and the second from 1988 to 1992. Again there are three sets of equations to be compared. In the first pair, the production function is examined without public infrastructure. Between 1982-1987 (1a) Greek manufacturing seems to exhibit decreasing returns to scale. This is probably due to the significant decline of private investment in this period, possibly caused by the adjustment shock due to the intensified competition from imported manufactured goods from the EU, arising out of new membership. It can be seen that private investment is the likely culprit because the coefficient of private capital is only 15 percent. The corresponding coefficient for the period 1988-1992 is 45 percent. In this latter period industry exhibits constant returns of scale (1b). When public capital is added to the equations it is shown to be statistically insignificant for both time periods, either for total infrastructure (2a and 2b), or in its productive and social parts (3a and 3b). These results confirm the argument that impact of public capital on economic development can be detected only over long time periods.

[19] During the period 1960-1985 the secondary sector in Greece increased its share of GDP from 25.7 to 29 percent. However, two thirds of this increase occurred during the period 1960-1970. As Vaitsos and Giannitsis (1987, p. 31) remark "after 1970, under the strain of economic crisis, and the general characteristics-problems of the development course of the Greek economy, there was a deceleration of both the quantitative and qualitative performance of the secondary sector, and the economy in general".

Table 4.7 Industrial output as a function of private capital stock (lnK), labour (lnL), infrastructure capital stock (lnG) and productive and social infrastructure capital stock (lnPG and lnSG), 1982-1987 and 1988-1992

Equation for Output (lnQ) according to specified time intervals

Time period	Constant	lnK	lnL	lnG	lnP(G)	lnS(G)	Time trend	lnCU	$\bar{R}^2$	SSE	SE
1982-87	11.450	0.149	0.641				0.044	0.124	0.988	9.252	0.196
(1a)	(2.305)**	(2.623)***	(6.411)***				(6.183)***	(0.110)			
1988-92	12.740	0.455	0.562				0.010	-1.366	0.989	6.665	0.186
(1b)	(1.880)*	(3.466)***	(7.152)***				(0.907)	(-0.930)			
1982-87	6.811	0.138	0.645	0.224			0.006	0.222	0.988	9.187	0.196
(2a)	(1.114)	(2.397)**	(6.457)***	(1.299)			(0.219)	(0.197)			
1988-92	22.284	0.475	0.559	-0.515			0.038	-1.189	0.989	6.607	0.186
(2b)	(2.228)**	(3.601)***	(7.131)***	(-1.296)			(1.564)	(-0.807)			
1982-87	8.951	0.126	0.666		0.226	-0.115	0.007	0.223	0.988	9.177	0.195
(3a)	(1.475)	(2.159)**	(6.618)***		(1.580)	(-1.141)	(0.256)	(0.197)			
1988-92	19.747	0.489	0.554		-0.512	0.141	0.032	-1.286	0.989	6.562	0.186
(3b)	(2.054)**	(3.695)***	(7.054)***		(-1.451)	(1.006)	(1.383)	(-0.874)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

4.6 Measuring the contribution of public infrastructure capital in Greece: Investigating the possibilities for constant and non-constant returns of scale

One of the most common assumptions in economic modelling is that of constant returns of scale (which reflects in essence the assumption of perfect competition). On the other hand, "*the basic problem with doing theory in economic geography has always been the observation that any sensible story about regional and urban development must hinge crucially on the role of increasing returns*" as Fujita, Krugman, and Venables have argued (forthcoming). It is evident that the type of returns of scale that the production process is a subject well worth pursuing.

The Cobb-Douglas production function is homogeneous[20] of degree $a+b$ if it has the standard form of the two input variables. With private capital (K) and labour (L) it becomes:

[20] A function is homogeneous of degree r, if once each of its independent variables is multiplied by a constant λ, then the value of the function will be altered by the proportion λ^r.

$$Q(\lambda K, \lambda L) = A(\lambda K)^a(\lambda L)^b = \lambda^{a+b}AK^aL^b = \lambda^{a+b}Q(K,L) \quad (4.6.1)$$

If the public capital input (G) is added it will be homogeneous of degree a+b+c as follows:

$$Q(\lambda K, \lambda L, \lambda G) = A(\lambda K)^a(\lambda L)^b(\lambda G)^c = \lambda^{a+b+c}AK^aL^bG^c = \lambda^{a+b+c}Q(K,L,G) \quad (4.6.2)$$

The degree of homogeneity means that if $a+b=1$[21] then constant returns to scale apply, if $a+b>1$ there are increasing returns, and if $a+b<1$ then there are decreasing returns to scale for the two input (*K, L*) production function. The respective formulations for the function in which public capital is added (*K, L, G*) are $a+b+c=1$ for constant returns, $a+b+c>1$ for increasing returns, and $a+b+c<1$ when decreasing returns to scale apply.

The returns to scale concept is important because it represents the type of technology of the production function. Constant returns of scale mean that if the amount of all inputs (and not just one of them as is the case of the diminishing returns) is increased by a constant factor, then the output will be increased by the same factor. In the long run, this is the expected type of returns of scale, as the replication of the production process will normally give twice the product. In the case of increasing returns, output increases will be greater than the increase in production factors (normally this can happen only for a limited range of output). Finally, in the case of decreasing returns, the output increase will be smaller (something like this can occur, normally, only in the short run).

To test for the type of returns of scale, a restricted least squares method of estimation was used. The first two rows of table 4.8 presents the results for the simple Cobb-Douglas production function, where output (*Q*) is a function of two inputs, private capital (*K*) and labour (*L*), where the first row is referring to the OLS model, and the second the LSDV specification. The results for these regressions have been already presented in table 4.4, and are given again here to compare them with the restricted version. It has also to be mentioned that the last column of table 4.8 gives the results for

[21]This case is sometimes called as linearly homogeneous.

the Chow test (F-test) which is used in order to discriminate between the OLS and LSDV models.

Table 4.8 Industrial output as an unrestricted and constrained function of private capital stock (K) and labour (L), with the (unrestricted) addition of public capital infrastructure stock (G), 1982-1992

								Equation for Output (lnQ)			
Row No.	**Specification**	**Restriction**	**Constant**	**lnK**	**lnL**	**Time trend**	**lnCU**	$\bar{R}^2$	**SSE**	**SE**	**F-test**
1	OLS	no restriction	17.692 (3.054)***	0.177 (9.592)***	0.865 (40.143)***	0.029 (3.477)***	-1.906 (-1.417)	0.966	57.994	0.330	
2	LSDV	no restriction	20.019 (5.057)***	0.093 (2.125)**	0.828 (16.800)***	0.028 (5.020)***	-1.870 (-2.068)**	0.985	23.784	0.221	14.563
3	OLS	a+b=1	17.619 (2.981)***	0.190 (10.260)***	0.810 (43.620)***	0.028 (3.323)***	-1.860 (-1.355)	0.964	60.508	0.336	
4	LSDV	a+b=1	19.349 (4.916)***	0.126 (3.311)***	0.874 (23.010)***	0.029 (5.159)***	-1.910 (-2.112)**	0.985	23.888	0.221	15.553

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

In the last rows of table 4.8 the same equation is tested for constant returns of scale ($a+b=1$). In this case, if the constraint is rearranged ($b=1-a$), the original equation will be:

$$Q = AK^{a}L^{1-a} \qquad (4.6.3)$$

(t, CU, e, and subscripts i and t from hereon will be omitted for clarity of the presentation)

which when expressed in logarithmic form becomes:

$$\ln Q = A + a\ln K + (1\text{-}a)\ln L, \qquad (4.6.4a)$$

or

$$\ln Q = A + a(\ln K\text{-}\ln L) + 1(\ln L) \qquad (4.6.4b)$$

where the coefficient of the last term of the right-hand side of the equation is constrained to be equal to one (the error term, time trend, and CU, are omitted for clarity of presentation).

It has to be mentioned at this point that in empirical work, there are two ways by which an equation with such kind of restrictions can be estimated. It can be either directly estimated by an econometric computer program, with the restriction imposed (in this case it can be estimated as an equation of the 4.6.4 form), or an equation of the following type can be used instead:

$$\ln Q - \ln L = A + a(\ln K - \ln L) \tag{4.6.5}$$

However, if this last form is being used (instead of equation 4.6.4) some care is needed, as some statistical tests might not be interpreted correctly.

For instance, it may be desirable to compare the restricted equation (with the assumption of constant returns of scale and, thus, the coefficients restricted to equal one) and the equation without such a restriction. One option is to use the *F*-test based on the R square results[22]. In this case, however, it has to be taken into account the fact that the dependent variable of these two equations is different (despite that these are essentially the same equation differently formulated). Thus, the results for the R squares and adjusted R squares would be different. Nevertheless, the results for the estimated coefficients, standard errors, variance of the estimate, sum of squared errors, and all the other statistics would be the same irrespective of which of the forms is chosen (for an extensive analysis of these points see Greene 1993, chapter 7). In order to avoid any confusion here equation 4.6.4 has been used, and not only for the case of constant returns of scale, but also for all the other cases examining the returns to scale considered in this section.

To return to the results of table 4.8, the first conclusion that can be drawn is that the LSDV calibrations must to be preferred to the OLS alternatives, based on the Chow tests (*F*-tests). The unrestricted LSDV equation in row 2 (the odd numbered rows generally give the OLS and the even numbered the LSDV specification) appears to exhibit slightly decreasing returns of scale, and the reason for this seems to be the poor performance of private capital. If this equation is compared to the LSDV version, where the restriction of constant returns of scale is imposed (row 4), then the latter appears to have a more reasonable coefficient for private capital (0.126 and statistically significant).

[22] If, however, an *F*-test based on the sum of squared residuals is used then there would not be a problem (see Greene 1993, pp. 208-209).

The coefficients for the labour input are more or less at the same level - that is 0.828 and 0.874 for the unconstrained and constrained versions respectively (both are statistically significant). The overall measures of performance (adjusted R square, sum of squared errors, and standard error of the estimate) of these regressions do not help to judge which variant is the best as they are almost all identical.

Table 4.9 gives the results for the unconstrained and several constrained versions of the Cobb-Douglas production function when the public capital variable is added into the equation. The unconstrained form will be:

$$\ln Q = A + a\ln K + b\ln L + c\ln G \qquad (4.6.7)$$

The results for this equation are given in the first and second rows of table 4.9, and refer to the OLS and LSDV formulations respectively. Again a Chow test helps to discriminate between these two variants. These results have been already reported in table 4.5. The next rows give the empirical findings for the different constraints imposed on equation (4.6.7). Rows 3 and 4 give the results for the case where there are constant returns of scale only for the private inputs ($a+b=1$). Rows 5 and 6 deals with constant returns of scale over all the production inputs ($a+b+c=1$). Rows 7 and 8 relate to constant returns of scale over all the production inputs but with the elasticities of private and public capital the same ($a+b+c=1$, and $a=c$).

Table 4.9 Industrial output as a constrained function of private capital stock (K), labour (L), and public capital infrastructure stock (G), 1982-1992

Equation for Output (lnQ)

Row No.	Specification	Restriction	Constant	lnK	lnL	lnG	Time trend	lnCU	$\bar{R}^2$	SSE	SE	F-test
1	OLS	no	16.151	0.178	0.849	0.052	0.023	-1.771	0.966	57.588	0.329	
		restriction	(2.769)***	(9.692)***	(36.679)***	(1.938)*	(2.515)**	(-1.318)				
2	LSDV	no	14.131	0.088	0.811	0.202	0.004	-1.385	0.985	23.473	0.220	14.685
		restriction	(3.091)***	(1.999)**	(16.387)***	(2.534)**	(0.353)	(-1.507)				
3	OLS	a+b=1	14.903	0.184	0.816	0.094	0.017	-1.647	0.966	58.162	0.330	
			(2.556)**	(10.090)***	(44.660)***	(4.641)***	(1.975)***	(-1.222)				
4	LSDV	a+b=1	14.018	0.129	0.871	0.177	0.008	-1.497	0.985	23.642	0.221	14.784
			(3.059)***	(3.407)***	(23.000)***	(2.246)**	(0.716)	(-1.628)				
5	OLS	a+b+c=1	18.847	0.180	0.860	-0.040	0.034	-1.995	0.965	59.109	0.333	
			(3.217)***	(9.669)***	(37.050)***	(-3.555)***	(3.939)***	(-1.468)				
6	LSDV	a+b+c=1	16.549	0.074	0.796	0.130	0.012	-1.539	0.985	23.535	0.220	15.304
			(4.089)***	(1.762)*	(16.710)***	(2.696)***	(1.475)	(-1.693)*				
7	OLS	a+b+c=1	20.244	0.010	0.979	0.010	0.029	-1.968	0.957	72.304	0.368	
		& b=c	(3.128)***	(0.912)	(43.280)***	(0.912)	(3.059)***	(-1.310)				
8	LSDV	a+b+c=1	16.984	0.100	0.801	0.100	0.016	-1.615	0.985	23.560	0.220	20.991
		& b=c	(4.247)***	(4.228)***	(16.990)***	(4.228)***	(2.457)**	(-1.789)*				
9	OLS	b=c	14.243	0.139	0.866	0.139	0.012	-1.580	0.965	59.268	0.333	
			(2.418)**	(8.863)***	(37.580)***	(8.863)***	(1.413)	(-1.161)				
10	LSDV	b=c	16.214	0.115	0.809	0.115	0.014	-1.586	0.985	23.546	0.220	15.361
			(3.817)***	(3.077)***	(16.340)***	(3.077)***	(1.966)**	(-1.753)*				

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Finally, in rows 9 and 10, the only restriction is that the elasticities of private and public capital are the same (*a*=*c*). The corresponding equations to these constraints will be:

$a + b = 1$: $\qquad \ln Q = A + a(\ln K - \ln L) + 1(\ln L) + c\ln G, \qquad (4.6.8)$

$a + b + c = 1$: $\qquad \ln Q = A + a(\ln K - \ln L) + 1(\ln L) + c(\ln G - \ln L), \qquad (4.6.9)$

$a + b + c = 1$, and $a = c$: $\qquad \ln Q = A + a(\ln K + \ln G - 2\ln L) + 1(\ln L), \qquad (4.6.10)$

$a = c$: $\qquad \ln Q = A + a(\ln K + \ln L) + b(\ln L), \qquad (4.6.11)$

All Chow tests (*F*-tests) in table 4.9 show that the OLS variations must be rejected in favour of the LSDV alternatives, as was also the case for the equations in table 4.8. However, as in table 4.8, the overall measures of performance do not help to distinguish the best LSDV version (among the even rows of table 4.9). All three measures appear to be extremely close. In any case, the unconstrained specification of row 2, the one in which there are constant returns of scale only for the private inputs (row 4), and the version with constant returns of scale over all the production inputs (row 6), appear to be much the same, in terms of the estimated coefficients. Only private capital's elasticity appears to be somewhat higher in row 4 (0.129), in comparison to the results in versions of rows 2 and 6 (0.088 and 0.074 respectively). The results for the last two versions, in rows 8 and 10, are also very close.

Overall the results presented in tables 4.8 and 4.9 can be summarised as follows. In all cases, with and without the presence of the infrastructure variable in the equations, with and without the constraints regarding the returns of scale, the OLS specifications were rejected in favour of the LSDV alternatives. This is in accordance to the findings of section 4.5 of this chapter. The other important conclusion is that the results for the unconstrained versions, for both the equations with and without public capital, are very similar to those obtained by the different versions with constraints regarding the type of returns of scale. Given the fact that the overall measures of performance of these regressions are so similar, it can at least be argued that the unconstrained equations cannot be rejected.

4.7 Measuring the contribution of public infrastructure capital in Greece: the impact on regional growth

This part of the chapter forms the regional analysis of the impact of public infrastructure. Table 4.10 presents the 51 prefectures of Greece (plus the 49 used in the analysis) and the way in which they are combined to form the thirteen official regions of Greece and the ten regions of analysis. Actually, the ten analytical regions are identical to the official thirteen, with only three exceptions. Attica was added to the Central Greece prefectures, Peloponnese and West Greece regions have been merged to form a bigger region, and the same was the case for the North and South Aegean Islands. These larger regions were dictated first by the need for larger regional panels (in order to increase the degrees of freedom), and secondly by the economic geography of Greece. Attica's economic influence can be extended at least into the adjacent prefecture of Viotia, and even though for administrative reasons it is justifiable to treat Attica as a single region, in economic analysis of this type, the interaction between the metropolitan area of Athens and its economic hinterland (in adjacent prefectures) is significant. In addition, it would be impossible, technically, to have a panel for a region constituted by only one prefecture.

Table 4.10 Official Regions of Greece (NUTS II), and Regions used in the Analysis

REGION	PREFECTURE	REGION	PREFECTURE
1. EAST MACEDONIA-THRACE	Evros	7. WEST GREECE	Aitoloakarnania
	Xanthi		Achaia
	Rodopi		Ilia
	Drama	8. CENTRAL GREECE	Viotia
	Kavala		Evia
2.CENTRAL MACEDONIA	Imathia		Evritania
	Thessaloniki		Fthiotis
	Kilkis		Fokida
	Pella	9. ATTIKI	Attica
	Pieria	10. PELOPONNESE	Argolida
	Serres		Arcadia
	Halkidiki		Korinthia
3. WEST MACEDONIA	Kastoria		Laconia
	Kozani		Messinia
	Florina	11. NORTH AEGEAN	Lesvos
	Grevena		Samos
4. EPIRUS	Arta		Chios
	Thesprotia	12. SOUTH AEGEAN	Dodecanissos
	Ioannina		Kyclades
	Preveza	13. CRETE	Iraklio
5. THESSALIA	Karditsa		Lasithi
	Larissa		Rethimno
	Magnisia		Chania
	Trikala		
6. IONIAN ISLANDS	Zakynthos*		
	Kerkyra		
	Kephalonia*		
	Lefkada**		

*These prefectures were merged for analytical reasons
**This prefecture was excluded from the analysis as there was no industrial activity

Regions Used in the Regression Analysis

1	EAST MACEDONIA-THRACE
2	CENTRAL MACEDONIA
3	WEST MACEDONIA
4	EPIRUS
5	THESSALIA
6	IONIAN ISLANDS
7	PELOPONNESE AND WEST GREECE (NUTS II regions 7 and 10)
8	ATTIKI AND CENTRAL GREECE (NUTS II regions 8 and 9)
9	AEGEAN ISLANDS (NUTS II regions 11 and 12)
10	CRETE

North Greece is comprised by regions (used in this analysis) 1, 2, 3, 4, 5
South Greece is comprised by regions (used in this analysis) 6, 7, 8, 9, 10

Table 4.11 begins the presentation of the empirical results. The first row repeats the results for the elementary Cobb-Douglas specification, without public infrastructure, for Greece as a whole. As above, labour elasticity is high, when at the same time that for private capital is low. Labour's elasticity is slightly higher in the Northern panel (0.970 and statistically significant) compared to the Southern panel (0.781). However, private capital's coefficient for the Southern panel appears to be insignificant. At first sight this result seems to be counterintuitive in that Attica (including the metropolitan area of Athens) not only concentrates more than 40 percent of the labour force, but has attracted the most skilled workers in the country. The explanation may, in part, lie in the nature of the panel. Even though Attica produces, on an average, 42 percent of the total national value added, and secures some 35 percent of all the private capital investment during the period of analysis, it is just one prefecture among many in this Southern panel.

Table 4.11 Industrial output as a function of private capital stock (lnK), and labour (lnL), 1982-1992

						Equation for Output (lnQ)		
REGION	**Constant**	**lnK**	**lnL**	**Time trend**	**lnCU**	$\bar{R}^2$	**SSE**	**SE**
Greece (as a total)	20.019	0.093	0.828	0.028	-1.870	0.985	23.784	0.221
	(5.057)***	(2.125)**	(16.800)***	(5.020)***	(-2.068)**			
North	13.832	0.185	0.970	0.028	-1.241	0.991	5.256	0.149
	(3.574)***	(3.940)***	(14.149)***	(5.171)***	(-1.424)			
South	22.234	0.038	0.781	0.027	-2.342	0.981	18.074	0.271
	(3.299)***	(0.544)	(10.803)***	(2.736)***	(-1.509)			
High Output	18.575	0.107	0.550	0.035	-1.208	0.992	1.411	0.095
	(5.471)***	(1.379)	(6.533)***	(7.903)***	(-1.775)*			
Intermediate Output	3.610	0.335	0.969	0.017	0.476	0.865	4.906	0.172
	(0.666)	(3.346)***	(10.225)***	(2.216)**	(0.399)			
Low Output	33.255	0.107	0.793	0.032	-4.943	0.868	16.242	0.323
	(3.317)***	(1.410)	(9.059)***	(2.160)**	(-2.135)**			
East Maced. & Thrace	16.876	0.039	0.623	0.034	-0.616	0.974	0.506	0.105
	(2.717)***	(0.373)	(3.629)***	(3.463)***	(-0.458)			
Central Macedonia	13.064	0.270	0.759	0.033	-1.066	0.988	1.257	0.138
	(1.692)*	(1.383)	(5.861)***	(3.514)***	(-0.710)			
West Macedonia	22.372	0.151	1.166	0.030	-3.430	0.985	1.495	0.204
	(1.757)*	(1.053)	(4.433)***	(1.406)	(-1.171)			
Epirus	19.711	0.185	1.073	0.044	-2.672	0.899	1.222	0.184
	(1.689)*	(2.228)**	(5.455)***	(2.609)**	(-1.003)			
Thessaly	3.827	0.210	1.022	0.024	0.880	0.995	0.327	0.095
	(0.589)	(1.646)	(6.897)***	(2.765)***	(0.644)			
Ionian Islands	46.123	0.313	0.957	0.079	-9.057	0.806	1.247	0.279
	(1.617)	(0.807)	(3.112)***	(1.483)	(-1.512)			
West Greece & Peloponn.	23.048	0.159	0.608	0.038	-2.558	0.987	2.268	0.173
	(2.819)***	(0.921)	(7.632)***	(3.045)***	(-1.464)			
Sterea	11.179	-0.155	1.045	0.006	0.992	0.982	5.456	0.312
	(0.701)	(-0.999)	(4.036)***	(0.265)	(0.271)			
Aegean Islands	24.447	-0.094	1.044	0.012	-2.538	0.892	4.424	0.310
	(1.328)	(-0.260)	(5.329)***	(0.394)	(-0.640)			
Crete	19.869	-0.035	0.575	0.043	-1.322	0.963	2.888	0.283
	(1.107)	(-0.243)	(2.524)**	(1.619)	(-0.316)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The panel for Northern Greece contains (it is said) some of the most dynamic industrial districts in Greece, while the Southern panel has some of the most backward prefectures in terms of economic and industrial development, as well as the majority of the prefectures solely oriented towards tourism. However, these results may simply reflect the reality of economic performance in the eighties. Other research has demonstrated that output and employment in prefectures such as Attica have been in heavy decline in this period, in total contrast with many areas in Northern Greece (Melachroinos and Spence, 1997).

Table 4.11 also reports the results for the three groups of prefectures characterised by high, intermediate, and low levels of manufacturing output defined in section 4.3. It is interesting to observe that the roles of the basic factor inputs are significantly different across these classes of prefectures. Intermediate output prefectures have the highest elasticity for labour 0.969, while for high and low output prefectures it is only 0.550 and 0.793 respectively. Again private capital's elasticity in intermediate output prefectures is 0.335 and significant, while for both high and low performance prefectures it is insignificant. The next ten regressions give the estimations for the most disaggregated spatial breakdown presented. It is obvious that there are notable differences between the coefficients for both private capital and labour. High labour elasticities are found in the regions of West Macedonia, Epirus, Thessaly, the Ionian Islands, Sterea (which includes Athens), and the Aegean Islands. The remaining regions also have a significant labour coefficient. In contrast, private capital's coefficient is statistically significant only for the Epirus region. These high labour coefficients and insignificant private capital elasticities can have two potential explanations. This picture may be a reflection of the decline of private investment in manufacturing (with labour using the existing capital stock). Another, possibility is that these regional panels are just not large enough - too few prefectures per panel to give a truly accurate picture of the true regional production functions.

In the next set of equations in table 4.12 the infrastructure variable has been added. The results for the private inputs of production are not greatly altered. From the second and third equations where the north-south divide is compared, it seems that public infrastructure has had a larger impact on the Southern part of the country. The coefficient for public capital is 0.153 for the North (and statistically significant only at the10 percent level), while in the South it is a substantial 0.329 (significant at 5 percent). The breakdown of prefectures based on output levels shows that infrastructure plays an important role for high output levels (0.158), and even more important (0.644) for low output prefectures, while it is not statistically significant for those at an intermediate level of output. The coefficient for low output regions is extremely high and it is possible that industries located there are extremely sensitive to perhaps modest changes of infrastructure levels.

Table 4.12 Industrial output as a function of private capital stock (lnK), labour (lnL), and public infrastructure capital stock (lnG), 1982-1992

Equation for Output (lnQ)

REGION	Constant	lnK	lnL	lnG	Time trend	lnCU	$\bar{R}^2$	SSE	SE
Greece	14.131	0.088	0.811	0.202	0.004	-1.385	0.985	23.473	0.220
(as a total)	(3.091)***	(1.999)**	(16.387)***	(2.534)**	(0.353)	(-1.507)			
North	8.908	0.200	0.950	0.153	0.010	-0.828	0.991	5.117	0.148
	(1.919)*	(4.217)***	(13.753)***	(1.896)*	(0.915)	(-0.927)			
South	13.212	0.005	0.756	0.329	-0.014	-1.605	0.981	17.649	0.268
	(1.730)*	(0.071)	(10.462)***	(2.430)**	(-0.708)	(-1.024)			
High	13.631	0.145	0.511	0.158	0.017	-0.899	0.992	1.358	0.094
Output	(3.502)***	(1.856)*	(6.058)***	(2.475)**	(1.998)**	(-1.319)			
Intermediate	0.025	0.368	0.942	0.104	0.005	0.728	0.865	4.876	0.172
Output	(0.004)	(3.488)***	(9.559)***	(0.995)	(0.377)	(0.597)			
Low	13.676	0.061	0.748	0.644	-0.052	-3.107	0.875	15.392	0.315
Output	(1.153)	(0.806)	(8.621)***	(2.926)***	(-1.607)	(-1.324)			
East Maced.	12.172	0.075	0.636	0.125	0.019	-0.302	0.974	0.496	0.105
& Thrace	(1.537)	(0.671)	(3.688)***	(0.959)	(1.034)	(-0.218)			
Central	10.965	0.286	0.744	0.057	0.028	-0.920	0.988	1.254	0.139
Macedonia	(1.143)	(1.422)	(5.447)***	(0.373)	(1.522)	(-0.590)			
West	23.321	0.145	1.173	-0.027	0.033	-3.507	0.984	1.494	0.207
Macedonia	(1.325)	(0.887)	(4.198)***	(-0.079)	(0.713)	(-1.123)			
Epirus	8.376	0.164	1.079	0.405	-0.007	-1.775	0.901	1.168	0.183
	(0.573)	(1.946)*	(5.532)***	(1.270)	(-0.168)	(-0.649)			
Thessaly	-3.434	0.255	0.811	0.251	-0.008	1.569	0.995	0.303	0.093
	(-0.447)	(1.999)*	(4.225)***	(1.671)	(-0.367)	(1.124)			
Ionian	12.040	-0.023	0.913	1.508	-0.102	-6.607	0.908	0.557	0.193
Islands	(0.567)	(-0.083)	(4.295)***	(4.307)***	(-1.821)*	(-1.582)			
West Greece	16.698	0.194	0.608	0.199	0.018	-2.202	0.987	2.209	0.172
& Peloponn.	(1.798)*	(1.119)	(7.682)***	(1.410)	(0.973)	(-1.255)			
Sterea	-3.803	-0.161	0.919	0.551	-0.062	1.878	0.982	5.245	0.309
	(-0.203)	(-1.046)	(3.408)***	(1.488)	(-1.207)	(0.513)			
Aegean	19.173	-0.084	1.017	0.177	-0.010	-2.132	0.890	4.411	0.313
Islands	(0.808)	(-0.231)	(4.807)***	(0.358)	(-0.145)	(-0.512)			
Crete	18.432	-0.045	0.581	0.049	0.036	-1.180	0.962	2.887	0.287
	(0.861)	(-0.271)	(2.463)**	(0.127)	(0.585)	(-0.269)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The regional breakdown to the NUTS II level does not give statistically significant results for any region, with the exception of the Ionian Islands, where the estimated coefficient is unrealistically high (1.508). These results probably mean that these production functions suffer from the limited dimensions of the respective panels[23].

Table 4.13 provides the results for the breakdown of public capital into its productive and social categories. The results for Greece as a whole and for the North are in line with both theoretical expectations and empirical results from other countries (for instance Munnell, 1990b for the US and Mas et al., 1993, 1994, and 1996 for Spain). Productive infrastructure has a positive and significant impact on the private sector, while social public capital is insignificant. However, for the Southern panel both productive and social categories of public capital appear to be positive, even though significant only at 10 percent. The results for prefectures classified by development level confirm the expected role of productive infrastructure having a positive and significant impact on high and low output levels (0.121 and a high 0.436 respectively). Insignificant results are recorded for all output classes of region for social infrastructure. The results for the regions give positive and significant productive infrastructure coefficients in West Macedonia, Epirus (only at the 10 percent level), the Ionian Islands, West Greece and Peloponnese, and Sterea (10 percent). The results for the social category are mixed. Some regions seem to have negative coefficients at the same time as others have positive values. (West Macedonia and the Ionian Islands have negative elasticities for social infrastructure, and Epirus, Sterea, and the Aegean Islands have the reverse.) If these coefficients are be taken at face value (and several are highly significant), it could be argued that social public capital has a positive effect in regions which are dominated by backward prefectures in terms of economic and industrial development or are predominately oriented towards tourism. Other research has demonstrated that output and employment in prefectures such as Attica (which is in Sterea) have been in heavy decline in this period, in total contrast to many areas in the supposedly more dynamic North of Greece (Melachroinos and Spence, 1997).

[23] The results from US research show that the larger the level of analysis, the greater is the estimated impact of public capital (Aschauer 1993), or at least this is the case for some infrastructure categories (Haughwout 1994). One potential explanation is that a larger scale analysis reveals spillover effects, which otherwise would remain undetectable. Indeed there are examples of research in which the existence of such spillovers has been specifically investigated (Mas 1996).

Table 4.13 Industrial output as a function of private capital stock (lnK), labour (lnL), and productive and social infrastructure capital stock (lnPG and lnSG), 1982-1992

Equation for Output (lnQ)

REGION	Constant	lnK	lnL	lnP(G)	lnS(G)	Time trend	lnCU	$\bar{R}^2$	SSE	SE
Greece	13.481	0.089	0.806	0.170	0.060	0.002	-1.329	0.985	23.402	0.220
(as a total)	(2.942)***	(2.035)**	(16.188)***	(2.526)**	(0.942)	(0.180)	(-1.445)			
North	9.001	0.199	0.956	0.148	-0.010	0.009	-0.780	0.991	5.146	0.148
	(1.880)*	(4.100)***	(13.523)***	(2.210)**	(-0.169)	(0.807)	(-0.869)			
South	11.865	0.001	0.741	0.228	0.204	-0.017	-1.656	0.981	17.454	0.268
	(1.566)	(0.018)	(10.196)***	(1.954)*	(1.751)*	(-0.898)	(-1.058)			
High	14.516	0.153	0.521	0.121	-0.019	0.020	-0.902	0.992	1.355	0.094
Output	(3.638)***	(1.944)*	(6.205)***	(2.418)**	(-0.390)	(2.327)**	(-1.317)			
Intermediate	-1.382	0.387	0.929	0.119	0.023	0.001	0.833	0.865	4.847	0.172
Output	(-0.210)	(3.569)***	(9.330)***	(1.192)	(0.238)	(0.062)	(0.683)			
Low	14.918	0.055	0.744	0.436	0.238	-0.042	-3.384	0.874	15.404	0.316
Output	(1.266)	(0.724)	(8.507)***	(2.339)**	(1.604)	(-1.350)	(-1.432)			
East Maced.	6.750	0.104	0.674	0.166	0.141	0.003	-0.044	0.974	0.482	0.105
& Thrace	(0.684)	(0.910)	(3.746)***	(1.446)	(0.749)	(0.102)	(-0.032)			
Central	14.367	0.255	0.742	0.060	-0.101	0.031	-1.051	0.988	1.225	0.138
Macedonia	(1.415)	(1.249)	(5.556)***	(0.485)	(-1.046)	(1.660)	(-0.673)			
West	26.792	0.236	1.354	0.716	-0.790	-0.025	-5.048	0.989	0.992	0.171
Macedonia	(1.886)*	(1.709)*	(5.817)***	(2.341)**	(-4.133)***	(-0.616)	(-1.951)			
Epirus	-4.427	0.228	1.031	0.415	0.538	-0.035	-1.197	0.915	0.972	0.169
	(-0.313)	(2.799)***	(5.624)***	(1.796)*	(2.705)**	(-0.886)	(-0.468)			
Thessaly	-1.796	0.256	0.859	0.170	0.000	0.000	1.486	0.995	0.309	0.095
	(-0.199)	(1.708)*	(4.026)***	(1.327)	(-0.002)	(0.010)	(1.029)			
Ionian	34.353	-0.590	0.962	1.338	-0.612	-0.015	-6.128	0.933	0.337	0.164
Islands	(1.840)*	(-2.031)*	(5.294)***	(5.249)***	(-1.971)*	(-0.288)	(-1.720)			
West Greece	17.779	0.248	0.606	0.347	-0.262	0.010	-2.215	0.987	2.128	0.170
& Peloponn.	(1.967)*	(1.418)	(7.752)***	(2.205)**	(-1.425)	(0.543)	(-1.279)			
Sterea	-15.869	-0.146	0.745	0.508	0.740	-0.098	1.494	0.984	4.651	0.294
	(-0.869)	(-0.995)	(2.822)***	(1.870)*	(2.866)***	(-1.992)*	(0.428)			
Aegean	-8.699	0.041	0.888	-0.105	1.751	-0.111	-1.783	0.925	2.943	0.259
Islands	(-0.430)	(0.135)	(5.061)***	(-0.289)	(4.705)***	(-1.765)*	(-0.518)			
Crete	15.490	-0.073	0.592	-0.119	0.422	0.021	-1.437	0.962	2.812	0.288
	(0.717)	(-0.429)	(2.476)**	(-0.347)	(0.957)	(0.332)	(-0.327)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

4.8 Measuring the contribution of public infrastructure capital in Greece: an analysis of the regional network effects

In the last two tables the outcomes of the network analysis[24] are presented. Table 4.14 gives the results for public capital in general. Here there is no analysis of Greece as a whole, nor of the north-south breakdown because it is expected that these panels as they stand can capture the network effects as they contain all or a large fraction of the prefectures. An examination of the findings shows that there are no spectacular changes

[24] As it was mentioned earlier (section 4.1), in network analysis the infrastructure endowment in the adjacent prefectures has been taken under consideration. This is also the case for islands-prefectures (where the infrastructure of the most proximate prefectures has been used).

between the results of table 4.14 (networks) from those of table 4.12 (prefectural infrastructure only without public capital network effects). The only significant changes in public capital coefficients when network infrastructure is used are for Epirus (0.609 significant at 10 percent) and Thessaly (0.433 at 5 percent).

Table 4.14 Industrial output as a function of private capital stock (lnK), labour (lnL), and infrastructure capital stock networks (lnG), 1982-1992

Equation for Output (lnQ)

REGION	Constant	lnK	lnL	lnG	Time trend	lnCU	$\bar{R}^2$	SSE	SE
East Maced. & Thrace	11.320 (1.385)	0.070 (0.643)	0.623 (3.629)***	0.151 (1.044)	0.017 (0.908)	-0.228 (-0.163)	0.974	0.494	0.105
Central Macedonia	16.774 (1.467)	0.232 (1.088)	0.783 (5.553)***	-0.097 (-0.442)	0.042 (1.895)*	-1.279 (-0.807)	0.988	1.253	0.139
West Macedonia	14.897 (0.839)	0.167 (1.136)	1.110 (3.950)***	0.221 (0.610)	0.003 (0.061)	-2.801 (-0.895)	0.984	1.479	0.206
Epirus	1.918 (0.127)	0.172 (2.121)**	1.026 (5.327)***	0.609 (1.791)*	-0.030 (-0.678)	-1.447 (-0.541)	0.905	1.119	0.179
Thessaly	-9.926 (-1.254)	0.273 (2.267)**	0.792 (4.889)***	0.433 (2.668)**	-0.029 (-1.328)	1.972 (1.484)	0.996	0.272	0.088
Ionian Islands	40.827 (1.535)	-0.451 (-0.837)	0.738 (2.401)**	1.168 (1.901)*	0.039 (0.728)	-10.246 (-1.833)*	0.833	1.005	0.259
West Greece & Peloponn.	21.591 (2.047)**	0.164 (0.936)	0.603 (7.262)***	0.050 (0.221)	0.033 (1.254)	-2.487 (-1.390)	0.986	2.266	0.174
Sterea	8.763 (0.444)	-0.159 (-1.009)	1.029 (3.787)***	0.095 (0.212)	-0.003 (-0.067)	1.101 (0.296)	0.981	5.452	0.315
Aegean Islands	21.335 (0.845)	-0.086 (-0.236)	1.029 (4.813)***	0.099 (0.183)	0.000 (-0.002)	-2.311 (-0.551)	0.889	4.420	0.313
Crete	24.447 (1.082)	-0.034 (-0.230)	0.570 (2.467)**	-0.138 (-0.341)	0.063 (0.962)	-1.706 (-0.389)	0.962	2.879	0.287

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 4.15, which presents the breakdown of public capital to productive and social categories with network effects, can be compared with table 4.13. The results are, at first sight, rather peculiar. The productive category is now significant only for the Ionian Islands, whereas in table 4.13, other regions such as West Macedonia, Epirus, West Greece and Peloponnese, and Sterea have significant productive coefficients (though some were only at the 10 percent level). Also the results for the social component of infrastructure have changed, both in terms of the sign of the coefficient and the level of significance. For instance, the negative and significant sign of the social infrastructure coefficient for West Macedonia when the network effects are taken under consideration becomes insignificant. The coefficients for some other regions (such as Epirus, the Ionian Islands, Sterea, and the Aegean Islands) have also changed. The only explanation, other than that the production functions are inadequate at this level of aggregation, is that the composition of the productive and social categories for the network aggregation is such that it transforms the respective coefficients. For instance, assume that the composition of infrastructure in a prefecture was such as to generate a positive and significant productive coefficient, then, if the infrastructure composition of the adjacent prefecture was dominated by non-productive categories, this might result in a negative network effect. Perhaps it is necessary to further disaggregate the productive and social categories into the basic sub-categories of public capital.

Table 4.15 Industrial output as a function of private capital stock (lnK), labour (lnL), and productive and social infrastructure capital stock networks (lnPG and lnSG), 1982-1992

Equation for Output (lnQ)

REGION	Constant	lnK	lnL	lnP(G)	lnS(G)	Time trend	lnCU	$\bar{R}^2$	SSE	SE
East Maced.	21.069	0.055	0.532	0.083	-0.296	0.045	-0.536	0.975	0.479	0.104
& Thrace	(1.733)*	(0.499)	(2.800)**	(0.659)	(-1.020)	(1.400)	(-0.376)			
Central	0.336	0.140	0.851	-0.186	0.831	0.015	-0.782	0.988	1.218	0.138
Macedonia	(0.022)	(0.629)	(5.697)***	(-0.973)	(1.389)	(0.550)	(-0.488)			
West	14.020	0.106	1.139	-0.197	0.582	0.015	-2.975	0.984	1.445	0.206
Macedonia	(0.809)	(0.652)	(4.003)***	(-0.343)	(0.862)	(0.287)	(-0.941)			
Epirus	3.792	0.160	1.040	0.804	-0.545	-0.034	-0.147	0.903	1.113	0.181
	(0.254)	(1.920)*	(5.278)***	(1.275)	(-0.528)	(-0.739)	(-0.044)			
Thessaly	-15.111	-0.035	0.864	0.209	0.857	-0.052	1.444	0.996	0.234	0.083
	(-1.961)*	(-0.205)	(5.611)***	(1.639)	(2.506)**	(-2.322)**	(1.120)			
Ionian	69.709	-0.618	1.107	1.141	-1.736	0.086	-8.535	0.872	0.720	0.227
Islands	(2.691)**	(-1.275)	(3.648)***	(2.485)**	(-2.210)**	(1.718)	(-1.728)			
West Greece	22.505	0.158	0.603	0.070	-0.056	0.033	-2.507	0.986	2.264	0.175
& Peloponn.	(1.960)***	(0.882)	(7.242)***	(0.333)	(-0.212)	(1.228)	(-1.390)			
Sterea	-17.972	-0.033	0.940	0.088	1.052	-0.058	1.372	0.982	5.187	0.310
	(-0.722)	(-0.189)	(3.446)***	(0.239)	(1.673)	(-0.970)	(0.374)			
Aegean	4.913	-0.195	1.034	-0.400	1.665	-0.065	-3.043	0.894	4.163	0.308
Islands	(0.184)	(-0.535)	(4.922)***	(-0.729)	(1.658)	(-0.758)	(-0.734)			
Crete	25.333	-0.032	0.576	-0.074	-0.098	0.065	-1.786	0.961	2.876	0.291
	(1.076)	(-0.217)	(2.348)***	(-0.129)	(-0.124)	(0.989)	(-0.400)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

4.9 Conclusions

In this chapter an attempt has been made to estimate the impact of public infrastructure on the economic development in Greece at the national and regional level. This was achieved by using a Cobb-Douglas production function analysis. This type of production function has been the dominant specification upon which the majority of the recent empirical work on infrastructure research has been based. The main reasons for this are that the Cobb-Douglas function provides a simple, easily applicable analytical framework, and the empirical results give a direct picture of the impact of public capital on private economic activity. It has to be kept always in mind, however, that Cobb-Douglas function concept is underpinned by several restrictive assumptions.

The empirical calibration of a Cobb-Douglas production function in the Greek case was based in the construction of panel data, for Greece as whole, as well as for several different regional levels. Infrastructure capital stocks were estimated using data for infrastructure investment from the Public Investment Programme, and the research also utilised data on the production inputs of the private manufacturing sector.

The formulation of a Cobb-Douglas production function that incorporated public capital was compared with an alternative in which infrastructure was excluded. As it is possible to estimate the data panels either using an OLS or a LSDV approach, using the data either in 'row' or first differences form, several econometric tests were used in order to discriminate and select between all the alternative formulations. There was also presented an extensive analysis of the type of the returns of scale, which the Cobb-Douglas function can exhibit.

Based on the empirical analysis presented here, several substantive points can be made about the infrastructure and development relationship in the Greek context. First, it is clear that there is some evidence of an overall positive and significant relationship between infrastructure provision and industrial output in Greece. The strength of the relationship varies between different model specifications. However, the estimated elasticities, for both overall infrastructure and its components (productive and social categories), do seem to be more moderate compared to the only previous attempt to assess the development impact of public capital in Greece. These elasticities are much more in line with the theoretical expectations and the empirical findings from other countries.

Second, it can be advanced that either the analytical framework provided by the Cobb-Douglas production function is problematic in the Greek case, or that there are some peculiarities apparent concerning the role of private capital. The rather low estimated coefficients for private capital, especially at the regional scale, can be interpreted in either way. One feature, however, is certain. Private investment dropped significantly during the eighties and this must be reflected in these coefficients.

Third, the spatial scale of analysis seems to affect greatly the results for the effect of public capital. The impact of infrastructure investment is larger when Greece is examined as a whole or when the country is divided broadly into North and South. When the regional breakdown is ten regions, it seems that it is more difficult to obtain coefficients of substantial value or significance. For that reason, additional panels were constructed in an attempt to capture the network effects of public capital. However, there was no notable difference in the results arising from this initiative. The phenomenon of better results for infrastructure at larger geographical scales is in line with the experience from other countries.

And finally, the breakdown of infrastructure into its productive and social parts generated results as expected. The productive part of infrastructure provision presents positive and significant coefficients, while the social component has a negative or/and insignificant impact on private sector production in most cases. The regional analysis showed only one exception - the Aegean Islands - where social infrastructure appears to play a vital role.

This research has selected the Cobb-Douglas production function framework and necessarily the results are dependent on such a choice. They must be read, then, within the caveat of the limitations of this analytical framework. This study has also specially constructed a new series on regional public infrastructure spending not previously available. Although they are the best that can be developed, these data are not without problems and again the results should be evaluated in this light.

In the following chapters (5 and 6), more sophisticated tools of analysis have been used in order to complement this production function analysis, as well as to shed light on some other aspects of the public infrastructure capital and development relationship.

Chapter 5

Using duality theory and cost function analysis to understand the influence of public capital on manufacturing production costs in Greece.

5.1 Introduction

The dominance of production function analysis in the infrastructure debate is not uncontested. An alternative analytical framework is provided by the duality theory and cost function approach. This approach can provide an insight into the effects of infrastructure on private sector production costs. The use of cost functions in some senses can be seen as a potential remedy for some of the problems that plague production function analysis. In the latter, output is considered as endogenous, and the production inputs as exogenous. As Berndt and Hansson (1991a, pp. 10-11) have argued, referring specifically to infrastructure research, "*the right-hand side variables in the various equations estimated by Aschauer and Munnell... should be treated as endogenous, not exogenous; in such a case estimation by OLS produces biased and inconsistent parameter estimates*". This, along to the fact that "*the desire to account for possible heterogeneity of production technologies among industries*" (Berndt 1991, p. 460) are some of the reasons for which "*most recent econometric studies of substitution relationships between inputs employ general cost or profit functions*".

Cost function analysis is based on the dual cost function of the (primal) production function. This former embodies all the parameters of the latter, but with a crucial difference. In cost function analysis, it is input quantities and production costs which are endogenous, and the level of output and input prices that are exogenous. An additional advantage of cost function analysis in comparison to the production function analytical framework is that it allows the use of more flexible functional forms. For instance, the use of Cobb-Douglas production function implies that the elasticity of substitution is equal to unity, while a cost function does not apply such an *a priori* restriction (for this point see, for instance, Sturm[1] 1998).

Despite these advantages, the cost function approach has been less popular in recent research than the production approach, probably due to the fact that the latter is easier to estimate and is less data-demanding. For a concise historical presentation of the cost function approach see Berndt (1991) and for a more extended theoretical analysis see, for example, Diewert[2] (1986) and Chambers (1988). At this point it would be useful to quote the last mentioned author's observation that it "*... is striking... that it took the economics profession so long to realize the ability of the cost function to characterize completely cost-minimizing behaviour since this was clearly outlined in Samuelson's (1948) Foundations of Economic Analysis and exhaustively investigated in Shephard's (1953) classic exposition of duality*" (Chambers 1988, p. 49).

However, there is now, in existence, a substantial body of work on the effects of infrastructure using the cost function approach. Nadiri and Mamuneas (1994) using a panel of industrial sectors in the United States found that public capital had a positive impact on private sector productivity. Lynde and Richmond (1992, and 1993a) and Morrison and Schwartz (1992, and 1996) have also reported beneficial effects of the provision of the US infrastructure. Similar research has been conducted for Europe. Berndt and Hansson (1991a) have investigated the Swedish case and Lynde and Richmond (1993b) looked at the United Kingdom. Conrad and Seitz (1994) have provided a sectoral analysis for Germany, while Seitz and Licht (1995) focused on a regional analysis for the (West) German states, and Seitz (1993 and 1994) analysed the effects of the total public capital and road infrastructure respectively. In all these cases, infrastructure capital appears to have, once again, a positive role regarding the private sector production costs and productivity.

[1] Sturm calls cost function analysis the 'behavioural approach', as "*one can describe the behaviour of agents (firms) by assuming that they minimize costs*" (1998, p. 97).
[2] W.E. Diewert not only introduced and developed some of the functional forms used in duality theory, which still form the basis for applied research (see for instance, his University of California-Berkley thesis in 1969 and his seminal article in the *Journal of Political Economy* [1971] 'An application of the Shephard duality theorem: A generalized linear production function'), but he has also provided a cost function analytical framework for public capital research (Diewert 1986).

Similarly positive results have been obtained for Greece in the previous attempts to analyse the impact of infrastructure at the national level using cost function analysis. Dalamagas (1995), and Segoura and Christodoulakis (1997) used time-series data, a translog form of cost function, and an 'all-encompassing' definition for public infrastructure capital. The time period of the empirical research, however, as well as the results obtained differ. The Segoura and Christodoulakis dataset spans 1963 to 1990, while Dalamagas analysed data over the period 1950 to 1992. This means that both these research projects have included very different periods of economic development from the analysis in hand. Furthermore, the rather general definition of infrastructure capital makes extremely problematic a direct comparison with the results of this chapter. That said, Segoura and Christodoulakis concluded that public infrastructure is both labour and intermediate inputs 'saving', and private capital 'using' in its influences. Dalamagas, on the other hand, argues that public capital is strongly competitive (substitutive) with labour and private capital, and a weak complement to energy (the author does not use an intermediate inputs variable, but energy instead). Both of these earlier pieces of research, then, have shown that there is a positive impact of public capital on the private sector's cost structure.

The following chapter utilises a different definition and data representation for infrastructure capital (see previous chapters) and additionally uses panel data analysis. Employing of the latter gives crucial information about the structure of the manufacturing industry at regional, urban, and sectoral levels. The next section presents a brief outline of the cost function analytical framework and the duality theory that underpins it. Section 5.3 shows how this theoretical framework can be used for an empirical investigation of the infrastructure impact on manufacturing costs. In the following section the presentation of the actual empirical results starts with the regional industry analysis. In section 5.5 the findings for a sectoral panel for Greece as a whole are presented. Similar analyses for the manufacturing sectors in the metropolitan area of Athens and a residual Rest of Greece region' follow in subsequent sections. The final part tries to assess the empirical findings and summarise the most important points. It has to be noted that due to space limitations, in the following sections public capital enters the cost equations only in terms of the 'productive' and 'social' categories. Thus, the aggregated public infrastructure category has been not used, as the presentation would have been rather cumbersome.

5.2 The cost function analytical framework: From production functions to cost functions and duality theory

The analytical framework of production functions can be extended with duality theory if it is assumed that firms in the private sector choose input quantities in such way that they minimise the cost of their production process, given the prices of these inputs. Let the production function be:

$$Y_i = f_i(L_i, K_i, M_i, G_i, t) \quad (5.2.1)$$

where,
Y_i is the output (gross production value) in sector i,
L_i is the labour input,
K_i is the private capital input,
M_i are the intermediate inputs,
G_i is public capital input,
t is a time counter which functions as a proxy for disembodied technical change[3],
and the subscript i is a regional (or sectoral) index.

Then the cost function of an industry in region (or sector) i will be:

$$C_i = C_i(w_i, p_k, p_m, Y_i, G_i, t) \quad (5.2.2)$$

where,
C_i is the private cost of production in sector i,
w_i is the wage in region (or sector) i,
p_k is the rental price of private capital,
p_m is the price of intermediate inputs,
and the others are as above.

Cost function (5.2.2) can be derived by minimising the private production cost function:

$$C_i = w_i L_i + p_k K_i + p_i M_i \quad (5.2.3)$$

[3] For a basic discussion on the notion of disembodied technical change refer to Berndt (1991).

subject to the production function (5.2.1).

From cost equation (5.2.2) is possible to derive the cost minimising factor demand equations using Shephard's Lemma (see for instance Takayama (1985) or Chambers (1988)) for labour L^*_i, private capital K^*_i, and intermediate inputs M^*_i. These equations would be:

$$L_i^* = \partial C_i / \partial w_i \tag{5.2.4}$$

$$K_i^* = \partial C_i / \partial p_k \tag{5.2.5}$$

$$M_i^* = \partial C_i / \partial p_m \tag{5.2.6}$$

The private costs of production for the optimising firms, using the left-hand side of equations (5.2.4) to (5.2.6), would be:

$$C_i = w_i L_i^* + p_k K_i^* + p_m M_i^* \tag{5.2.7a}$$

or, using the right hand sides, which is the application of Shephard's lemma, of equations (5.2.4) to (5.2.6) the equivalent expression would be:

$$\frac{\partial C_i}{\partial G_i} = -w_i \frac{\partial L_i^*}{\partial G_i^*} - p_k \frac{\partial K_i^*}{\partial G_i^*} - p_m \frac{\partial M_i^*}{\partial G_i} \qquad \text{or}$$

$$\frac{\partial C_i}{\partial G_i} = -w\varepsilon_{Li} - p_k\varepsilon_{Ki} - p_m\varepsilon_{Mi} \tag{5.2.7b}$$

$$= s_{Li} + s_{Ki} + s_{Mi} = -s_{Gi} \tag{5.2.7c}$$

A measure of the impact of public capital on private cost is the cost elasticity with respect to public infrastructure (ε_{CGi}). This elasticity can be construed as the amount by which infrastructure capital will reduce the costs of industries operating in the region (or sector). More formally, ε_{CGi} is the percentage change of the private cost of production as a result of a unitary change in the public capital stock, *ceteris paribus*. The elasticity ε_{CGi} would be:

$$\varepsilon_{CGi} = -\frac{\frac{\partial C_i}{C_i}}{\frac{\partial G_i}{G_i}} = -\frac{\frac{\partial C_i}{\partial G_i}}{\frac{C_i}{G_i}} \tag{5.2.8}$$

Closely linked with cost elasticity with respect to public infrastructure (ε_{CG}) is the concept of the 'shadow value' of public capital. As the flow of services from public capital can be considered as a free public good, there is no market price for these services[4]. Nevertheless, it is possible to have an estimate of their shadow value[5] (s_{Gi}). The shadow value of public capital is a measure of the impact on private cost of an exogenous change in the level of services delivered by public capital, *ceteris paribus*. It shows private sector willingness to pay in order to obtain an additional unit of service from public capital. This shadow value of public capital would be:

$$s_{Gi} = -\frac{\partial C_i(w_i, p_k, p_m, Y_i, G_i, t)}{\partial G_i} \tag{5.2.9}$$

If there is such an exogenous increase in infrastructure services, it is expected that there will be a corresponding increase in private sector productivity ($\partial Y_i / \partial G_i \geq 0$). The value ε_{CG} is directly linked with the shadow value s_{Gi}. Expression (5.2.8) can be derived by (5.2.9) and the reverse:

[4] There is, of course, the case where the value of these services can be assessed with the use of a toll mechanism. It is assumed here that public capital services are a free public capital good. However, the arguments for the introduction of efficient toll mechanisms as the centrepiece of an efficient infrastructure policy are most relevant (see Holtz-Eakin 1993a, 1993c).

[5] 'Shadow value' is also sometimes called 'shadow price' (see Seitz 1994), or 'marginal benefit' of public capital (see Nadiri and Mamuneas, 1994).

$$\varepsilon_{CGi} = s_{Gi} \frac{G_i}{C_i} \quad \text{or}$$

$$s_{Gi} = \varepsilon_{CGi} \frac{C_i}{G_i} \tag{5.2.10}$$

It is also possible to have a measure of infrastructure's impact on the private input shares (labour, private capital, or intermediate input) to production. If an increase (or decrease, or no change) of the stock of public capital has an effect of an increase (or decrease, or no change) of a private factor of production, then it can be argued that infrastructure is using this input (or saving it or has a neutral effect, respectively). A measure of the this cost share change is the 'factor bias effect' (see Nadiri and Mamuneas, 1994) and the respective effects in the case of three private inputs would be:

for labour,

$$bias_{LG} = \frac{\partial S_L}{\partial \ln G_i} \tag{5.2.11}$$

for private capital,

$$bias_{LG} = \frac{\partial S_K}{\partial \ln G_i} \tag{5.2.12}$$

and for intermediate inputs,

$$bias_{LG} = \frac{\partial S_M}{\partial \ln G_i} \tag{5.2.13}$$

The total infrastructure effect on the demand for private inputs can be estimated using private input elasticities with respect to public infrastructure (ε_{XG}), where X = L, K, M. These elasticities would be:

$$\varepsilon_{XG_i} = \frac{\dfrac{\partial Q_X}{Q_X}}{\dfrac{\partial G_i}{G_i}} = \frac{\partial \ln Q_X}{\partial \ln G_i} \tag{5.2.14}$$

where,
Q_X is the quantity of inputs *L, K, M*)

The total impact of public capital on input demand (ε_{XG}) is the sum of the productivity effect (cost elasticities) and the factor bias effect. Thus, in an applied research context these elasticities can be easily calculated for labour and private capital inputs[6] (ε_{LG} and ε_{KG} respectively) by the following formula (see Nadiri et al. 1994, p.32):

$$\varepsilon_{XGi} = \varepsilon_{CGi} + \frac{\beta_{XG}}{S_X} \tag{5.2.15}$$

where,
X is *L, K* (but not *M*)

The intermediate inputs' elasticity with respect to public infrastructure (ε_{MG}) can also calculated given the following equation (ibid.):

$$\varepsilon_{MG} = \varepsilon_{CG} - \frac{\sum_x \beta_{XG}}{1 - \sum_x S_X} \tag{5.2.16}$$

where,
S_X is the cost share of *L, K*

[6] This is because in the empirical calibration of the model the equation for the intermediate inputs' share is the one that has been selected for exclusion (due to the homogeneity restriction for the econometric system of estimated equations). For an analysis of this point, see the next section in this chapter.

Again the sign of the private input elasticities with respect to public capital (ε_{XG}) indicates the type of relation between the public infrastructure and private input. If ε_{XG} has a positive (zero, or negative) sign, then public capital would be complementary (neutral, or substitutive, respectively) to the X private input. As ε_{XG} is the sum of two different components (cost elasticities and factor bias effect), ε_{XG} sign and the magnitude would depend on the signs of the respective cost elasticities and the bias effect over share (ibid.).

5.3 Issues of empirical calibration within a duality theoretical framework

This section presents the generic form of the empirical calibration for the cost and shares functions, as well as some econometric tests that will help to distinguish between alternative (and competing) formulations. There are several empirical forms that the general cost function can take. According to Berndt (1991), in his review of the history of the development of such functional forms, it was Diewert who first introduced the generalised Leontief form, which is used in infrastructure research by Berndt and Hansson (1991a) for Sweden and Seitz (1993; 1994) for Germany. An alternative form is the translog cost function used by Conrad and Seitz (1994), and Seitz and Licht (1995) for sectoral and regional analyses of the role of German public capital respectively. Another potential empirical form is the Generalised Cobb-Douglas cost function used by Nadiri and Mamuneas (1994) in their analysis of the effects of public infrastructure on US manufacturing costs.

It is exactly this last form which has been used in the subsequent analysis here. This is because a full translog calibration (which was employed initially) generated rather poor results (insignificant t-ratios for some of the estimated variables), even without the introduction of public capital into the equation. The cost function used here has the following form:

$$\ln\frac{C_i}{p_m}=\sum_{i=1}^{n}\alpha_{0,i}D_i+\sum_{i=1}^{n}\alpha_{L,i}\ln\left(\frac{w_i}{p_m}\right)D_i+\sum_{i=1}^{n}\alpha_{K,i}\ln\left(\frac{p_k}{p_m}\right)*D_i+\alpha_Y\ln Y_i+\alpha_G\ln G_i+\alpha_T t$$
$$+\beta_{LK}\ln\left(\frac{w_i}{p_m}\right)\ln\left(\frac{p_k}{p_m}\right)+\beta_{LY}\ln\left(\frac{w_i}{p_m}\right)\ln Y_i+\beta_{LG}\ln\left(\frac{w_i}{p_m}\right)\ln G_i+\beta_{LT}\ln\left(\frac{w_i}{p_m}\right)t$$
$$+\beta_{KY}\ln\left(\frac{p_k}{p_m}\right)\ln Y_i+\beta_{KG}\ln\left(\frac{p_k}{p_m}\right)\ln G_i+\beta_{KT}\ln\left(\frac{p_k}{p_m}\right)*t+\beta_{YT}\ln Y_i t+u_C \quad (5.3.1)$$

(for notational definitions, see previous section)

The respective cost share equations then would be:

for the labour input,

$$s_L=\frac{wL^*}{C_i}=\sum_{i=1}^{n}\alpha_{L,i}D_i+\beta_{LK}\ln\left(\frac{p_k}{p_m}\right)+\beta_{LY}\ln Y_i+\beta_{LG}\ln G_i+\beta_{LT}t+u_L \qquad (5.3.2)$$

and for private capital input,

$$s_K=\frac{p_kK^*}{C_i}=\sum_{i=1}^{n}\alpha_{K,i}D_i+\beta_{LK}\ln\left(\frac{w_i}{p_m}\right)+\beta_{KY}\ln Y_i+\beta_{KG}\ln G_i+\beta_{KT}t+u_K \qquad (5.3.3)$$

It is also possible to have a third share equation - that for intermediate inputs (s_M). However, as the cost shares add to unity ($s_L + s_K + s_M = 1$), it is necessary to exclude one of the cost share equations, because otherwise the system of equations would be singular[7]. The system of equations that is estimated comprises the set (5.3.1)-(5.3.3)[8]. This is the homogeneity restriction for the estimated system.

[7] For an illustration of this point see Berndt (1991, chapter 9) or Greene (1993, chapter 17).
[8] Note that the estimated set of equations has been divided by the price of the intermediate goods (p_m).

An additional set of restrictions, regarding symmetry conditions across equations (5.3.1) to (5.3.3), has also been imposed. For instance, the coefficient β_{KL} obtained by the cost share equation (5.3.2) has been constrained to be equal to coefficient β_{KL} obtained by the cost share equation (5.3.3), and to β_{LK} obtained by the cost function (5.3.1). The parameters for the excluded equation, dealing with the cost share of intermediate inputs, can be derived from the estimated parameters of the cost equation and the labour and private capital share equations, given the aforementioned restrictions.

It is assumed that the error terms in equations (5.3.1) to (5.3.3) (u_C, u_L, and u_K respectively) are jointly normally distributed with zero expected value, and also that the covariance matrix is positive definite symmetric. The estimation method selected is that of iterative seemingly unrelated regression (SUR)[9].

The basic premise of this method is that, instead of estimating a set of equations separately (i.e. estimate the coefficients for each equation), it is better to 'stack' them together[10] and estimate the coefficients simultaneously. The theoretical assumption behind the SUR approach is that "*the disturbances in those different equations at a given time are likely to reflect some common unmeasurable or omitted factors, and hence could be correlated... Correlation between disturbances from different equations at given time is know as contemporaneous correlation. It is distinct from autocorrelation... When contemporaneous correlation exists, is may be more efficient to estimate all equations jointly, rather than to estimate each one separately using least squares*" (Judge et al. 1988, p. 443). In the case of the cost function (5.3.1) it is obvious that common unmeasurable or omitted factors that have affected its disturbances would have also affected the disturbances of the cost share equations (5.3.2) and (5.3.3), as the these equations have been directly derived from equation (5.3.1).

A concise delineation of the stacking process can be described as follows. If equation (5.3.1) is written compactly:

$$y_{a,1} = X_{a,1}b_1 + e_{a,1} \qquad (5.3.1a)$$

[9] For an extensive presentation of this method see Berndt (1991) or Greene (1993).
[10] In the case of panel data analysis, an initial 'stacking' of data is used, as different regional or sectoral units have been already added in order to have a single dataset.

where,

$y_{a,1}$ is the $\ln\frac{C_i}{p_m}$,

$X_{a,1}$ is the right hand side data of equation (5.3.1),
b_1 is the set of coefficients that we want to estimate (a_{0i}, a_{Li}, a_{Ki}, a_Y, a_G, etc.),
$e_{a,1}$ and is the disturbance
(subscripts a, and 1 are referring to the number of equation [a in this case is equation 5.3.1] and to the year of observation [1 in this case denotes the first year-observation]).

If the other years-observations are added, then equation (5.3.1a) can be estimated (with the use of OLS, for instance).

$$\begin{aligned}
y_{a,1} &= X_{a,1}b_1+e_{a,1}\\
y_{a,2} &= X_{a,2}b_2+e_{a,2}\\
y_{a,3} &= X_{a,3}b_3+e_{a,3}\\
&\ldots\ldots\ldots\ldots\ldots\\
y_{a,T} &= X_{a,T}b_T+e_{a,T}
\end{aligned} \tag{5.3.4}$$

Similarly, in order to estimate equation (5.3.2) T observations are needed:

$$\begin{aligned}
y_{b,1} &= X_{b,1}b_1+e_{b,1}\\
y_{b,2} &= X_{b,2}b_2+e_{b,2}\\
y_{b,3} &= X_{b,3}b_3+e_{b,3}\\
&\ldots\ldots\ldots\ldots\ldots\\
y_{b,T} &= X_{b,T}b_T+e_{b,T}
\end{aligned} \tag{5.3.5}$$

and T observations are needed for equation (5.3.3):

$$
\begin{aligned}
&y_{c,1} = X_{c,1}b_1 + e_{c,1} \\
&y_{c,2} = X_{c,2}b_2 + e_{c,2} \\
&y_{c,3} = X_{c,3}b_3 + e_{c,3} \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&y_{c,T} = X_{c,T}b_T + e_{c,T}
\end{aligned}
\tag{5.3.6}
$$

Equations (5.3.4) to (5.3.6) can be estimated with OLS separately. If, however, the SUR method is used then all these observations will be stacked together:

$$
\begin{aligned}
&y_{a,1} = X_{a,1}b_1 + e_{a,1} \\
&y_{a,2} = X_{a,2}b_2 + e_{a,2} \\
&y_{a,3} = X_{a,3}b_3 + e_{a,3} \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&y_{a,T} = X_{a,T}b_T + e_{a,T} \\
&y_{b,1} = X_{b,1}b_1 + e_{b,1} \\
&y_{b,2} = X_{b,2}b_2 + e_{b,2} \\
&y_{b,3} = X_{b,3}b_3 + e_{b,3} \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&y_{b,T} = X_{b,T}b_T + e_{b,T} \\
&y_{c,1} = X_{c,1}b_1 + e_{c,1} \\
&y_{c,2} = X_{c,2}b_2 + e_{c,2} \\
&y_{c,3} = X_{c,3}b_3 + e_{c,3} \\
&\ldots\ldots\ldots\ldots\ldots\ldots \\
&y_{c,T} = X_{c,T}b_T + e_{c,T}
\end{aligned}
\tag{5.3.7}
$$

The (Zellner's) SUR estimator for coefficients b is given in Appendix III. For the moment it is sufficient to say that these coefficients are estimated with an iterative method (also presented in Appendix III), and that they are *'numerically equivalent to those of the maximum likelihood estimator'* (see Berndt 1991, p. 463).

As the analysis is based on a panel of regional data, the estimated set of equations has to be calibrated in such a way that ensures that the specific nature of the dataset has been taken into consideration. Thus, every equation of the system (5.3.1) to (5.3.3) has been appended with a set of regional-specific dummies D_i (where i is a regional [sectoral] indicator, and the regional dummy is equal to one in region [sector] i, and zero in all other regions [sectors]). Such a formulation is necessary in order to capture the regionally [sectorally] specific characteristics (see, for instance, Hsiao 1986, or Baltagi 1995). Some examples of the infrastructure research literature, where comparable datasets have been employed for the estimation of similar sets of equations, have extended the use of dummy variables such as these to the cases of $\alpha_{L,i}$, and $\alpha_{K,i}$ coefficients (see Nadiri and Mamuneas, 1994; Seitz, 1993, 1994; Seitz and Licht, 1995). Such a formulation has also been followed here, as it ensures that the labour and private capital demand equations can be consistently derived by the cost equation.

Even though a cost equation similar in form to that of Nadiri and Mamuneas (1994) is used here, there is one significant difference. Here there is no *a priori* assumption that there are constant returns of scale (CRS). In contrast to the Nadiri and Mamuneas approach, a CRS variant is compared to a version without such a restriction. Such a comparison has been proposed and tested by Seitz (1994) and, in a regional context, by Seitz and Licht (1995). In order to compare the two versions, with and without the CRS restriction, a log-likelihood ratio test (LRT) has been used. The LRT is a rather simple test, which can be briefly described as follows: if the values of the maximised log-likelihood functions are lnL_r for the restricted (the CRS model), and lnL_u for the unrestricted model, then the likelihood ratio statistic is given by:

$$\lambda = -2(\ln L_r - \ln L_u) \tag{5.3.8}$$

This statistic is asymptotically distributed as chi-squared and the degrees of freedom are equal to the imposed number of restrictions[11].

[11] For a more formal presentation of log-likelihood ratio test see Greene (1993) and for its implementation in a cost function analysis context see Berndt (1991).

The LRT has been also used here to compare the unrestricted model with regional dummy variables to an alternative specification where such variables have been excluded. Following Seitz (1994) and Seitz and Licht (1995), the log-likelihood ratio test has also been utilised in order to discern if the public capital variable should be included in the estimated equations or not. Again, the unrestricted model is the one with the inclusion of infrastructure and the restricted the version is without public capital.

5.4 A cost function analysis for the regions of Greece

In this section the cost function theoretical framework has been used to analyse public infrastructure's impact on Greek manufacturing industry at the prefectural level. The empirical specification of the cost function has been already discussed. The following sub-section 5.4.1 gives a description of the used data in the analysis, as well as some technical details. The results come next in section 5.4.2. and the overall conclusions are left until the end of the chapter.

5.4.1 Calibrating regional cost functions in Greece

The dataset used in this analysis is a panel with a time dimension from 1982 to 1991 and a cross-sectional vector of 49 prefectures. There is an extensive description of this dataset in chapter 4, and of the original data of the Public Investment Programme in chapter 3. It is worthwhile recalling again that even though there are 51 prefectures[12] in the Greek administrative and statistical system the spatial units of the analysis have been reduced to forty-nine. This is due to the fact that for one prefecture there was no industrial activity and, thus, was excluded from the analysis, and two others were merged, as the industrial activity in the one of them only commenced in 1984 (for a detailed analysis, see section 4.7). The infrastructure variable enters the estimated equations (throughout this chapter) as an instrument lagged one year[13] (for the reasons, see the previous chapter).

[12] After the exclusion of the semi-autonomous prefecture of Agion Oros.
[13] The results of the estimation of a system of equations, where the infrastructure variable is not lagged, are not very different.

The economic variables that enter the cost function representing the private sector have been constructed as follows. The quantity of labour (L) is the total working hours in manufacturing in prefecture i. Total working hours, in turn, were estimated by multiplying the average annual employment in the manufacturing industry by the number of hours worked[14]. The price of the labour input (w_i) has been calculated by dividing the total remuneration[15] of labour input in prefectural industry i by the quantity of labour input (L). It has to be noted that w_i enters the system of equations normalised to equal one for the first year of the panel.

Private capital stocks for prefectural manufacturing have been used as a proxy for the quantity of private capital input (K). The estimation method is again via the method of perpetual inventory accounting:

$$K_{it} = (1-\delta_p)K_{it-1} + IP_{it} \qquad (5.4.1)$$

where,
K_{it} is the end-of-year private capital stock in year t in prefecture i,
δ_p is the geometric rate of depreciation,
and IP_{it} is real investment in private capital during years t in prefecture i.

Even though there is not a price for private capital, in the sense that a price can be defined for the labour or intermediate inputs, a user cost of capital p_K can be calculated as follows[16]:

[14] As there are no available data, at least not known to this author, about the number of working hours it has been assumed here that all workers in manufacturing have worked the same number of working days per year for the same number of hours per day.
[15] The published data on labour remuneration refer to the wage bill paid to workers and employees excluding the employers' (insurance) contributions. However, the unpublished data from the National Statistical Service of Greece provide information specifically about these contributions. There is the possibility that sectoral differences in the level of such payments might create anomalies in relation to the data that excludes them. In this analysis both datasets were tested and the results were similar. The subsequent results refer to the dataset that includes employers' contributions.
[16] For this method of estimation of private capital price see Berndt and Hansson (1991a).

$$p_K = (r + \delta_p)q_K \qquad (5.4.2)$$

where,
δ_p is as in equation (5.4.1),
r is the long-term lending rate for the industrial sector (nominal, referring to loans for more than a year),
and q_K is the investment deflator for capital goods.

This capital goods investment deflator is a weighted measure of the national price indexes of building and equipment investment in manufacturing[17]. The price of private capital (p_K) has been normalised[18] to be equal to one for the first year of the panel -1982.

The quantity of intermediate inputs M is the sum of materials, energy, and services that were consumed during the production process, divided by the price index of intermediate inputs (p_m). This index is a weighted average of the raw materials and semi-finished products index, and the fuel and lubricant index (again obtained from the National Statistical Service of Greece). The price index of intermediate inputs is also normalised to be equal to one for the first year of the panel.

Output quantity is estimated as the total value of gross regional manufacturing output divided by the output price index. This is the final products index as provided by the National Statistical Service of Greece, normalised here to be equal to one for 1982.

The cost variable (C) is the sum of the cost of the labour input ($L * w_i$), private capital input ($K * p_k$), and intermediate inputs ($M * p_m$). The value S_L is the percentage of the labour input to the total cost, while S_K is the percentage of private capital, and the S_M the percentage of intermediate inputs.

5.4.2 Interpreting the results of regional cost functions in Greece

As mentioned earlier, the estimation model consists of the cost equation (5.3.1), and the share equations (5.3.2) and (5.3.3), for labour and private capital inputs

[17] These, as well as all other, indices and data were obtained from the National Statistical Service of Greece.
[18] This normalisation process is necessary for an accurate estimation of the equations' system. For the 'mechanics' of this procedure see Berndt (1991).

respectively. Table 5.4.1 presents the results from the estimation of the system of equations, where productive public capital has been included[19], as well as the test statistics from the comparison of this specification to alternative formulations.

The 'fitness' measures appear to be satisfactory, either in terms of explained variance or standard errors, for the equations of the system. However, the coefficients for a_G, b_{LK}, b_{LT}, b_{KT}, and b_{YT} appear not to be statistically significant. It has to be noted at this point that the standard errors of the coefficients are asymptotically estimated. This is a result of the method of estimation employed (see Berndt and Hansson 1991a).

The last part of table 5.4.1 gives the results from the comparisons of the formulation with public infrastructure, fixed effects, and without the restriction of constant returns to scale, with alternative formulations. The comparison with a specification without fixed effects (region-specific dummy variables) gives a value for LRT_D as 2,076.86 (with 147 degrees of freedom). For the formulation where public infrastructure has been excluded, the LRT_G is 76.02 (with 3 degrees of freedom), and for the alternative, where the assumption of constant returns to scale is imposed, the LRT_Y is 137.26 (with 4 degrees of freedom). In all cases the alternative specifications have been rejected decisively (the associated probability value is 0.000).

[19] Some researchers have argued that it is imperative to adjust public capital for capacity utilisation (Hilton 1990, Ford et al. 1991, Nadiri et al. 1994). In this research, however, the results with infrastructure adjusted for capacity utilisation (these figures for Greece are available only after 1982 and obtainable from the OECD) were similar to those for unadjusted public capital. The latter that are used here.

Table 5.4.1 Regional cost function for manufacturing in Greece: results of panel-estimation incorporating the effects of productive infrastructure capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	14.171	237.854
aL	0.232	12.979
aK	0.292	8.228
aY	7.87E-01	32.980
aG	-5.93E-02	-1.545
aT	3.02E-02	5.487
bLK	3.13E-03	0.149
bLY	-3.33E-02	-4.989
bLG	-2.37E-02	-2.043
bLT	1.96E-03	1.160
bKY	-1.28E-01	-10.620
bKG	1.10E-01	5.373
bKT	1.04E-03	0.344
bYT	-1.67E-04	-0.241
	R-Square	Standard Error
Cost function	0.996	0.113
Labour share	0.785	0.033
Capital share	0.818	0.059
Log of Likelihood	2228.86	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	2076.86	147
LRT_G	76.02	3
LRT_Y	137.26	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
The total number of observations is 490.
[b]The associated p-values for all tests are 0.000.

It has to be mentioned here that a similar analysis was conducted to generate results for the social category of public capital. Again the formulation with social infrastructure and regional fixed effects (the unrestricted model) was tested against a formulation with public capital but without fixed effects (LRT_D), one with fixed effects but no public capital (LRT_G), and one similar to the unrestricted version but with no constant returns to scale imposed (LRT_Y). The assumption that social public capital is a part of the estimated system has to be rejected in favour of the alternative hypothesis ($LRT_G = 4.72$, with 3 degrees of freedom, as it is shown in table 5.4.2). For this reason all of the subsequent analysis presented here refers only to productive public capital.

Table 5.4.2 Regional cost functions for manufacturing in Greece: likelihood ratio-tests for panel estimation results incorporating the effects of social infrastructure capital, 1982-1991

	Likelihood ratio test	Degrees of freedom
LRT_D	2019.4	147
LRT_G	4.72	3
LRT_Y	268.42	4

The total number of observations is 490.

As argued earlier, the effect of public capital on regional manufacturing can be estimated using the cost elasticity with respect to public infrastructure (ε_{CG}). The results for the different prefectures of the analysis are presented in table 5.4.3. In all cases the sign of the prefectural cost elasticity is negative, which means that infrastructure tends to reduce the manufacturing costs in all cases. However, this cost reduction seems rather small and certainly is without significant regional variation. The highest cost elasticity is that of Zakynthos-Kephalonia (-0.071), followed by Ioannina (-0.066)[20]. Low values are recorded for Chios (with -0.059), and Evros, Kozani, and Serres (-0.058). It is somewhat disappointing to discern no clear pattern in these elasticities. It is also difficult to compare these results to the findings of other research, as there are few similar analyses at the regional level. In the research conducted by Seitz and Licht (1995), the 11 (West) Germany states (Bundesländer) are far larger than the Greek prefectures. (Bavaria is not much smaller than Greece as a whole, both in geographical and economic terms.) All German regions appear to have significantly larger cost elasticities, and only for Berlin and Bremen are the figures similar to those of Greek prefectures. It has to be noted, however, that it is likely that the fact that the regional data refer only to aggregate manufacturing has played an important role here.

[20] A point of confusion concerning the estimation of elasticities (whatever the type) in economics is when the estimated elasticity has a negative sign. As Varian has puts it "*from an algebraic point of view –3 is smaller than –2, but economists tend to say that the...elasticity of –3 is 'more elastic' than the one with –2*" (1993, p.266). This convention has been followed here.

Table 5.4.3 Regional cost function for manufacturing in Greece: cost elasticities of manufacturing with respect to productive infrastructure capital, 1982-1991

Prefecture	ε_{CG}	**Prefecture**	ε_{CG}	**Prefecture**	ε_{CG}
Achaia	-0.062	Halkidiki	-0.062	Magnisia	-0.062
Aitoloakarnan.	-0.062	Ilia	-0.064	Messinia	-0.061
Arcadia	-0.061	Imathia	-0.061	Pella	-0.065
Argolida	-0.063	Ioannina	-0.066	Pieria	-0.062
Arta	-0.061	Iraklio	-0.064	Preveza	-0.064
Attiki	-0.064	Karditsa	-0.062	Rethimno	-0.062
Chania	-0.063	Kastoria	-0.061	Rodopi	-0.064
Chios	-0.059	Kavala	-0.061	Samos	-0.064
Dodekanissos	-0.061	Kerkyra	-0.062	Serres	-0.058
Drama	-0.064	Kilkis	-0.064	Thesprotia	-0.063
Evia	-0.062	Korinthia	-0.064	Thessaloniki	-0.062
Evritania	-0.063	Kozani	-0.058	Trikala	-0.063
Evros	-0.058	Kyklades	-0.064	Viotia	-0.061
Florina	-0.063	Laconia	-0.065	Xanthi	-0.062
Fokida	-0.065	Larisa	-0.062	ZakyKepha	-0.071
Fthiotis	-0.064	Lasithi	-0.062	**Total Average**	-0.063
Grevena	-0.063	Lesvos	-0.060		

The effect of infrastructure on the cost shares of the production inputs is measured by the factor bias effects, which are equal to the coefficients of private inputs to public capital, β_{LG} and β_{KG} respectively for labour and capital, plus the derived coefficient β_{MG} for intermediate inputs. Table 5.4.4 presents these effects divided by the corresponding private input share, following the form of presentation favoured by Nadiri and Mamuneas (1994). The overall result, from a first look at these figures, is that for all prefectures public capital appears to be labour and intermediate inputs saving, and private capital using. The first column of table 5.4.4 (biasLG) gives the estimations[21] for labour input. The highest values (that is the greatest cost reduction) appear to be in Korinthia (biasLG = -0.589), Lasithi (-0.482), and Laconia (-0.370). The lowest values are those for Kyklades (-0.051), Grevena (-0.096), and Drama (-0.100). There is no discernible spatial pattern in these figures. The fact that the regional manufacturing under examination is the sum of all manufacturing sectors may, in part, be contributory factor in this respect. Certainly, it is not difficult to argue from a theoretical standpoint that sectoral

[21] As the coefficients are divided by each year's share in each prefecture, this means that for a specific prefecture there will be 10 such shares. The results refer to the average for every prefecture, as well as the total average.

composition should play a significant role, as some industrial sectors are expected to be more affected by changes in infrastructure stock levels than others.

Table 5.4.4 Regional cost function for manufacturing in Greece: productive infrastructure factor bias effects over respective private input shares, 1982-1991

Prefecture	bias LG	bias KG	bias MG	Prefecture	bias LG	bias KG	bias MG
Achaia	-0.165	0.285	-0.185	Kerkyra	-0.188	0.455	-0.160
Aitoloakarnan.	-0.184	0.602	-0.131	Kilkis	-0.164	0.450	-0.145
Arcadia	-0.165	0.746	-0.138	Korinthia	-0.589	0.599	-0.113
Argolida	-0.196	0.412	-0.143	Kozani	-0.146	0.196	-0.335
Arta	-0.164	0.511	-0.171	Kyklades	-0.051	0.503	-0.277
Attiki	-0.132	0.485	-0.153	Laconia	-0.370	0.284	-0.164
Chania	-0.221	0.871	-0.113	Larisa	-0.161	0.387	-0.152
Chios	-0.171	0.339	-0.168	Lasithi	-0.482	2.217	-0.100
Dodekanissos	-0.119	0.425	-0.164	Lesvos	-0.173	0.797	-0.127
Drama	-0.100	0.591	-0.154	Magnisia	-0.226	0.348	-0.151
Evia	-0.177	0.288	-0.178	Messinia	-0.175	0.614	-0.130
Evritania	-0.137	1.005	-0.163	Pella	-0.188	0.415	-0.143
Evros	-0.150	0.488	-0.152	Pieria	-0.132	0.274	-0.214
Florina	-0.164	0.716	-0.125	Preveza	-0.147	0.599	-0.137
Fokida	-0.196	1.391	-0.110	Rethimno	-0.144	0.416	-0.207
Fthiotis	-0.222	0.351	-0.149	Rodopi	-0.167	0.296	-0.178
Grevena	-0.096	0.237	-0.313	Samos	-0.220	0.250	-0.197
Halkidiki	-0.187	0.496	-0.133	Serres	-0.170	0.535	-0.138
Ilia	-0.233	0.313	-0.158	Thesprotia	-0.142	0.295	-0.416
Imathia	-0.197	0.569	-0.128	Thessaloniki	-0.188	0.514	-0.132
Ioannina	-0.232	0.401	-0.138	Trikala	-0.167	0.535	-0.135
Iraklio	-0.240	0.406	-0.139	Viotia	-0.247	0.215	-0.225
Karditsa	-0.266	0.847	-0.111	Xanthi	-0.192	0.308	-0.165
Kastoria	-0.113	2.192	-0.123	ZakyKepha	-0.212	0.450	-0.141
Kavala	-0.168	0.307	-0.174	**Total Average**	-0.193	0.556	-0.165

The results for private capital bias (KG) are all positive, which can be interpreted as public capital being private capital using. However, here the variation amongst prefectures is greater in terms of magnitude, than for the case of the labour input. The highest factor bias effects for private capital can be found in Lasithi (biasKG = 2.217), which has one of the highest values for labour input. The next highest bias effect for private capital is that of Kastoria, which in contrast is one of the lowest cases for labour. Other prefectures with high bias effects for private capital are Fokida (1.391) and

Evritania (1.005). The lowest values can be found in Samos (0.250), Viotia (0.215), and Kozani (0.196). The last column of table 5.4.4 presents the factor bias effects for intermediate inputs (biasMG). The sign for all prefectures is negative, which means that public infrastructure is intermediate inputs saving. The highest savings can be found in Thesprotia (biasMG = -0.416), Kozani (-0.335) - which has one of the lowest effects for capital, and Grevena (-0.313). The lowest values are observed in Chania, Korinthia (biasMG = -0.113 for both regions), Karditsa (-0.111) and Fokida (-0.110).

The cost elasticity with respect to public capital can be considered the 'productivity' effect of infrastructure and, if this measure is combined with the factor bias effect, the total effect of infrastructure on private inputs can be obtained. This measure (table 5.4.5), as indicated previously, is the private input elasticity with respect to public infrastructure. There is, of course, the possibility that the two components of these elasticities - the productivity and the factor bias effects - could offset each other, in terms of magnitude and sign. But for the Greek prefectures, all private input elasticities have the same sign as the respective factor bias effects. A comparison of these figures to those of table 5.4.4 shows that the demand elasticities are determined, at least in most cases, by the factor bias effects, as the magnitudes of cost elasticities with respect to public capital are rather small. Thus, the majority of those prefectures that have high (low) bias effects also have high (low) demand elasticities. All prefectures have a negative sign for labour and intermediate inputs cost elasticities (ε_{LG} and ε_{MG} respectively), and a positive sign for private capital (ε_{KG}). In economic terms, this means that an expansion of the infrastructure stock results in a decline in the demand for labour and intermediate inputs, and an increase in the demand for private capital input.

The prefectures with the highest labour demand elasticity are Korinthia (ε_{LG} = -0.653), Lasithi (-0.544) and Laconia (-0.436). On the other hand, the lowest values are recorded for Drama (-0.163), Grevena (-0.159) and Kyklades (-0.115). The second column of table 5.4.5 presents the findings for private capital demand elasticity. Here, as for the bias effects for capital, there is a greater spatial variation in the elasticities compared to those for labour input. The largest elasticities were observed in Lasithi (ε_{KG} = 2.155), Kastoria (2.131 – which, in contrast, has a low labour elasticity) and Fokida (1.326). At the opposite extreme are prefectures such as Samos (0.185), Grevena (0.174, which also has one of the lowest elasticities for labour), Viotia (0.154) and Kozani (0.138). Finally, table 5.4.5 offers the demand elasticities for intermediate inputs where the highest are observed in Thesprotia (-0.479), Kozani (-0.393), Grevena (-0.376) and Kyklades (-0.341). Prefectures with low demand elasticities for intermediate inputs are Korinthia (-0.178), Fokida (-0.175), Karditsa (-0.173) and Lasithi (-0.162).

Table 5.4.5 Regional cost functions for manufacturing in Greece: private input demand elasticities with respect to productive infrastructure capital, 1982-1991

Prefecture	ε_{LG}	ε_{KG}	ε_{MG}	Prefecture	ε_{LG}	ε_{KG}	ε_{MG}
Achaia	-0.227	0.223	-0.247	Kerkyra	-0.250	0.393	-0.221
Aitoloakarnan.	-0.246	0.540	-0.193	Kilkis	-0.228	0.386	-0.209
Arcadia	-0.226	0.685	-0.199	Korinthia	-0.653	0.535	-0.178
Argolida	-0.258	0.350	-0.206	Kozani	-0.204	0.138	-0.393
Arta	-0.226	0.449	-0.232	Kyklades	-0.115	0.439	-0.341
Attiki	-0.196	0.421	-0.216	Laconia	-0.436	0.219	-0.229
Chania	-0.284	0.808	-0.176	Larisa	-0.223	0.325	-0.214
Chios	-0.230	0.280	-0.227	Lasithi	-0.544	2.155	-0.162
Dodekanissos	-0.180	0.364	-0.225	Lesvos	-0.234	0.736	-0.187
Drama	-0.163	0.528	-0.217	Magnisia	-0.289	0.286	-0.213
Evia	-0.239	0.226	-0.240	Messinia	-0.236	0.553	-0.191
Evritania	-0.200	0.942	-0.227	Pella	-0.253	0.350	-0.208
Evros	-0.209	0.430	-0.210	Pieria	-0.194	0.212	-0.276
Florina	-0.226	0.653	-0.188	Preveza	-0.212	0.535	-0.202
Fokida	-0.261	1.326	-0.175	Rethimno	-0.206	0.355	-0.269
Fthiotis	-0.285	0.288	-0.213	Rodopi	-0.231	0.232	-0.242
Grevena	-0.159	0.174	-0.376	Samos	-0.285	0.185	-0.261
Halkidiki	-0.248	0.435	-0.194	Serres	-0.228	0.476	-0.196
Ilia	-0.296	0.249	-0.222	Thesprotia	-0.205	0.232	-0.479
Imathia	-0.258	0.508	-0.189	Thessaloniki	-0.249	0.452	-0.194
Ioannina	-0.298	0.336	-0.204	Trikala	-0.230	0.472	-0.198
Iraklio	-0.305	0.342	-0.203	Viotia	-0.308	0.154	-0.286
Karditsa	-0.328	0.785	-0.173	Xanthi	-0.254	0.246	-0.227
Kastoria	-0.174	2.131	-0.184	ZakyKepha	-0.282	0.379	-0.212
Kavala	-0.230	0.246	-0.235	**Total Average**	-0.255	0.493	-0.228

The private input elasticities with respect to public infrastructure obtained from this analysis can be compared to those obtained from similar research. Seitz and Licht (1995) have found that private capital (which they divide into two categories) has a complementary relationship with public infrastructure, while labour is substitutive. This is also the case in this study. Similar relationships have been identified for Sweden by Berndt and Hansson (1991a). Nadiri and Mamuneas (1994), on the other hand, find that although infrastructure has a substitutive effect for labour, in their research private capital also appears to have a substitutive relationship with public capital, while intermediate inputs are complementary.

The final results describe the estimations of the shadow values (s_{Gi}) for infrastructure capital in the different prefectures. Thus, table 5.4.6 shows the differences in the amounts that regional manufacturing is willing to pay in order to have an additional unit of public capital. Here, in contrast to the other measures of the impact of infrastructure, it looks as if a clear regional pattern emerges. There is a substantial variation in these shadow values and it seems that those prefectures that are adjacent to the two main metropolitan areas - Athens and Thessaloniki - have the highest shadow values. The only prefecture that is not adjacent to a principal economic centre and has a high value is Magnesia and this contains the significant industrial area of Volos.

Table 5.4.6 Regional cost functions for manufacturing in Greece: shadow values of productive infrastructure capital, 1982-1991

Prefecture	s_{GI}	Prefecture	s_{GI}	Prefecture	s_{GI}
Achaia	1.098	Halkidiki	0.070	Magnisia	1.121
Aitoloakarnan.	0.090	Ilia	0.097	Messinia	0.150
Arcadia	0.056	Imathia	1.133	Pella	0.301
Argolida	0.186	Ioannina	0.134	Pieria	0.212
Arta	0.072	Iraklio	0.214	Preveza	0.084
Attiki	0.713	Karditsa	0.110	Rethimno	0.007
Chania	0.067	Kastoria	0.039	Rodopi	0.118
Chios	0.028	Kavala	0.509	Samos	0.076
Dodekanissos	0.035	Kerkyra	0.044	Serres	0.280
Drama	0.264	Kilkis	0.429	Thesprotia	0.068
Evia	1.211	Korinthia	2.645	Thessaloniki	1.093
Evritania	0.056	Kozani	0.364	Trikala	0.143
Evros	0.046	Kyklades	0.066	Viotia	1.654
Florina	0.018	Laconia	0.028	Xanthi	0.602
Fokida	0.079	Larisa	0.473	Zaky-Kepha	0.036
Fthiotis	0.934	Lasithi	0.020	**Total**	
Grevena	0.004	Lesvos	0.038	**Average**	0.353

5.5 A cost function analysis for the manufacturing sectors of the whole of Greece

In the previous section the cost function analytical framework was used to assess the impact of public infrastructure on prefectural manufacturing industry. These data, as demonstrated, refer only to the sum of all manufacturing sectors for the respective prefecture. There are also available three additional datasets, with a detailed sectoral breakdown, one for Greece as whole, another for the metropolitan area of Athens, and finally one that refers to the rest of Greece. In this section the analysis will be focused on the first of these.

5.5.1 Manufacturing activities in Greece

The sectoral breakdown of manufacturing is available from the National Statistical Service of Greece (NSSG) both for industries employing more and less than twenty employees (the cut-off for large scale industry). Here, the dataset that is based on more than twenty employees has been employed for two reasons. First, as it is argued in chapter 4, data for the large scale industry are more 'accurate', as they are collected via a full census questionnaire survey, while those for the smaller establishments are collected via a sample. Second, given the fact that the prefectural-regional data for manufacturing are available only for the large scale industry and have already been used here for the regional analysis, it makes sense to be consistent. Thus, the sectoral panel can be directly compared to the prefectural-regional one. The only caveat is that the information for the nation refers to the 20 two-digit sectors of manufacturing, while for the regions it refers only to total manufacturing.

The classification of the different manufacturing sectors, as provided by the NSSG, is presented in table 5.5.1. A more detailed presentation of the composition of these sectors, at three-digit level, is given in appendix IV.

Table 5.5.1 National Statistical Service of Greece classification of manufacturing sectors (branches).

20	Food and Kindred Products
21	Beverages
22	Tobacco Manufactures
23	Textile Mill Products
24	Apparel and Other Textile Products
25	Lumber, Wood and Cork Products
26	Furniture and Fixtures
27	Paper and Allied Products
28	Printing and Publishing
29	Leather, Leather Products and Furs
30	Rubber and Miscellaneous Plastics Products
31	Chemicals and Allied Products
32	Petroleum and Coal Products
33	Non-metallic Minerals and Allied Products
34	Primary Metal Industries
35	Fabricated Metal Products, except for Machinery and Transport Equipment
36	Machinery Except Electrical
37	Electric and Electronic Equipment
38	Transportation Equipment
39	Miscellaneous Manufacturing Establishments

Source: National Statistical Service of Greece (Annual industrial survey)

Some of the most important descriptive statistics relating to Greek manufacturing sectors are given in table 5.5.2. covering the average percentage of each measure for the period 1982 to 1991 for each of the twenty sectors of large scale industry. Column (2) presents the average percentage of establishments per sector. The footwear, food, and textiles have the largest numbers of establishments, and the metal and petroleum industries, as expected, the smallest. The next column (3) gives the percentages for the average annual employment. The highest percentages are again observed for the textiles, food, and footwear industries (a slightly different order from the previous ranking). However, the lowest percentages here are somewhat different - the miscellaneous, and leather sectors featuring prominently. Similar is the sectoral ranking in column (4), which gives the average remuneration of employment. One notable difference is that transport equipment sector now occupies third rank.

The two measures for the production activity of the sectors are given in columns (5) and (6). In terms of gross production, the food, petroleum, and textiles sectors are the highest achievers. At the other end of the spectrum are the furniture, leather, and miscellaneous industries. These industries have also the lowest percentages in terms of added value (even though in a different rank order). The highest value added percentage here belongs to the textile industry, followed by the food and chemical industries.

The highest percentages in intermediate inputs use, shown in column (7) are taken by the food, and petroleum sectors. Leather, furniture, and miscellaneous sectors have the lowest percentages of intermediate inputs use. Column (8) gives one of the most important measures of all - that of gross asset formation. The transport equipment, food, textiles, and petroleum sectors have the highest investment percentage, while, the furniture, miscellaneous, and leather industries the lowest.

Table 5.5.2 Descriptive statistics (average percentages) for manufacturing sectors (establishments with 20 persons and over) in Greece, 1982-1991

Sector	Number of Establism.	Av.Annual Employment	Remuneration of Employm.	Gross Prod. Value	Value Added	Intermediate Inputs	Total Gross Asset Form.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
20 (food)	14.873	13.672	12.038	16.911	13.292	18.573	12.407
21 (beverages)	2.928	3.146	3.603	4.033	5.011	3.588	6.114
22 (tobacco)	1.682	2.808	2.631	3.433	2.878	3.693	1.671
23 (textiles)	13.739	17.237	15.023	12.233	14.671	11.113	10.360
24 (footwear)	16.250	11.248	7.243	4.070	5.948	3.217	2.335
25 (wood)	2.205	1.722	1.601	1.293	1.535	1.186	1.448
26 (furniture)	3.234	1.289	0.947	0.567	0.887	0.422	0.586
27 (paper)	2.058	2.666	2.774	2.603	2.723	2.546	2.130
28 (printing)	2.853	2.577	2.816	1.557	2.417	1.165	1.652
29 (leather)	1.735	0.657	0.512	0.551	0.532	0.558	0.267
30 (rubber)	4.076	3.254	3.233	2.745	3.411	2.445	2.613
31 (chemical)	5.647	6.805	8.532	8.253	9.377	7.733	6.199
32 (petroleum)	0.817	1.577	2.332	13.607	3.682	18.122	10.212
33 (mineral)	6.673	6.259	7.260	5.561	7.632	4.625	9.157
34 (metal)	1.232	3.300	5.323	8.168	6.712	8.819	9.366
35 (fabr.metal)	5.600	5.864	6.107	5.054	5.547	4.831	5.119
36 (machinery)	4.010	1.946	1.843	1.029	1.486	0.819	0.920
37 (electrical m.)	4.249	4.314	4.504	3.986	4.607	3.705	2.918
38 (transport eq.)	4.491	8.833	11.025	3.898	6.971	2.502	14.137
39 (miscellaneous)	1.649	0.828	0.652	0.446	0.681	0.338	0.391
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: National Statistical Service of Greece (Annual industrial survey)

5.5.2 Interpreting the results of national manufacturing cost functions in Greece

The cost function used for the sectoral panels is exactly the same as that used for the regional panel, the only difference being the *i* subscript where in the regional set of equations it signifies regions and here it refers to sectors. Table 5.5.3 presents the estimation results for the system's parameters. All coefficients are significantly different from zero, with the only exception being the interaction parameter for output and time (β_{YT}). It has to be emphasised, again, that the standard errors of the coefficients are asymptotically estimated. The overall fitness of the formulation is highly satisfactory given the results of the R-Square and t-ratio statistics.

The last part of table 5.5.3 presents the results of the log-likelihood ratio tests (LRT). The purpose of these tests, as mentioned above, is to test the employed formulation against other alternatives. The log of the likelihood for the employed specification (with public infrastructure and dummy variables) is 1,586.13. Using the LRT this specification is initially compared to the alternative without dummy variables[22] (LRT_D = 1,591.79), and the latter was rejected. The next likelihood ratio test compared the full unconstrained model to one where the parameters regarding public capital were constrained to be equal zero (both models were formulated with *n* dummy variables). This test rejected the constrained specification (LRT_G = 90.34, with 3 degrees of freedom). Finally, the unconstrained specification was compared to an alternative with constant returns of scale (with respect to private sector inputs). This means that α_Y was constrained to be equal to one, and β_{LY}, β_{KY} , and β_{YT} were constrained to be equal to zero. Both for models *n* dummies were included, and the alternative was rejected as the LRT_Y equalled 217.46, with 4 degrees of freedom.

[22] The unconstrained model was formulated as follows: each term is multiplied with a dummy variables matrix of *n-1* dummies (where *n* is the number of cross sectional units, sectors in this case) and the *n* dummy variable is a constant. The constrained model has the *n-1* dummies dropped. The degrees of freedom in this LRT_D were 57, as the *n-1* dummies equalling 19 were multiplied by three.

Table 5.5.3 National sectoral manufacturing cost functions in Greece: results of panel estimation incorporating the effects of productive infrastructure capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	16.563	52.236
aL	1.080	9.082
aK	1.440	7.088
aY	0.702	33.941
aG	-0.271	-5.015
aT	0.024	3.983
bLK	-0.035	-2.145
bLY	-0.025	-4.057
bLG	-0.145	-7.102
bLT	0.015	6.972
bKY	-0.134	-13.093
bKG	-0.119	-3.375
bKT	0.019	4.935
bYT	-0.001	-0.755
	R-Square	Standard Error
Cost function	0.998	0.034
Labour share	0.976	0.011
Capital share	0.963	0.017
Log of Likelihood	1586.13	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1591.79	57
LRT_G	90.34	3
LRT_Y	217.46	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
[b]The associated p-values for all tests are 0.000.
The total number of observations is 200.

The cost elasticities with respect to public infrastructure (ε_{CG}), for the twenty manufacturing sectors, are given in table 5.5.4. These elasticities range from -0.283 to -0.258, and they are higher than those reported by Nadiri and Mamuneas (1994) for US industrial sectors. The highest is that of miscellaneous manufacturing - followed closely by wood industries (-0.281). At the other side of the spectrum, that for printing and publishing is the smallest (-0.258), and the next smallest (-0.261) is leather products. It is difficult to discern a pattern from these figures, as both industrial sectors achieving high and low elasticities are not dissimilar. One possible difference is that the high achievers have a higher capital/labour ratio, but it has to be kept in mind that there are other industrial sectors with equally high ratio which have a more 'average' cost elasticity.

Table 5.5.4 National sectoral manufacturing cost functions in Greece: cost elasticities of manufacturing sectors with respect to productive infrastructure capital, 1982-1991

Sector	ε_{CG}	Sector	ε_{CG}
20 (food)	-0.270	30 (rubber)	-0.275
21 (beverages)	-0.277	31 (chemical)	-0.271
22 (tobacco)	-0.270	32 (petroleum)	-0.263
23 (textiles)	-0.270	33 (mineral)	-0.268
24 (footwear)	-0.269	34 (basic metal)	-0.266
25 (wood)	-0.281	35 (fabr. metal)	-0.271
26 (furniture)	-0.266	36 (machinery)	-0.269
27 (paper)	-0.270	37 (electrical m.)	-0.275
28 (printing)	-0.258	38 (transport eq.)	-0.271
29 (leather)	-0.261	39 (miscellaneous)	-0.283
	Total	Average	-0.270

The factor bias effects over share are reported in table 5.5.5 - the column with heading 'bias LG' presents the results for labour input, and that with heading 'bias LK' those for private capital. The last column of the table presents the derived bias over share for the intermediate inputs. Again the results resemble those for US manufacturing, if not in absolute figures, at least in the sense that public capital seems to save labour and capital inputs, but is using intermediate inputs in each industrial sector. It seems that there is a large labour bias (labour saving) in the case of the petroleum and coal refining and, to a lesser extent, for basic metal industries, the food sector, and tobacco manufactures. The larger capital bias effects (capital saving) can be found for petroleum and coal refining (which seems to be heavily affected in both labour and capital bias), leather and fur products, tobacco manufactures, manufacturing of footwear, and the food sector. As already mentioned, public capital seems to have an opposite bias effect for the intermediate inputs share (it is using, instead of saving, intermediate goods). The highest bias effect is for the case of non-metallic mineral products, followed closely by the transport equipment sector, and the machinery and appliances except electrical sector.

Table 5.5.5 National sectoral manufacturing cost functions in Greece: productive infrastructure factor bias effects over respective private input shares, 1982-1991

Sector	bias LG	bias KG	bias MG
20 (food)	-1.636	-0.509	0.391
21 (beverages)	-1.404	-0.303	0.525
22 (tobacco)	-1.422	-0.696	0.367
23 (textiles)	-1.056	-0.331	0.527
24 (footwear)	-0.595	-0.529	0.497
25 (wood)	-1.083	-0.315	0.542
26 (furniture)	-0.691	-0.362	0.574
27 (paper)	-1.149	-0.397	0.461
28 (printing)	-0.623	-0.412	0.557
29 (leather)	-1.120	-0.712	0.380
30 (rubber)	-1.022	-0.363	0.499
31 (chemical)	-1.103	-0.433	0.447
32 (petroleum)	-6.741	-0.956	0.317
33 (mineral)	-1.264	-0.227	0.732
34 (basic metal)	-1.990	-0.361	0.445
35 (fabr. metal)	-1.048	-0.376	0.490
36 (machinery)	-0.704	-0.352	0.606
37 (electrical m.)	-0.994	-0.461	0.445
38 (transport eq.)	-0.443	-0.390	0.724
39 (miscellaneous)	-0.781	-0.393	0.519
Total	-1.344	-0.444	0.502

The total impact of public capital on input demand is given by the private input elasticities with respect to public infrastructure (ε_{XG}, where X = L, K, M). The results for all three private input elasticities are presented in table 5.5.6. Again the overall picture, at least in terms of signs, is similar to the findings of Nadiri and Mamuneas (1994, table 6). The Swedish results, reported by Berndt and Hansson (1991b) differ from both the US and the Greek cases in that Swedish public capital is complementary to private capital. The results from Germany for private capital demand complementarity are similar to the Swedish case (see Seitz 1994, but with the caveat that here a Leontief cost function was estimated).

The highest labour demand elasticity is that for petroleum and coal refining, followed by that for the basic metal industries sector. High labour demand elasticities are also generated for the food, beverage, and tobacco industries. High capital demand elasticities have been observed for the petroleum and coal refining sector, tobacco, and leather and fur products. Infrastructure seems to have a positive effect on the demand for intermediate inputs, especially for industries such as non-metallic mineral products, transport equipment, and machinery and appliances except electrical.

Table 5.5.6 National sectoral manufacturing cost functions in Greece: private input demand elasticities with respect to productive infrastructure capital, 1982-1991

Sector	ε_{LG}	ε_{KG}	ε_{MG}
20 (food)	-1.906	-0.778	0.121
21 (beverages)	-1.681	-0.580	0.248
22 (tobacco)	-1.692	-0.966	0.097
23 (textiles)	-1.326	-0.601	0.257
24 (footwear)	-0.864	-0.798	0.228
25 (wood)	-1.364	-0.596	0.261
26 (furniture)	-0.957	-0.628	0.308
27 (paper)	-1.419	-0.666	0.192
28 (printing)	-0.881	-0.671	0.298
29 (leather)	-1.381	-0.974	0.118
30 (rubber)	-1.297	-0.638	0.224
31 (chemical)	-1.374	-0.704	0.176
32 (petroleum)	-7.004	-1.219	0.054
33 (mineral)	-1.533	-0.496	0.463
34 (basic metal)	-2.256	-0.627	0.179
35 (fabr. metal)	-1.319	-0.647	0.218
36 (machinery)	-0.973	-0.621	0.337
37 (electrical m.)	-1.269	-0.737	0.170
38 (transport eq.)	-0.713	-0.660	0.453
39 (miscellaneous)	-1.064	-0.676	0.236
Total	-1.614	-0.714	0.232

The estimations for the shadow values of the Greek manufacturing sectors are presented in table 5.5.7 These range from an extremely high 0.202 for the food sector, through 0.159 for textile manufacturing, 0.148 for petroleum and coal refining, and 0.106 for the basic metal industries, to the comparatively low value of 0.007 for furniture and fixture industries, 0.006 for leather and fur, and 0.005 for the miscellaneous industries. These sectoral results are in some cases significantly larger than those reported by Nadiri and Mamuneas for the US economy (1994, table 7). However, the Greek results closely approximate the shadow values estimations for the German manufacturing sector reported by Conrad and Seitz (1994, table 3).

Table 5.5.7 National sectoral manufacturing cost functions in Greece: shadow values of productive infrastructure capital, 1982-1991

Sector	s_{GI}	Sector	s_{GI}
20 (food)	0.202	30 (rubber)	0.034
21 (beverages)	0.054	31 (chemical)	0.095
22 (tobacco)	0.038	32 (petroleum)	0.148
23 (textiles)	0.159	33 (mineral)	0.091
24 (footwear)	0.044	34 (basic metal)	0.106
25 (wood)	0.018	35 (fabr. metal)	0.064
26 (furniture)	0.007	36 (machinery)	0.013
27 (paper)	0.032	37 (electrical m.)	0.047
28 (printing)	0.017	38 (transport eq.)	0.050
29 (leather)	0.006	39 (miscellaneous)	0.005
	Total	Average	0.062

The next set of tables replicates the analysis immediately above, but here the productive public capital is replaced by its social counterpart. Table 5.5.8 reports the coefficients from the estimation of the respective system of equations. The results are not greatly different than those for the productive infrastructure for the sectoral panel. Two of the estimated coefficients, however, now appear to be statistically insignificant (β_{LK} and β_{YT}, at the five-percent level). The general measures (R-squares) of the system's equations are completely satisfactory. The likelihood ratio tests again reject the alternative specifications, the first without specific sectoral effects (sectoral dummies), the second constraining the infrastructure variable to equal zero, and the third assuming constant returns to scale.

Table 5.5.8 National sectoral manufacturing cost functions in Greece: results of panel estimation incorporating the effects of social public capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	16.709	46.585
aL	1.139	8.766
aK	1.378	6.048
aY	0.701	33.770
aG	-0.360	-4.824
aT	0.022	3.753
bLK	-0.022	-1.413
bLY	-0.025	-4.056
bLG	-0.189	-6.943
bLT	0.014	6.765
bKY	-0.135	-13.060
bKG	-0.131	-2.721
bKT	0.016	4.338
bYT	-0.001	-0.731
	R-Square	Standard Error
Cost function	0.999	0.035
Labour share	0.976	0.010
Capital share	0.962	0.017
Log of Likelihood	1585.1	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1589.776	57
LRT_G	88.28	3
LRT_Y	216.9	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
[b]The associated p-values for all tests are 0.000.
The total number of observations is 200.

The cost elasticities with respect to social public capital are presented in table 5.5.9. These are slightly higher than those reported for productive infrastructure. The estimation of the cost elasticities hinges on the estimated coefficients, a_G, b_{LG}, and b_{KG}, and the values $\ln_w$, $\ln p_k$, and $\ln p_m$ for the various sectors. Thus, it is logical that as the coefficients for social infrastructure are not dissimilar to those for productive public capital (the values for the sectors are, of course, the same) the estimated sectoral cost elasticities also will be similar to the respective measures for productive infrastructure. The rank order of these elasticities is also much the same, with the highest being that of miscellaneous industries (ε_{CG} = -0.376) and the lowest (-0.345) for printing and publishing industry. The average elasticity for social public capital is –0.360, which is significantly higher than that for productive infrastructure (-0.270). In common sense terms this means that social infrastructure investment tends to reduce the costs in all industrial sectors to a larger degree than is the case for productive infrastructure.

Table 5.5.9 National sectoral manufacturing cost functions in Greece: cost elasticities of manufacturing sectors with respect to social infrastructure capital, 1982-1991

Sector	ε_{CG}	Sector	ε_{CG}
20 (food)	-0.360	30 (rubber)	-0.366
21 (beverages)	-0.369	31 (chemical)	-0.361
22 (tobacco)	-0.359	32 (petroleum)	-0.351
23 (textiles)	-0.359	33 (mineral)	-0.358
24 (footwear)	-0.358	34 (basic metal)	-0.355
25 (wood)	-0.374	35 (fabr. metal)	-0.361
26 (furniture)	-0.355	36 (machinery)	-0.358
27 (paper)	-0.359	37 (electrical m.)	-0.367
28 (printing)	-0.345	38 (transport eq.)	-0.360
29 (leather)	-0.349	39 (miscellaneous)	-0.376
	Total	Average	-0.360

Table 5.5.10 presents the factor bias effects over shares for social public capital. Social infrastructure is labour and private capital saving, and intermediate inputs using, as indeed was the case for productive public capital. The sector with the highest labour 'saving bias' is the petroleum industry, and the one with the lowest is the transport equipment industry. The average labour bias effect for social infrastructure is significantly higher than the respective bias effect for productive infrastructure (-1.751 and –1.344, respectively). The highest private capital bias effect is observed for petroleum and coal refining and the lowest for non-metallic mineral products. The average private capital bias effect for social infrastructure (-0.489), however, is not much different from its productive counterpart (-0.444). Finally, in the case of intermediate inputs, the highest value bias effect belongs to the non-metallic mineral industry (factor using at 0.887) and the lowest is for the petroleum and coal refining. The average intermediate inputs bias effect is somewhat higher than was the case for the productive one (0.609 and 0.502, respectively).

Table 5.5.10 National sectoral manufacturing cost functions in Greece: social infrastructure factor bias effects over respective private input shares, 1982-1991

Sector	bias LG	bias KG	bias MG
20 (food)	-2.132	-0.560	0.473
21 (beverages)	-1.830	-0.333	0.637
22 (tobacco)	-1.854	-0.767	0.445
23 (textiles)	-1.376	-0.365	0.638
24 (footwear)	-0.776	-0.583	0.603
25 (wood)	-1.412	-0.347	0.657
26 (furniture)	-0.901	-0.399	0.696
27 (paper)	-1.498	-0.437	0.559
28 (printing)	-0.812	-0.454	0.675
29 (leather)	-1.459	-0.785	0.461
30 (rubber)	-1.332	-0.400	0.605
31 (chemical)	-1.438	-0.477	0.541
32 (petroleum)	-8.786	-1.053	0.384
33 (mineral)	-1.648	-0.250	0.887
34 (basic metal)	-2.593	-0.397	0.540
35 (fabr. metal)	-1.366	-0.414	0.594
36 (machinery)	-0.918	-0.388	0.734
37 (electrical m.)	-1.295	-0.508	0.540
38 (transport eq.)	-0.577	-0.429	0.878
39 (miscellaneous)	-1.018	-0.433	0.629
Total	-1.751	-0.489	0.609

The total effects of social infrastructure interpreted this way are presented in table 5.5.11. These measures, as already mentioned, are the sum of the cost elasticities and the bias effects. The results for the private input elasticities with respect to social infrastructure are, not surprisingly given what has gone before, similar to those for productive public capital. The labour input elasticities are all negative (social infrastructure is a substitute for labour input). Similarly, all private capital elasticities are negative. The intermediate inputs elasticities are, nevertheless, all positive, which implies that these inputs are complements to social capital services. Generally speaking, the average values of the private input elasticities for social infrastructure are higher than the respective elasticities of productive public capital. The average labour elasticity for social is -2.111 (against -1.614 for productive) and the average private capital elasticity is -0.849 (-0.714 for productive). In the case of intermediate inputs, however, the difference is rather insignificant (0.249 for social and 0.232 for productive infrastructure respectively).

Table 5.5.11 National sectoral manufacturing cost functions in Greece: private input demand elasticities with respect to social infrastructure capital, 1982-1991

Sector	ε_{LG}	ε_{KG}	ε_{MG}
20 (food)	-2.492	-0.920	0.114
21 (beverages)	-2.199	-0.702	0.268
22 (tobacco)	-2.213	-1.126	0.085
23 (textiles)	-1.736	-0.724	0.279
24 (footwear)	-1.134	-0.941	0.244
25 (wood)	-1.786	-0.720	0.284
26 (furniture)	-1.255	-0.754	0.341
27 (paper)	-1.857	-0.796	0.200
28 (printing)	-1.156	-0.799	0.330
29 (leather)	-1.808	-1.133	0.112
30 (rubber)	-1.699	-0.766	0.239
31 (chemical)	-1.799	-0.838	0.181
32 (petroleum)	-9.137	-1.404	0.033
33 (mineral)	-2.006	-0.608	0.530
34 (basic metal)	-2.948	-0.752	0.185
35 (fabr. metal)	-1.727	-0.776	0.232
36 (machinery)	-1.275	-0.746	0.377
37 (electrical m.)	-1.662	-0.875	0.173
38 (transport eq.)	-0.938	-0.790	0.517
39 (miscellaneous)	-1.394	-0.810	0.253
Total	-2.111	-0.849	0.249

Finally, table 5.5.12 gives the shadow values of the industrial sectors regarding social infrastructure. A comparison of these shadow values with those for productive public capital shows that the manufacturing sectors appear more willing to pay for an additional unit of social infrastructure than for a unit of productive capital. However, what is more impressive is the magnitude of this difference. The average shadow value for productive infrastructure is 0.062, whereas the average for social infrastructure is several times higher at 0.284. The food, textiles, and petroleum sectors are those with the highest shadow values.

Table 5.5.12 National sectoral manufacturing cost functions in Greece: shadow values of social infrastructure capital, 1982-1991

Sector	s_{GI}	Sector	s_{GI}
20 (food)	0.936	30 (rubber)	0.159
21 (beverages)	0.250	31 (chemical)	0.437
22 (tobacco)	0.174	32 (petroleum)	0.670
23 (textiles)	0.733	33 (mineral)	0.419
24 (footwear)	0.206	34 (basic metal)	0.492
25 (wood)	0.084	35 (fabr. metal)	0.296
26 (furniture)	0.031	36 (machinery)	0.060
27 (paper)	0.148	37 (electrical m.)	0.215
28 (printing)	0.080	38 (transport eq.)	0.231
29 (leather)	0.026	39 (miscellaneous)	0.025
	Total	Average	0.284

5.6 A cost function analysis for the manufacturing sectors of the metropolitan area of Athens

The metropolitan area of Athens concentrates a significant part of the overall manufacturing activity of Greece (around the one third of national industrial activity). For this reason was deemed necessary to extend the analysis of public infrastructure impact on manufacturing costs to this 'urban' level.

The public investment in the productive and social categories for the three spatial levels of Greece as a whole, the metropolitan area of Athens, and the Rest of Greece region is presented in table 5.6.1. What is evident from this table is the fact that the percentage in the social category is significantly higher than the productive for Athens, certainly in comparison to the respective social percentage spent invested in the Rest of Greece. This does not mean that the investment in social infrastructure was higher than the investment in productive public capital in the Athens area, but that Athens concentrates comparatively a higher percentage of social than productive public capital.

Table 5.6.1 Productive and social public infrastructure capital in Greece and its sub-national components of the metropolitan area of Athens and the Rest of Greece.

	Productive			Social		
Year	**Athens**	**Rest**	**Greece**	**Athens**	**Rest**	**Greece**
(1)	(2)	(3)	(5)	(6)	(7)	(8)
1976	15.88	84.12	100	25.30	74.70	100
1977	25.40	74.60	100	35.46	64.54	100
1978	19.77	80.23	100	32.48	67.52	100
1979	24.95	75.05	100	33.80	66.20	100
1980	15.89	84.11	100	31.09	68.91	100
1981	10.82	89.18	100	25.23	74.77	100
1982	8.04	91.96	100	23.15	76.85	100
1983	11.63	88.37	100	31.70	68.30	100
1984	16.33	83.67	100	30.82	69.18	100
1985	12.71	87.29	100	34.16	65.84	100
1986	16.50	83.50	100	30.44	69.56	100
1987	13.10	86.90	100	23.42	76.58	100
1988	11.87	88.13	100	23.54	76.46	100
1989	11.52	88.48	100	31.49	68.51	100
1990	8.42	91.58	100	35.35	64.65	100
1991	18.47	81.53	100	13.84	86.16	100
1992	9.04	90.96	100	12.65	87.35	100

Source of original data: Ministry of National Economy
These percentages are based on deflated figures (base year = 1970)

5.6.1 Manufacturing activities in the Athens region

Table 5.6.2 provides the aggregate information for the manufacturing industry in the metropolitan area of Athens for the period 1982 to 1991 in similar fashion to table 5.5.2. A comparison of these two tables reveals that the sectoral composition of manufacturing in the Athens area is rather different from that for Greece as a whole, at least in terms of some of the indicators.

For instance, as column (2) of table 5.6.2 shows in the Athens area the footwear sector has the largest percentage of manufacturing establishments, as was the case for Greece as a whole. However, the percentage of food sector establishments in Athens is significantly lower than the average of Greece as a whole. In terms of average annual employment, shown in column (3), the textiles industry has the highest percentage both for Athens area and Greece as a whole. In second position for Athens is the transport equipment sector, which at the national level has a lower percentage. These differences in annual employment have been reflected in the remuneration of labour shown in column (4), where the transport equipment industry while located in third position for Greece as a whole has 'jumped' to first for the Athens area.

Regarding the gross production value percentages (shown for Athens in column 5), the food sector has the highest percentage for both Athens and Greece as a whole. As it evident from this column, the great bulk of production of petroleum and coal refining is located out of the metropolitan area of Athens. Even though the food industry has the highest percentage in terms of gross production, the textiles industry has the highest percentage of added value for both Greece as a whole and the area of Athens. This is due to the fact that for both these spatial levels of sectoral aggregation, the food sector has the highest use of intermediate inputs (column 7). As expected, the petroleum industry, which is ranked second at national level, is last in the value added ranking, and second from last in terms of intermediate inputs use for the Athens area. Finally, while the transport equipment sector has the higher investment percentage at the national level, in the Athens area it has a very moderate percentage of the total fixed asset formation (column 8). It is the food industry which has the highest investment in the area of Athens, and to this percentage should probably be added the percentage of the related sector of beverages, ranked third in Athens.

Table 5.6.2 Descriptive statistics (average percentages) for manufacturing sectors (establishments with 20 persons and over) in the Athens region, 1982-1991

Sector	Number of Establishm.	Av.Annual Employment	Remuneration of Employm.	Gross Prod. Value	Value Added	Intermediate Inputs	Total Gross Asset Form.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
20 (food)	8.445	10.313	10.270	17.436	13.573	20.087	17.495
21 (beverages)	1.738	3.175	3.978	5.259	5.238	5.275	12.102
22 (tobacco)	0.574	2.057	2.204	3.838	3.329	4.192	3.580
23 (textiles)	13.391	16.171	13.715	14.402	14.000	14.651	14.197
24 (footwear)	17.784	10.226	6.888	7.256	7.397	7.158	3.749
25 (wood)	1.029	0.409	0.405	0.127	0.114	0.137	0.053
26 (furniture)	3.521	1.558	1.170	0.908	1.110	0.772	0.641
27 (paper)	2.290	3.048	3.273	3.664	3.562	3.735	3.499
28 (printing)	5.968	6.247	6.658	5.676	6.814	4.903	6.323
29 (leather)	1.253	0.556	0.470	0.782	0.626	0.884	0.377
30 (rubber)	4.931	3.909	3.570	3.593	3.427	3.711	3.774
31 (chemical)	7.631	10.109	11.412	13.494	12.879	13.867	9.940
32 (petroleum)	0.709	0.582	0.677	0.130	0.063	0.178	0.251
33 (mineral)	4.207	3.363	4.128	2.509	2.685	2.410	8.020
34 (metal)	1.059	0.804	1.126	1.561	0.803	2.069	2.076
35 (fabr.metal)	6.028	5.997	5.930	4.917	4.514	5.179	5.498
36 (machinery)	3.424	1.500	1.281	1.047	1.156	0.972	0.825
37 (electrical m.)	5.916	4.903	5.110	5.027	5.217	4.899	3.237
38 (transport eq.)	7.438	13.927	16.836	7.636	12.594	4.295	3.840
39 (miscellaneous)	2.663	1.144	0.897	0.736	0.899	0.626	0.523
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: National Statistical Service of Greece (Annual industrial survey)

5.6.2 Interpreting the results of manufacturing cost functions in the Athens metropolitan area

In a similar manner to the sectoral cost and share equations for Greece as a whole, a system of equations has been constructed for the panel based on the sectoral data from the metropolitan area of Athens. The only difference is that this panel is one sector 'shorter'. The petroleum and coal refining industry (sector 32) has been excluded due to the fact that its gross production value appears to be zero for the period 1987 to 1991 (this implies a negative added value for this period). This zero production value, as odd as it seems at first sight, is probably due to profit transfers via transfer prices[23]. The panel,

[23] Seitz in his analysis for the impact of public infrastructure capital on the German manufacturing industries (similarly at two-digit level) has also excluded the 'mineral oil refining industry' on the grounds of negative added value (1994, footnote 3).

then, for the metropolitan area of Athens has a ten years time-series dimension (from 1982 to 1991) and a nineteen two-digit sectors cross-sectional dimension.

Table 5.6.3 presents the results for the estimation of the system of equations if the infrastructure variable is comprised of the productive category. The measures of overall fitness of the system are satisfactory, but what are of more interest are the estimated log-likelihood ratio tests (LRTs). The full model (with dummies and public infrastructure capital, without being constrained to have constant returns to scale) was compared to a model without the sectoral dummies, and to another with dummies but constrained to have constant returns to scale.

Table 5.6.3 Sectoral cost function for manufacturing in Athens region: results of panel-estimation incorporating the effects of productive public capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	14.671	49.409
aL	1.264	4.478
aK	1.348	3.936
aY	0.728	50.740
aG	-0.043	-0.598
aT	0.002	0.256
bLK	-0.237	-7.490
bLY	-0.151	-13.090
bLG	-0.177	-2.598
bLT	0.014	2.642
bKY	-0.235	-17.720
bKG	-0.154	-1.851
bKT	0.025	3.577
bYT	-0.001	-1.320
	R-Square	Standard Error
Cost function	0.998	0.044
Labour share	0.806	0.042
Capital share	0.826	0.048
Log of Likelihood	1047.87	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1138.292	54
LRT_G	7.76	3
LRT_Y	331.646	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
The total number of observations is 190.
[b]The associated p-values for LRT_D and LRT_Y tests are 0.000.
However, in the case of LRT_G the alternative hypothesis (G=0) cannot be rejected.

Both these alternatives have been rejected, as LRT_D was equal to 1138.3 with 54 degrees of freedom, and LRT_Y to 331.6 with 4 degrees of freedom. However, the alternative model that excludes the productive infrastructure variable cannot be rejected, at least at 5 percent level, as the LRT_G is equal to 7.76 with 3 degrees of freedom. Thus, it can be concluded that productive public capital does not appear to have a statistically significant impact on the costs of the manufacturing sectors in the metropolitan area of Athens.

Table 5.6.4 gives the results for the system of equations if the social category for the Athens area is used as the public capital variable. Again the overall fitness measures are satisfactory and for this system all the alternative specifications have been rejected.

Table 5.6.4 Sectoral cost function for manufacturing in Athens region: results of panel-estimation incorporating the effects of social public capital, 1982-1991

Variable	**Estimated Coefficient**	**T-Ratio**[a]
aO	14.806	49.646
aL	1.577	5.432
aK	1.701	4.586
aY	0.726	50.640
aG	-0.086	-1.047
aT	0.004	0.644
bLK	-0.256	-7.500
bLY	-0.154	-13.510
bLG	-0.290	-3.611
bLT	0.021	3.629
bKY	-0.238	-18.040
bKG	-0.274	-2.665
bKT	0.032	4.160
bYT	-0.001	-1.199
	R-Square	Standard Error
Cost function	0.998	0.044
Labour share	0.812	0.041
Capital share	0.829	0.048
Log of Likelihood	1051.39	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1145.468	54
LRT_G	14.8	3
LRT_Y	337.628	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
The total number of observations is 190.
[b]The associated p-values for all tests are 0.000.

The likelihood ratio test for the model without dummies (LRT_D) is equal to 1145.5 with 54 degrees of freedom, for the model in which social infrastructure is excluded (LRT_G) it is equal to 14.8 with 3 degrees of freedom, and for the formulation assuming constant returns to scale (LRT_Y) it is equal to 337.6 with 4 degrees of freedom. Thus, the formulation with the social category, with sectoral dummy variables, and no constraint about the type of returns of scale imposed, has been accepted.

The estimated cost elasticities for social infrastructure in the Athens region are given in table 5.6.5. It may be useful to be reminded that for the Athens area the panel sectors are not twenty, but nineteen, as the petroleum and coal refining sector has been excluded. Consequently, the sectoral measures presented in the following tables have also been reduced to nineteen sectors. The highest elasticity is that for the wood industry with an elasticity ε_{CG} equal to -0.159 (the highest elasticity for Greece as a whole belongs to miscellaneous industries, with ε_{CG} = -0.376), and the smallest is for printing and publishing (-0.064). These elasticities (their average is –0.089) are significantly smaller than those for both the productive and social categories for Greece as a whole (averaging -0.270 and –0.360 respectively).

Table 5.6.5 Sectoral cost function for manufacturing in Athens region: cost elasticities of manufacturing with respect to productive infrastructure capital, 1982-1991

Sector	ε_{CG}	Sector	ε_{CG}
20 (food)	-0.088	30 (rubber)	-0.093
21 (beverages)	-0.102	31 (chemical)	-0.097
22 (tobacco)	-0.084	33 (mineral)	-0.074
23 (textiles)	-0.075	34 (basic metal)	-0.082
24 (footwear)	-0.081	35 (fabr. metal)	-0.083
25 (wood)	-0.159	36 (machinery)	-0.071
26 (furniture)	-0.071	37 (electrical m.)	-0.088
27 (paper)	-0.092	38 (transport eq.)	-0.085
28 (printing)	-0.064	39 (miscellaneous)	-0.103
29 (leather)	-0.093	Average	-0.089

The factor bias effects (over share) of social public capital in Athens are given in table (5.6.6). The general direction of the relationship between social infrastructure and the private inputs is the same as was the case for productive and social public capital for

Greece as a whole. Thus, social capital appears to be a substitute for labour and private capital inputs as the signs in all the respective bias effects (bias LG and KG, respectively) are negative, and a complement for the intermediate inputs (as all the signs for the MG bias are positive). These bias effects for social infrastructure in Athens, in terms of average magnitude, are higher than the respective effects for Greece as a whole. The sole exception is the average bias effect for labour (-1.572 for Athens compared to –1.751 for Greece as a whole). However, the higher average for Greece as a whole is due to the very high bias effect for the petroleum sector. This sector has been excluded from the Athens panel, and if the average of the Athens bias effect is compared to an average for Greece from which also the petroleum industry is excluded, then the former is higher than the latter. For Athens the most important labour bias effects are those for basic metal industries and the tobacco sector. The highest bias effects for private capital input belong to the leather and fur sector and the footwear industry. Finally, the highest factor bias effect for the intermediate inputs is observed for the sectors of wood and non-metallic minerals.

Table 5.6.6 Sectoral cost function for manufacturing in Athens region: social infrastructure factor bias effects over respective private input shares, 1982-1991

Sector	bias LG	bias KG	bias MG
20 (food)	-2.292	-1.392	0.843
21 (beverages)	-2.022	-0.835	1.089
22 (tobacco)	-2.370	-1.161	0.901
23 (textiles)	-1.783	-0.757	1.210
24 (footwear)	-1.366	-1.445	0.947
25 (wood)	-0.989	-0.627	2.208
26 (furniture)	-1.102	-1.038	1.199
27 (paper)	-1.587	-1.098	0.804
28 (printing)	-1.213	-0.986	1.180
29 (leather)	-2.050	-2.024	0.787
30 (rubber)	-1.599	-0.905	1.112
31 (chemical)	-1.665	-1.132	0.977
33 (mineral)	-1.462	-0.578	1.875
34 (basic metal)	-2.485	-0.954	0.985
35 (fabr. metal)	-1.373	-0.981	1.145
36 (machinery)	-1.394	-0.809	1.289
37 (electrical m.)	-1.337	-1.249	1.046
38 (transport eq.)	-0.644	-1.161	1.840
39 (miscellaneous)	-1.132	-1.078	1.161
Total	-1.572	-1.064	1.189

The combination of the cost elasticity and factor bias effects generates the demand elasticities with respect to the infrastructure capital. The computation of these elasticities for social infrastructure in Athens area is provided in table 5.6.7. Here social public capital appears to be a substitute for labour and private capital inputs, and complement for intermediate inputs, as was the case for the bias effects. The highest demand elasticities are, for labour, basic metal industries (ε_{LG} equal to –2.567), for private capital, leather goods manufacture (–2.117), and, for intermediate inputs, wood based industry (2.050). All the average demand elasticities with respect to social capital are higher than the respective elasticities for Greece as a whole, with the exception of labour.

Table 5.6.7 Sectoral cost functions for manufacturing in Athens region: private input demand elasticities with respect to social infrastructure capital, 1982-1991

Sector	ε_{LG}	ε_{KG}	ε_{MG}
20 (food)	-2.380	-1.480	0.755
21 (beverages)	-2.124	-0.936	0.987
22 (tobacco)	-2.454	-1.246	0.817
23 (textiles)	-1.858	-0.833	1.135
24 (footwear)	-1.447	-1.526	0.866
25 (wood)	-1.148	-0.786	2.050
26 (furniture)	-1.173	-1.109	1.129
27 (paper)	-1.679	-1.190	0.712
28 (printing)	-1.277	-1.050	1.116
29 (leather)	-2.143	-2.117	0.694
30 (rubber)	-1.693	-0.998	1.018
31 (chemical)	-1.762	-1.229	0.880
33 (mineral)	-1.536	-0.652	1.801
34 (basic metal)	-2.567	-1.035	0.903
35 (fabr. metal)	-1.455	-1.064	1.063
36 (machinery)	-1.466	-0.880	1.217
37 (electrical m.)	-1.425	-1.338	0.958
38 (transport eq.)	-0.729	-1.246	1.755
39 (miscellaneous)	-1.235	-1.181	1.058
Total	-1.661	-1.152	1.101

The last consideration for the Athens region (table 5.6.8) is the shadow value of social infrastructure capital for the manufacturing sectors. These values, as indicated previously, show the 'willingness' of the different sectors to pay for the additional units (services) of the particular infrastructure input. The highest shadow value appears to be that of the food sector (s_{Gi} equal to 0.192). Chemicals and textiles manufactures closely follow (0.157 and 0.144, respectively). However, overall these values of social infrastructure capital for Athens are significantly lower, on average, than those for the social category at the national level.

Table 5.6.8 Sectoral cost functions for manufacturing in Athens region: shadow values of social infrastructure capital, 1982-1991

Sector	s_{Gi}	Sector	s_{Gi}
20 (food)	0.192	30 (rubber)	0.043
21 (beverages)	0.074	31 (chemical)	0.157
22 (tobacco)	0.039	33 (mineral)	0.039
23 (textiles)	0.144	34 (basic metal)	0.020
24 (footwear)	0.066	35 (fabr. metal)	0.052
25 (wood)	0.005	36 (machinery)	0.009
26 (furniture)	0.008	37 (electrical m.)	0.044
27 (paper)	0.042	38 (transport eq.)	0.082
28 (printing)	0.046	39 (miscellaneous)	0.009
29 (leather)	0.008	Average	0.057

5.7 A cost function analysis for the manufacturing sectors of the Rest of Greece region

For the metropolitan area of Athens it was shown that the basic indicators for the manufacturing activities in this area were somewhat different from the respective indicators at the national level. This discrepancy was as expected for there is no doubt that the economy of Athens is much different from that of the remaining parts of Greece. For the region that constitutes the Rest of Greece[24] table 5.7.1 shows (column 2) that it is the food sector that has the highest percentage of manufacturing establishments. The footwear and sewing of fabric industry (for which it should repeated that has the highest number of establishments in the Athens area) then follows, and the similar sector of textiles ranks third. These three sectors do not only have the highest (double figure) percentages in terms of establishments, but they also have the highest percentages of average annual employment, even though in somewhat different rank order (the textiles industry coming first). Not surprisingly, the percentage for employment remuneration in the textiles and food sectors also are among the most important, but this is not the case for the footwear and sewing sector. The average salaries in this last mentioned sector are then clearly lower in comparison with others, for instance the non-metallic minerals or transport equipment industries, where remuneration percentages are much higher than their employment fractions.

Table 5.7.1 Descriptive statistics (average percentages) for manufacturing sectors (establishments with 20 persons and over) in the Rest of Greece region, 1982-1991

Sector	Number of Establishments	Av.Annual Employment	Remuneration of Employment	Gross Prod. Value	Value Added	Intermediate Inputs	Total Gross Asset Form.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
20	18.693	15.437	13.031	16.757	13.175	18.201	11.344
21	3.635	3.130	3.393	3.672	4.917	3.173	4.863
22	2.341	3.202	2.871	3.313	2.690	3.570	1.273
23	13.946	17.797	15.758	11.594	14.950	10.242	9.559
24	15.338	11.785	7.442	3.132	5.345	2.247	2.039
25	2.903	2.412	2.274	1.636	2.125	1.444	1.740
26	3.063	1.148	0.822	0.467	0.795	0.336	0.574
27	1.919	2.466	2.494	2.291	2.374	2.253	1.843
28	1.002	0.648	0.657	0.344	0.591	0.244	0.676
29	2.021	0.710	0.535	0.483	0.493	0.477	0.244
30	3.568	2.910	3.043	2.495	3.404	2.133	2.370
31	4.468	5.069	6.914	6.710	7.921	6.223	5.417
32	0.882	2.100	3.262	17.576	5.186	22.541	12.293
33	8.139	7.780	9.021	6.460	9.688	5.170	9.394
34	1.334	4.612	7.681	10.114	9.167	10.481	10.889
35	5.346	5.794	6.206	5.095	5.977	4.745	5.040
36	4.357	2.180	2.158	1.024	1.623	0.781	0.939
37	3.258	4.004	4.164	3.680	4.354	3.411	2.851
38	2.739	6.156	7.760	2.797	4.635	2.061	16.289
39	1.046	0.661	0.514	0.361	0.590	0.267	0.363
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Source: National Statistical Service of Greece (Annual industrial survey)

[24] This dataset is derived by subtracting the Athens data from those at national level.

The different sectoral composition is also reflected in the production indicators. In the Rest of Greece the petroleum and coal sector has the highest percentage of gross production value (column 5), followed by the food industry. It has to be mentioned again that the petroleum sector in Athens has the second from lowest percentage of gross production. The petroleum sector has this high ranking as a result of its high use of intermediate inputs (column 7). Thus, in terms of value added this sector has a relatively poor ranking. It is the textiles and food industries that have the higher value added performance. On the investment front, the two heavy industrial sectors of transport equipment and petroleum figure prominently in terms of gross asset formation, followed by a light industrial food sector.

5.7.2 Interpreting the results of manufacturing cost functions in the Rest of Greece region

This last section of empirical results presents the empirical findings for the manufacturing sectors in the Rest of Greece region. The former set of tables analyses the case of productive infrastructure and the latter the results for the social category.

Table 5.7.2 presents the estimation results, including productive infrastructure capital, of the cost and share functions. In similar fashion to the previous cost analyses the specification with the infrastructure variable has been tested against several alternatives. These alternative formulations, that of no sectoral effects, that of constant returns of scale, and that productive capital has no effect, have been rejected in favour of the model with public capital and sectoral effects. The respective log-likelihood ratio tests are LRT_D = 1362.04 (57 degrees of freedom), LRT_Y = 134.8 (4 degrees of freedom), and LRT_G = 95.58 (3 degrees of freedom). As the overall statistics of the productive public capital model are most satisfactory, the next step is to estimate the various measures of infrastructure impact on costs in private sector manufacturing.

Table 5.7.2 National sectoral cost function for manufacturing in Rest of Greece region: results of panel-estimation incorporating the effects of productive infrastructure capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	16.409	45.815
aL	1.191	9.826
aK	1.641	7.501
aY	0.751	36.690
aG	-0.300	-4.657
aT	0.030	4.132
bLK	-0.084	-5.040
bLY	-0.019	-3.253
bLG	-0.180	-8.270
bLT	0.021	8.679
bKY	-0.105	-10.290
bKG	-0.183	-4.599
bKT	0.028	6.077
bYT	-0.001	-1.328
	R-Square	Standard Error
Cost function	0.998	0.043
Labour share	0.959	0.012
Capital share	0.946	0.022
Log of Likelihood	1482.63	
	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1362.044	57
LRT_G	95.58	3
LRT_Y	134.8	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
The total number of observations is 200.
[b]The associated p-values for all tests are 0.000.

One of the measures of infrastructure's impact on private costs is cost elasticity with respect to public capital (ε_{CG}). These average elasticities for the twenty manufacturing sectors for the Rest of Greece are given in table 5.7.3. Here, the highest elasticity can be found for the miscellaneous manufacturing industries with a value of ε_{CG} equalling -0.321. The next highest come the electrical appliances (-0.311) and beverages sectors (-0.310). At the other end of the spectrum is printing and publishing (-0.279), leather and fur (-0.280) and petroleum and coal refining (-0.288). There seems, then, little distinct patterning in these elasticities, but, on the other hand, the variation around the total manufacturing average is rather small.

Table 5.7.3 National sectoral cost function for manufacturing in Rest of Greece region: cost elasticities of manufacturing with respect to productive infrastructure capital, 1982-1991

Sector	ε_{CG}	Sector	ε_{CG}
20 (food)	-0.297	30 (rubber)	-0.304
21 (beverages)	-0.310	31 (chemical)	-0.293
22 (tobacco)	-0.300	32 (petroleum)	-0.288
23 (textiles)	-0.301	33 (mineral)	-0.299
24 (footwear)	-0.299	34 (basic metal)	-0.293
25 (wood)	-0.309	35 (fabr. metal)	-0.301
26 (furniture)	-0.297	36 (machinery)	-0.297
27 (paper)	-0.294	37 (electrical m.)	-0.311
28 (printing)	-0.279	38 (transport eq.)	-0.299
29 (leather)	-0.280	39 (miscellaneous)	-0.321
	Total	Average	-0.299

In order to obtain the factor bias effects over share (table 5.7.4) the respective estimated coefficients from table 5.7.2 were divided by the corresponding private input share. Public capital appears to be labour and private capital saving, and intermediate inputs using for all industrial sectors. For petroleum and coal refining there seems to be a very high negative bias (-9.416), which means that public capital is labour saving in this sector. Other sectors having a high negative bias, which can be translated as large decreases of the labour input given increased infrastructure, are the basic metal industries (-2.558) and the food and beverage sectors (-2.308 and -2.101 respectively). Relatively low bias effect sensitivity for the labour input occurs in footwear manufacturing (-0.686), the transport equipment sector (-0.739) and the machinery and appliances industries, excluding electrical appliances (-0.902).

All the results for productive public capital bias are, as just mentioned, negative. This implies that productive public capital is saving private capital input and the highest bias can be found again for the petroleum and coal refining (-1.472). Similar bias occurs in the tobacco industries and the leather and fur (-1.234 and -1.015 respectively. At the opposite end of the ranking are non-metallic mineral products, beverages, and wood based industries (-0.346, -0.437, and -0.486 respectively. The bias effects for private capital, even though trending in the same direction, are much smaller in value than those for labour bias. The case for intermediate inputs bias is different. It seems that productive public capital appears to use, instead of saving, intermediate inputs. Thus, the high levels of bias for intermediate inputs are provided by non-metallic mineral products, transport equipment and the machinery and appliances industries, excluding the electrical appliances (0.989, 0.914, and 0.837 respectively). The lower saving bias for intermediate inputs comprises the sectors of petroleum and coal refining (0.434), tobacco industries (0.484) and leather and fur products (0.531).

Table 5.7.4 Sectoral cost function for manufacturing in Rest of Greece region: productive infrastructure factor bias effects over respective private input shares, 1982-1991

Sector	bias LG	bias KG	bias MG
20 (food)	-2.308	-0.751	0.536
21 (beverages)	-2.101	-0.437	0.733
22 (tobacco)	-1.920	-1.234	0.484
23 (textiles)	-1.416	-0.509	0.708
24 (footwear)	-0.686	-0.738	0.743
25 (wood)	-1.423	-0.486	0.732
26 (furniture)	-1.006	-0.501	0.800
27 (paper)	-1.760	-0.568	0.640
28 (printing)	-0.917	-0.536	0.802
29 (leather)	-1.456	-1.015	0.531
30 (rubber)	-1.455	-0.537	0.678
31 (chemical)	-1.688	-0.625	0.609
32 (petroleum)	-9.416	-1.472	0.434
33 (mineral)	-1.750	-0.346	0.989
34 (basic metal)	-2.558	-0.550	0.612
35 (fabr. metal)	-1.547	-0.557	0.660
36 (machinery)	-0.902	-0.539	0.837
37 (electrical m.)	-1.504	-0.664	0.601
38 (transport eq.)	-0.739	-0.520	0.914
39 (miscellaneous)	-1.241	-0.553	0.702
Total	-1.890	-0.657	0.687

The combined effect of the cost elasticities ε_{CG} (which can be considered as the 'productivity effect' of infrastructure) and the bias effect is measured by the private input elasticities with respect to public infrastructure (ε_{XG}, presented in table 5.7.5), where X =

L, K, M (see theoretical section). In this light, it is not surprising that the high bias effect for labour input has determined the labour input elasticity for petroleum and coal refining, with ε_{LG} equal to -9.703. Basic metal industries have the second largest labour demand elasticity (-2.851) and the food sector closely follows (-2.605). The lowest labour demand elasticities can be found in footwear manufacturing (-0.985) and transport equipment (-1.038). The private capital elasticity demand is again highest in petroleum and coal refining industries where ε_{KG} is -1.759, and this is followed by the values for tobacco (-1.535) and leather and fur manufacturing (-1.295). The lowest private capital elasticity demand figures in non-metallic mineral industries (-0.645). Other industries with low capital elasticity demand are beverages (-0.747), and wood (-0.795). It has already been said that the bias effect was positive in the case of the intermediate inputs for all industrial sectors. As the intermediate elasticity demand is the combined effect of this positive bias effect annd the negative cost elasticity (it was negative for all sectors), the intermediate elasticity demand could be either negative or positive. However, the larger absolute value of intermediate inputs bias effect has given positive values for the intermediate elasticity demand (ε_{MG}) of all industrial sectors. This means that an increase of public capital has a positive effect (increase) on demand for intermediate inputs. This effect is largest in non metallic mineral industries, with ε_{MG} = 0.690, followed by that in transport equipment (0.615), and the machinery and appliances industries, excluding electrical appliances (0.540). The lowest intermediate elasticity demand is observed for petroleum and coal refining (0.147) and other relatively low values occur in the tobacco and food industries (0.183 and 0.239 respectively). The overall conclusion, not only from the analysis of the private input elasticities with respect to productive public infrastructure, but also corroborated by the bias effects and the cost elasticities, is that labour and private capital inputs are substitutes to public capital, and intermediate inputs are complementary. This is similar to the general conclusion about US manufacturing (Nadiri and Mamuneas 1994, table 6) but different to the results of the German and Swedish cases (see Seitz 1994, p.305 and Berndt et al. 1991b), where public capital appears to be complementary to private capital.

Table 5.7.5 Sectoral cost functions for manufacturing in Rest of Greece region: private input demand elasticities with respect to productive infrastructure capital, 1982-1991

Sector	ε_{LG}	ε_{KG}	ε_{MG}
20 (food)	-2.605	-1.047	0.239
21 (beverages)	-2.410	-0.747	0.424
22 (tobacco)	-2.220	-1.535	0.183
23 (textiles)	-1.718	-0.811	0.407
24 (footwear)	-0.985	-1.037	0.443
25 (wood)	-1.732	-0.795	0.423
26 (furniture)	-1.303	-0.798	0.503
27 (paper)	-2.053	-0.862	0.346
28 (printing)	-1.196	-0.815	0.523
29 (leather)	-1.736	-1.295	0.251
30 (rubber)	-1.759	-0.841	0.374
31 (chemical)	-1.981	-0.918	0.316
32 (petroleum)	-9.703	-1.759	0.147
33 (mineral)	-2.049	-0.645	0.690
34 (basic metal)	-2.851	-0.843	0.319
35 (fabr. metal)	-1.849	-0.859	0.359
36 (machinery)	-1.199	-0.837	0.540
37 (electrical m.)	-1.815	-0.975	0.291
38 (transport eq.)	-1.038	-0.819	0.615
39 (miscellaneous)	-1.562	-0.874	0.381
Total	-2.188	-0.956	0.389

In table 5.7.6 the estimates for the average shadow prices for the twenty two-digit industrial sectors for this version of the analysis are given. As in the previous sections, here is presented only the average values of these elasticities, as every sector for every year has a different such elasticity. High shadow values are found in food production (s_G = 0.206), followed by petroleum and coal refining (0.191) and textile manufacturing (0.154). The sectors with the lowest shadow prices are printing and publishing (0.004), and leather/fur products and miscellaneous manufacturing (both 0.005). It is again difficult do discern a pattern in these values. However, it can be argued that one potential explanation is that the industries having high shadow prices are those with relatively high capital/labour ratios, and high output (measured in gross production value) to labour ratio. The opposite holds for those sectors with low shadow prices.

Generally speaking, the shadow prices for the Rest of Greece are they higher than those reported by Nadiri and Mamuneas (1994, table 7) for US manufacturing but much closer to those for Germany reported in Conrad and Seitz (1994, table 3).

Table 5.7.6 Sectoral cost functions for manufacturing in Rest of Greece region: shadow values of productive infrastructure capital, 1982-1991

Sector	s_{GI}	Sector	s_{GI}
20 (food)	0.206	30 (rubber)	0.031
21 (beverages)	0.051	31 (chemical)	0.077
22 (tobacco)	0.037	32 (petroleum)	0.191
23 (textiles)	0.154	33 (mineral)	0.106
24 (footwear)	0.036	34 (basic metal)	0.132
25 (wood)	0.023	35 (fabr. metal)	0.066
26 (furniture)	0.006	36 (machinery)	0.013
27 (paper)	0.029	37 (electrical m.)	0.046
28 (printing)	0.004	38 (transport eq.)	0.040
29 (leather)	0.005	39 (miscellaneous)	0.005
	Total	Average	0.063

The final set of tables (5.7.7 to 5.7.11) offers the analysis for the impact of social public capital on manufacturing costs in the region that constitutes the Rest of Greece. In similar fashion to its productive counterpart, the specification which introduces the social infrastructure category in the system of estimated equations, with sectoral dummy variables, and unconstrained in regard the returns of scale, has proved to be the most successful alternative. The alternative formulation that excluded sectoral effects (i.e. without dummy variables) was rejected based on the log-likelihood ratio test (LRT_D = 1,343.84). The version in which it was assumed that the social infrastructure has no impact on the manufacturing costs was also rejected with a log-likelihood ratio test (LRT_G =77.08 with 3 degrees of freedom). Finally, the alternative assuming constant returns of scale was also rejected, as the respective log-likelihood ratio test (LRT_Y) was equal to130.62 (with 4 degrees of freedom). The overall measures for the system of equations are, as in the case of productive infrastructure highly satisfactory.

Table 5.7.7 National sectoral cost function for manufacturing in Rest of Greece region: results of panel-estimation incorporating the effects of social infrastructure capital, 1982-1991

Variable	Estimated Coefficient	T-Ratio[a]
aO	16.748	39.777
aL	1.143	8.099
aK	1.592	6.340
aY	0.754	36.710
aG	-0.460	-4.758
aT	0.031	4.202
bLK	-0.059	-3.684
bLY	-0.018	-3.101
bLG	-0.218	-6.744
bLT	0.017	7.158
bKY	-0.106	-10.270
bKG	-0.220	-3.796
bKT	0.023	5.231
bYT	-0.001	-1.183

	R-Square	Standard Error
Cost function	0.988	0.043
Labour share	0.956	0.012
Capital share	0.946	0.022

Log of Likelihood	1473.38	

	Likelihood ratio test[b]	Degrees of freedom
LRT_D	1343.84	57
LRT_G	77.08	3
LRT_Y	130.62	4

[a]Value of Ratio of Parameter Estimate to Asymptotic Standard Error.
The total number of observations is 200.
[b]The associated p-values for all tests are 0.000.

The cost elasticities with respect to social infrastructure for the Rest of Greece are shown in table 5.7.8, where it can be seen that the highest value relates to miscellaneous industries. On average, the respective cost elasticities for this national residual region are higher than those for Greece as whole, and significantly higher than those for Athens.

Table 5.7.8 National sectoral cost function for manufacturing in Rest of Greece region: cost elasticities of manufacturing with respect to social infrastructure capital, 1982-1991

Sector	ε_{CG}	**Sector**	ε_{CG}
20 (food)	-0.456	30 (rubber)	-0.465
21 (beverages)	-0.472	31 (chemical)	-0.451
22 (tobacco)	-0.460	32 (petroleum)	-0.445
23 (textiles)	-0.462	33 (mineral)	-0.459
24 (footwear)	-0.459	34 (basic metal)	-0.452
25 (wood)	-0.470	35 (fabr. metal)	-0.462
26 (furniture)	-0.457	36 (machinery)	-0.457
27 (paper)	-0.453	37 (electrical m.)	-0.473
28 (printing)	-0.434	38 (transport eq.)	-0.459
29 (leather)	-0.436	39 (miscellaneous)	-0.485
	Total	Average	-0.458

The factor bias effects over share, presented in table 5.7.9, show that the type of relationships between the private inputs and social infrastructure in the Rest of Greece are the much the same as those seen nationally and in Athens. This confirms that social infrastructure is a substitute for labour and private capital, and a complement to the intermediate inputs, for all manufacturing sectors. In terms of magnitude, the highest bias effect for the labour input is that for the petroleum industry (–11.397) and this is also the case for private capital (–1.775) For the intermediate inputs the highest value is achieved by non-metallic mineral products (1.194).

Table 5.7.9 Sectoral cost function for manufacturing in Rest of Greece region: social infrastructure factor bias effects over respective private input shares, 1982-1991

Sector	bias LG	bias KG	bias MG
20 (food)	-2.793	-0.905	0.647
21 (beverages)	-2.543	-0.527	0.886
22 (tobacco)	-2.324	-1.489	0.584
23 (textiles)	-1.714	-0.614	0.856
24 (footwear)	-0.830	-0.890	0.897
25 (wood)	-1.722	-0.587	0.884
26 (furniture)	-1.218	-0.604	0.967
27 (paper)	-2.130	-0.685	0.773
28 (printing)	-1.110	-0.646	0.969
29 (leather)	-1.762	-1.224	0.641
30 (rubber)	-1.762	-0.647	0.820
31 (chemical)	-2.043	-0.754	0.736
32 (petroleum)	-11.397	-1.775	0.525
33 (mineral)	-2.118	-0.417	1.194
34 (basic metal)	-3.097	-0.663	0.740
35 (fabr. metal)	-1.873	-0.672	0.798
36 (machinery)	-1.091	-0.651	1.011
37 (electrical m.)	-1.821	-0.801	0.727
38 (transport eq.)	-0.894	-0.627	1.105
39 (miscellaneous)	-1.503	-0.668	0.848
Total	-2.287	-0.792	0.830

The overall effect of social infrastructure, provided by the private input demand elasticities, is given in table 5.7.10. The nature of the relationships is the same as for the factor bias effects and again it can be seen that the results for the Rest of Greece are much higher than those for Athens. Individually, the highest sectoral demand elasticity in this part of the analysis for the labour input is for the petroleum sector (ε_{LG} equal to –11.843, demonstrating that social infrastructure saves labour). The same is the case for the private capital input (–1.775 again saving private capital). The highest elasticity for intermediate inputs is that for non-metallic mineral products (0.736, which implies that the infrastructure is using intermediate inputs).

Table 5.7.10 Sectoral cost functions for manufacturing in Rest of Greece region: private input demand elasticities with respect to social infrastructure capital, 1982-1991

Sector	ε_{LG}	ε_{KG}	ε_{MG}
20 (food)	-3.250	-1.362	0.191
21 (beverages)	-3.015	-0.999	0.414
22 (tobacco)	-2.785	-1.949	0.124
23 (textiles)	-2.176	-1.076	0.394
24 (footwear)	-1.289	-1.349	0.438
25 (wood)	-2.193	-1.057	0.413
26 (furniture)	-1.675	-1.061	0.510
27 (paper)	-2.583	-1.138	0.321
28 (printing)	-1.545	-1.081	0.534
29 (leather)	-2.198	-1.660	0.206
30 (rubber)	-2.227	-1.112	0.355
31 (chemical)	-2.494	-1.205	0.285
32 (petroleum)	-11.843	-2.220	0.080
33 (mineral)	-2.577	-0.876	0.736
34 (basic metal)	-3.548	-1.115	0.288
35 (fabr. metal)	-2.335	-1.134	0.336
36 (machinery)	-1.548	-1.107	0.555
37 (electrical m.)	-2.294	-1.274	0.253
38 (transport eq.)	-1.353	-1.086	0.646
39 (miscellaneous)	-1.988	-1.153	0.363
Total	-2.746	-1.251	0.372

The shadow values of social public capital in the Rest of Greece are generally higher than for nation (the average for the latter is 0.284 compared to 0.402 for the national residual having excluded Athens). The highest individual values are for the food and petroleum industries (s_G equal to 1.322 and 1.205, respectively).

Table 5.7.11 Sectoral cost functions for manufacturing in Rest of Greece region: shadow values of social infrastructure capital, 1982-1991

Sector	s_{GI}	Sector	s_{GI}
20 (food)	1.322	30 (rubber)	0.201
21 (beverages)	0.328	31 (chemical)	0.493
22 (tobacco)	0.238	32 (petroleum)	1.205
23 (textiles)	0.980	33 (mineral)	0.675
24 (footwear)	0.232	34 (basic metal)	0.850
25 (wood)	0.145	35 (fabr. metal)	0.419
26 (furniture)	0.038	36 (machinery)	0.084
27 (paper)	0.187	37 (electrical m.)	0.294
28 (printing)	0.026	38 (transport eq.)	0.253
29 (leather)	0.032	39 (miscellaneous)	0.030
	Total	Average	0.402

5.8 Conclusions

Duality theory and cost function analysis is an alternative to the production function analytical framework. Despite the fact that the estimation of cost functions is more data demanding, this type of analysis has several significant advantages. It can provide an insight into the way in which infrastructure investment affects private sector costs. Another advantage is that it can produce unbiased and consistent results in comparison with the production function approach. Additionally, the cost function analytical framework is not characterised by some of the restrictive assumptions that underlie production functions, and especially the Cobb-Douglas variant.

For the empirical investigation of the infrastructural impact on manufacturing costs four different datasets were used. The first is familiar from the previous chapter regional panel and is based on prefectural data for total manufacturing. The second does not have a regional dimension, but instead was constructed from the data concerning manufacturing sectors in Greece at the national level. The third is again a sectoral set and refers to manufacturing industries in the metropolitan area of Athens. The last dataset is comprised of the remaining national manufacturing having excluded the Athens area. This 'region' has been labelled 'Rest of Greece'. Thus, there is one regional panel and three sectoral panels. The regional panel, undoubtedly, is richer in information about the variations of the infrastructure variable. However, the sectoral panels contain all the necessary information about the differential impacts of public capital on the various manufacturing sectors.

The public infrastructure variable has entered into the estimated systems of equations either as productive or as social public capital for all estimated panels of data. The formulation comprising the infrastructure variable and dummy variables (supposed to capture the specific regional/sectoral effects) and with no constraint about the type of returns of scale, was tested against three alternatives. In the first, it was supposed that there are no regional/sectoral effects; in the second, that public capital has no effect on private costs, and in the third, it was assumed that manufacturing operates under constant returns of scale. Again, these alternative hypotheses were tested with all four different datasets. In all cases the hypotheses for constant returns of scale and no regional/sectoral specific effects have been rejected.

The empirical findings based on the regional dataset have shown that productive infrastructure does have a significant and positive impact on the performance of private manufacturing, measured in terms of the cost elasticity with respect to public (productive) capital. In contrast, the social category of public capital does not appear to have an impact on private costs at regional level. It seems that productive capital has a substitutive relationship with labour and intermediate inputs, and complementary one for private capital input. Put somewhat differently, infrastructure provision tends to save labour and other intermediate costs and it tends to lever additional investment in the private sector.

These results are in accordance with the results based on the production function analysis for the same period and same spatial analysis (Rovolis and Spence, 1997a and 1997b). However, a significant limitation of the dataset employed here is that it refers to the aggregate form of manufacturing only. Supplementary analysis extended to regional sectors of manufacturing, as well as to other activities of the private sector, has not been possible here due to lack of data. Data limitations have also restricted the time dimension of this analysis to only 10 years.

As a concluding comment, one further set of findings can be reported, about which certainly more investigation is needed. If the values for simple single factor productivity are calculated (output per private input ratio), then these seem to be highly correlated with private input demand elasticities with respect to public infrastructure capital. Taking labour costs first, there is a distinct tendency for those regions with higher levels of labour productivity to substitute more infrastructure input for labour inputs. Areas with high labour productivity tend to be associated with high negative elasticities for labour. A plausible explanation is that in remote locations the opportunities for externalising parts of the production process are small. Add extra infrastructure and the possibilities are raised and if taken up might possibly lead to labour shedding. Much the same can be said for intermediate private inputs into the production process. Conversely, there is a tendency for those regions with higher levels of capital productivity to benefit more, in terms of the leverage of private capital, from an additional unit of infrastructure investment. High capital productivity is associated with high positive elasticities for capital.

The analysis for the sectoral panel of Greek manufacturing sectors has produced results that are in some ways contradictory, and in others complementary, to those obtained by the regional panel. First, the empirical findings from the sectoral analysis confirm that infrastructure capital reduces the costs of manufacturing. In the sectoral analysis it is not only the productive infrastructure that plays a significant role in cost reduction, but also the social dimension of public capital. In fact, the latter appears to have a larger impact than the former. It has to be remembered that at the regional level social infrastructure has no significant impact.

The sectoral ranking according to the various measures used in this analysis do not seem to follow a pattern in the same way that the values of simple factor productivity accord with the input demand elasticities (with respect to public infrastructure) obtained regionally.

Another point of difference between the sectoral and regional results concerns the actual magnitudes of the estimated measures. The average cost elasticity with respect to productive infrastructure, for instance, in the regional panel estimation is much smaller than the respective measure for the sectoral panel. What appears, however, to be most problematic between the two panels is the difference in direction of the relationship between productive infrastructure and private capital and intermediate inputs. In the regional panel the overall effect (measured by the private input demand elasticities) of public capital shows that it is a substitute for intermediate inputs and a complement for the private capital. These two relationships are exactly opposite in the case of the sectoral panel. A point of stability in these two analyses is that public infrastructure appears to be a substitute for labour input (saving labour).

The potential source of these discrepancies is the different nature of the two panels. Even though both refer to large-scale industry, the information contained in each panel is different. The regional panel contains the regional differences of total manufacturing, without uncovering the sectoral dimension, while the sectoral panel lacks the regional dimension. There is, however, a most important difference concerning the way in which public infrastructure 'enters' into the two panels. In the regional panel there is rich information about prefectural differences in infrastructure levels, as in every regional unit there corresponds a different regional stock of public capital. In the sectoral panel each sectoral unit 'faces' the same national stock of infrastructure. It is obvious that in an ideal world the NSSG should provide a regional breakdown for the sectoral data (such data are available for many other countries). Unfortunately, the metropolitan area of Athens is the only spatial unit for which such data are available. Thus, logically, the next step was to estimate infrastructure impact on the manufacturing sectors in the Athens area.

In the Athens region the productive category seems to play no great role in the cost structure of manufacturing. The social category's impact, too, is smaller than the same respective effect at the national level. The relationships between social infrastructure and private inputs are similar to the respective relationships at national level. If the Athens area is expected, *a priori*, to provide a different environment for private sector companies due to agglomeration economies, it is interesting to see how public capital affects manufacturing sectors elsewhere in the country.

The results obtained for the Rest of Greece, as expected, reflect the sectoral panel results at national level, if the results for the area of Athens are taken into consideration. Thus, both the productive and social categories seem to have a significant impact on the cost structure of this residual region's manufacturing. The magnitude of this impact is higher for both categories than at the national level regardless of the measure used. This also means that the direction of infrastructure relationship with the private inputs is similar to that of the national level.

The bigger effects discovered for infrastructure categories in the Rest of Greece compared to the lesser impact on the more advanced economy of the metropolitan area of Athens, is, probably, an indication that public capital has a more significant effect on economies at an intermediate stage of development. This point may help to explain some of the differences between the results of the regional panel on the one hand, and the three sectoral panels on the other.

Chapter 6

Public Capital, Scale Economies, and Returns to Variety: Investigating Alternative Channels of Infrastructure Effects at Different Spatial Levels

6.1 Introduction

The recent resurgence of infrastructure research has basically used production and cost function analytical frameworks. The empirical results obtained by these approaches have given some indications as to the relationship between the public infrastructure and economic and regional growth, even though the direction of this relation still remains somewhat unclear in some cases (see chapter 2 for a more extensive presentation of the theoretical debate). More recently a different way analysing this relationship has been formulated that basically involves the construction of economic models incorporating public capital as one of their basic parameters.

Several such models have been proposed with the objective of combining infrastructure research with dynamic growth modelling. Barro and Sala-i-Martin have used the production function approach, as well as attempting to model the impact of infrastructure on different economic growth rates. Their overall conclusion was that public capital could well have a positive effect on the growth process (Barro 1990, and Barro and Sala-i-Martin 1992). Similar to these models is that presented by Alogoskoufis and Kalyvitis (1996), the main difference being that these authors did not assume that the economy achieves a new steady growth rate[1] immediately.

[1] For an introductory analysis of the term 'steady growth rate' see Jones (1998) or Mankiw (1997).

Holtz-Eakin and Schwartz (1994), also using a neoclassical growth model for the (48 contiguous) US states, concluded that infrastructure does not play "*an important quantitative role in the explaining the growth patterns of the states*" (p. 20). However, they noted that their results must be viewed with the caveat that the model does not allow for any interaction between public capital and private investment incentives. Erenburg (1993), on the other hand, using a rational expectations model, concluded that the relationship between the investment behaviour of private and public sector in the United States was positive.

All the aforementioned models have shed some light on the mechanisms by which public capital transmits its effects to the economy of the private sector. Some of them are at a totally theoretical level. Others have been used for empirical research. However, it has not been possible to use any of them to analyse the different spatial levels of the Greek economy due to the existing data limitations. Instead, a complete model of a small open economy is has been used here which incorporates public infrastructure capital, and is similar to that presented by Holtz-Eakin and Lovely (1996). Section 2 of this chapter offers the theoretical construction and assumptions of the model.

Following this, the next part presents the empirical results for the different sectors and spatial levels of the Greek economy. These results can be classified under two major headings. First, the findings for the non-manufacturing sector of the economy are provided. More specifically the role of the public capital in impacting upon the regional Gross Domestic Product (GDP) and its sub-categories, has been analysed with the use of quasi-production functions.

Secondly, the results for the manufacturing sector of the economy are presented. The Holtz-Eakin and Lovely model delineates two channels by which infrastructure affects the secondary sector: one by altering the scale of production (and subsequently the level of total manufacturing output), and the other by affecting the equilibrium number of manufacturing establishments, perhaps better described by the phrase 'returns to variety'. There are again four different spatial levels for the empirical investigation of the Greek case. The first refers to a regional panel based on the Greek prefectures, though, at this level there is no sectoral breakdown. The second is that of a sectoral breakdown for

Greece as a whole. Third, is the sectoral breakdown for the metropolitan area of Athens. The findings for Athens are then compared to those obtained in the fourth and last level that represents the sectoral breakdown for manufacturing in the Rest of Greece.

The final part of this chapter draws some basic conclusions from the empirical analysis based on the modelling. These results are then compared to those of the Holtz-Eakin and Lovely paper for the US economy, and have been also used to put this analysis in perspective. More particularly, the results for the infrastructure's impact on a number of establishments are compared to recent findings and research.

6.2 Scale economies, returns to variety, and public capital

One of the most important recent models used in public capital research was that constructed by Holtz-Eakin and Lovely (1996). There follows a concise presentation of this model, which has been the basis for the empirical analysis for the Greek case. It has to be noted that the origin of the model can be attributed to the research by Ethier (1979, 1982). The economy of the model is sketched as a small, open one, with two sectors, one producing consumption goods ('wheat' in the Holtz-Eakin and Lovely terminology[2]) and the other finished manufactured goods ('manufactures' as they call them). In this economy there are two production inputs (factors of production), labour and capital[3].

In the model, consumption goods are produced by firms that operate under perfect competition. The perfect competition framework implies constant returns to scale (in the use of the two production inputs). The model ascribes a sector for the production of intermediate goods ('components' as they are termed. These intermediates are necessary for the production of the final goods of the manufacturing sector. It is hypothesised again that the intermediate goods sector is operating under perfect competition.

The two production factors, labour and private capital, can be used either for the production of consumption goods (W), or for the production of 'factor bundles' (m). The latter are used as inputs for the production of the intermediate goods. It is assumed that

[2] Here, some of the terminology is different to that of Holtz-Eakin and Lovely.
[3] This model can easily extended for the case of three production inputs, private capital, labour, and land (see Holtz-Eakin and Lovely (1996), footnote 6).

there is the following transformation function[4] for the economy (as the quantities of the production factors are given):

$$W = f(m) \tag{6.1}$$

In the Holtz-Eakin and Lovely model consumption goods (wheat) are used as numeraire (p. 108). As consumption goods and factor bundles are produced and sold under conditions of perfect competition, their relative price will be:

$$\mathrm{P_m} = -\mathrm{f}'(\mathrm{m}) \tag{6.2}$$

This comprises the opportunity cost for the production of factor bundles.

As was mentioned earlier, factor bundles are used for the production of intermediate goods. Intermediate goods, in turn, are used for the production of the final goods of the manufacturing sector, in a manner described by the following production function:

$$M = n^{\alpha}\left[\sum_{i=1}^{n}\frac{x_i^{\beta}}{n}\right]^{\frac{1}{\beta}} \tag{6.3}$$

where x_i is the input of intermediate good i into the production of final goods of the manufacturing sector, M. It is supposed that there are n varieties of intermediate goods in the model economy. Parameter α is a measure of economies of scale with respect to the

[4] The 'transformation function' is a description of the technologically efficient plans (of the particular economy), or, equivalently, this function picks out the maximal vectors of net outputs (Varian 1992). Equation 6.1 may be represented by a production possibilities frontier, which is convex to the origin. This implies that the first derivative of equation 6.1 is $\mathrm{f}'(\mathrm{m}) < 0$, and the second derivative is $\mathrm{f}''(\mathrm{m}) \leq 0$ (see, for this point, Holtz-Eakin and Lovely (1996), p. 108, and for the convexity of transformation functions in a multioutput context refer to Chambers (1988), pp. 260-261).

range of intermediate goods ($\alpha > 1$ denotes increasing returns to variety). Parameter β is a measure of the degree of differentiation between any pair of intermediate goods, as it has been assumed that they are imperfect substitutes[5]. Higher (lower) values of β denote less (more) differentiation among the intermediate goods. Holtz-Eakin and Lovely pointed out that 'intermediate goods' (components in their terminology) have been interpreted in different ways in the existing examples of similar economic modelling[6]. In any case, the crucial point is that the final goods production process is dependent on a wide variety of specialised services and goods (see for this point Holtz-Eakin and Lovely 1996, p.109). They assumed that all varieties of intermediate goods have identical production technologies, and argue that "*since each variety enters symmetrically into the production of finished manufactures, in equilibrium an identical quantity, x_0, will be supplied of each variety*" (ibid.). Under this assumption, 6.3 will become:

$$M = n^{\alpha} x_0 \qquad (6.4)$$

It is obvious from this last equation that the final goods of the manufacturing sector are linearly homogeneous in input x_0, and homogeneous to degree a in n. It is assumed that there are many competitive firms which produce final goods using the intermediate factor bundles. For this reason Holtz-Eakin and Lovely (1996, p. 109) argue that "*each of [these firms] takes n as given*" and, more crucially, that the n varieties of intermediate goods can be viewed as an index of the range of economic activity in an economy. Higher values for n, in this context, indicate a more dynamic economy.

An increase of the public infrastructure can raise x_0[7]. But even in cases where there is no such increase, there is the possibility of an indirect increase of productivity, as there is the possibility that a change of infrastructure capacity can increase the number of n (therefore, the range of economic activity).

[5] The elasticity of substitution between any pair of intermediate goods is $1/(1-\beta)$.
[6] See, for instance, Holtz-Eakin and Lovely's own interpretation (1996), Ethier's (1982) as specialised intermediate inputs, or Markusen's (1989) as producer services.
[7] This case corresponds to the increases in productivity usually considered with production and cost function analyses.

There are several other assumptions for the model used here. It is assumed that unlimited quantities of consumption and finished manufactured goods can be traded at P_m price. In the Holtz-Eakin and Lovely model it is assumed that intermediate goods are not tradeable[8]. It is also assumed that the producers of intermediate goods behave as monopolistic competitors (n is adequately large and there is free entry into this sector of the economy).

Each variety of intermediate goods (x) is produced by factor bundles, under the relationship $ax+b$, where $a, b > 0$. A certainpart of the necessary factor bundles in the economy, such as road networks, sewage systems, etc, can be provided by the public sector. This will save private resources that would, otherwise, have been directed to the production of this infrastructure.

As Holtz-Eakin and Lovely point out, public infrastructure can decrease either fixed or variable costs, or both. If F is the reduction in fixed costs, and v the reduction in variable costs, then the production of x units of any variety of intermediate goods would require the use of a quantity of factor bundles given by:

$$Q(x) = (a - v)x + b - F \tag{6.5}$$

The private cost of these factor bundles will be:

$$C_{fb} = P_m((a - v)x + b - F) \tag{6.6}$$

The marginal private cost for the intermediate goods producers will be:

[8] This assumption is important for spatial analysis. Ethier (1979, 1982) assumed that intermediate goods can be traded. However, Markusen (1991) and Holtz-Eakin and Lovely (1996) presumed that intermediate goods (and services) that contribute to the manufacturing sector are unique to the local economy. Thus, finished manufactured goods are "assembled from intermediate goods and services produced exclusively in the home jurisdiction" (Holtz-Eakin and Lovely 1996, p.110).

$$MPC = P_m(a - v) \tag{6.7}$$

and the marginal revenue will be[9]:

$$MR = \beta P_c \tag{6.8}$$

where,

P_c is the price of each intermediate good.

This price can be expressed in the terms of the Pm numeraire. As the producers of intermediate goods will equate their marginal cost to their marginal revenue, Pc will be:

$$P_c = \frac{P_m(a - v)}{\beta} \qquad [\text{as} \quad P_m(a - v) = \beta P_c] \tag{6.9}$$

The equation for the profit of each intermediate goods producer will be:

$$\pi = P_c x_0 - P_m((a - v)x_0 + b - F) \tag{6.10}$$

In equilibrium there will be free entry and exit of producers, and the profit π will be equal to zero. Equating equation 6.10 to zero and replacing P_c with the right hand side of equation 6.9, equation 6.10 will be:

[9] For the derivation of this marginal revenue, see Holtz-Eakin and Lovely (1996), footnote 9.

$$\frac{P_m(a-v)}{\beta}x_0 - P_m((a-v)x_0 + b - F) = 0 \tag{6.11}$$

Rearranging equation 6.11 means that:

$$x_0 = \frac{\beta(b-F)}{(1-\beta)(a-v)} \tag{6.12}$$

Equation 6.12 can be interpreted as follows. As x_0 is increasing in β, the more a variety of intermediate goods can be substituted from other varieties, the more each firm will produce that particular variety.

In this model the demand for factor bundles comes from the producers of intermediate goods and the public sector (for the creation of the infrastructure stock). There are two extreme possibilities regarding the nature of the public capital. One possibility is for it to be a pure public good. Such goods are not excludable and non-rival, i.e. "*people cannot excluded from consuming them... and one person's consumption does not reduce the amount available to other consumers*" (Varian 1992, p. 414). Another possibility is for it to be a public sector good that is little different from those produced in the private sector (in this case the goods are ordinary, that is both excludable and rival)[10].

Holtz-Eakin and Lovely, in order to capture the whole range of possibilities (including the two extremes), sketched the total demand for factor bundles as:

$$m = n((a-v)x_0 + b - F) + n^{\gamma}(vx_0 + F) \tag{6.13}$$

In the above equation it is parameter γ that denotes the nature of infrastructure. If $\gamma = 0$, v and F are pure public goods. If $\gamma = 1$, v and F are pure private goods.

[10] There can be many in between cases. On such intermediate type are the 'club' goods (nonrival, but excludable [see Varian 1992, p. 415]).

The supply price of the finished manufactured goods must be equal to P_m (prices are measured in terms of wheat)[11]. The profits in the sector of the economy where the intermediate goods are assembled into final manufactured goods will be zero. This means that:

$$P_m M = P_c x_0 n \tag{6.14}$$

The above relationship can be transformed, with the use of equation 6.4, to become:

$$P_m = n^{1-a} P_c \tag{6.15}$$

It is apparent from the last equation that an increase in n will have, as a result, an increase in productivity, and subsequently a decrease in the supply price of finished manufactured goods. An increase of P_c, will have the opposite effect - that is it will increase P_m.

Holtz-Eakin and Lovely asked the question, what would be the effects of an increase of public capital[12] in the context of this particular model. The system of basic equations of the model (equations 6.9, 6.12, 6.13, and 6.15) can be used for the purpose of answering this question.

An increase in public capital would have, as a result, a change in the cost structure of intermediate goods (by changing the preferred levels of output). Equation 6.16 can be derived from equation 6.12 by total differentiation:

[11] As is usually the norm in economic modelling, a good (in this case wheat) 'plays' the role of money, and the prices for the other goods are calculated on the basis of how many units of wheat can be bartered for one unit of the particular good in question.

[12] It has to be noted that Holtz-Eakin and Lovely, in order to clarify the effects of an infrastructure increase, abstracted "from issues of distortionary-tax financing and assumed that government spending is funded by lump-sum taxation of households" (Holtz-Eakin and Lovely 1996, p.111).

$$\hat{x}_0 = \frac{-F}{b-F}\hat{F} + \frac{v}{a-v}\hat{v} \equiv -\delta_F \hat{F} + \delta_v \hat{v} \tag{6.16}$$

where,
the symbol {^} denotes proportional changes.

Equation 6.16 shows that increases in F will reduce x_0, and increases of v will raise x_0. Similarly, total differentiation of the other basic equations (equation 6.9, 6.13, and 6.15) provides that:

$$\hat{P}_c = \xi \hat{m} - \delta_v \hat{v} \tag{6.17}$$

and

$$\hat{m} = \phi_n \hat{n} + \phi_x \hat{x} - \phi_v \hat{v} - \phi_F \hat{F} \tag{6.18}$$

[where, $$\phi_n = \frac{n((a-v)x_0 + b - F) + \gamma n^{\gamma}(vx_0 + F)}{m} \tag{6.19}$$

$$\phi_x = \frac{n((a-v)x_0 + n^{\gamma} vx_0)}{m} \tag{6.20}$$

$$\phi_v = \frac{(n - n^{\gamma})vx_0}{m} \tag{6.21}$$

$$\phi_F = \frac{(n^{\gamma} - n)F}{m} \tag{6.22}$$]

$$\hat{P}_M = (1-a)\hat{n} + \hat{P}_C = 0 \tag{6.23}$$

Equation 6.17 shows the changes in the price of intermediate goods as a result of a change of public capital provision (the subsidy to variable costs, v). This equation also shows that P_c is affected by changes in m (factor bundles). Holtz-Eakin and Lovely argued that if resources are withdrawn from the production of consumption goods (the case where $\hat{m} > 0$), then the price of factor bundles will rise. The magnitude of this increase depends on the curvature of the production possibility frontier, ξ (see Holtz-Eakin and Lovely, p. 112).

The changes in the demand for factor bundles are given by equation 6.18. It is clear from this equation that there are three sources of such changes. One results from changes in the number of intermediate goods producers (shown by the first term of the right-hand side of equation 6.18). Another source is changes of the production level of these producers (shown by the second term). Finally, government purchases can affect the demand for factor bundles (shown by the third and fourth terms).

Equation 6.23, which closes the system, shows the external price constraint on the supply price of finished manufactured goods. As this equation demonstrates, an increase (decrease) in the number [varieties] of intermediate goods will decrease (increase) the supply price (if $a > 1$). This change must be offset by the positive (negative) effect in the price of the intermediate goods.

Holtz-Eakin and Lovely, using this theoretical model, studied the effects of changes in public capital on the level of output and productivity in equilibrium. They first examined changes in that part of infrastructure that decreases fixed costs (that is, F). If the system of equations 6.16, 6.17, 6.18, and 6.23 is solved, it is possible to derive the proportionate changes in the price of intermediate goods, the demand for factor bundles, and the number of intermediate goods. These changes are given in equations 6.24, 6.25, and 6.26 respectively:

$$\frac{\hat{P}_c}{\hat{F}} = \frac{(a-1)\xi(\phi_x\delta_F + \phi_F)}{D} > 0 \qquad (6.24)$$

$$\frac{\hat{m}}{\hat{F}} = \frac{(a-1)(\phi_x \delta_F + \phi_F)}{D} > 0 \tag{6.25}$$

$$\frac{\hat{n}}{\hat{F}} = \frac{\xi(\phi_x \delta_F + \phi_F)}{D} > 0 \tag{6.26}$$

where,

$D \equiv \xi\phi_n - (a-1) > 0$.[13]

The provision of public capital attracts production factors into the production process of intermediate goods. This has, as a consequence, an increase in the marginal cost of factor bundles (in terms of consumption goods). The producers of intermediate goods would pass on this cost, *ceteris paribus*, but only to the extent of their market power and in terms of a mark-up percentage). Holtz-Eakin and Lovely observed that "*an increase in component prices must be accompanied by an expansion in varieties if the economy is to retain a competitor in finished manufactures*" (Holtz-Eakin and Lovely 1996, p.113). Due to the mark-up, the intermediate goods industry will have profits at the initial phase of the economy (the phase with *n* varieties). These profits will generate entry of new firms into the sector producing intermediate goods. As Holtz-Eakin and Lovely argue "*an increase in public infrastructure increases the number of component producers and enhances any external economies of the finished manufactures industry*" (ibid.).

[13] This condition is necessary in order to have a positive price-output relation for the manufacturing sector. This assumption restricts the analysis to the concave part of the production frontier for the consumption and manufactured goods (for further analysis, see Holtz-Eakin and Lovely 1996, footnote 11).

From equation 6.4 the proportionate change in finished manufactured goods is:

$$\hat{M} = a\hat{n} + \hat{x}_0 \tag{6.27}$$

An increase in the number of the firms producing intermediate goods does not ensure an expansion of the sector producing manufactured goods. It can also be seen in equation 6.16 that a public capital increase which reduces the fixed costs (F) will decrease the level of output of the manufacturing sector that is maximising profits. If the solutions for $\hat{n}$ and $\hat{x}_0$ are substituted in the above equation, the effect of F on the manufacturing sector can be derived as:

$$\frac{\hat{M}}{\hat{F}} = \frac{\xi\delta_G(a\phi_x - \phi_n) + a\xi\phi_F + (a-1)\delta_G}{D} \tag{6.28}$$

The sign of the numerator of the right-hand side of equation 6.28 depends on the sign of quantity $a\phi_x - \phi_n$ (as all the other terms are positive). If this quantity is positive then $\hat{M}$ will be positive. This will be the case if:

$$(a-1) > \frac{1-\beta}{\beta} \qquad (6.29)^{14}$$

As Holtz-Eakin and Lovely helpfully point out *"the left-hand side of this equation is the rate at which the economy realizes returns to variety (see Ethier, 1982) while the right-hand side is a measure of the firms' market power: the percentage mark-up over marginal cost. If the return to variety dominates the ability of firms to capture the returns*

[14] For the derivation of this equation, see Holtz-Eakin and Lovely (1996), p.114.

to restricting output M will rise. Alternatively, if firms have sufficient market power to enforce greater mark-ups, the contraction of x_0 will dominate and M will fall" (Holtz-Eakin and Lovely 1996, p.114).

In summary, it can be argued that changes in the provision of public capital can affect the economy in different ways depending, on the one hand, upon market structure, and, on the other, on technological factors.

Holtz-Eakin and Lovely argue that infrastructure changes do not affect the economy only by reducing the fixed costs (*F*), but also by reducing the variable costs (*v*). For the study of the effects of the latter they reproduced the aforementioned analysis for *v*. These effects are given by the following set of equations:

$$\frac{\hat{P_c}}{\hat{v}} = \frac{-(a-1)(\xi(\phi_x\delta_v - \phi_v) - \delta_v)}{D} \tag{6.30}$$

$$\frac{\hat{m}}{\hat{v}} = \frac{\phi_n\delta_v - (\phi_x\delta_v - \phi_v)(a-1)}{D} \tag{6.31}$$

$$\frac{\hat{n}}{\hat{v}} = \frac{-(\xi(\phi_x\delta_v - \phi_v) - \delta_v)}{D} \tag{6.32}$$

Equation 6.30, 6.31, and 6.32 give the effects of the price of intermediate goods, factor bundles used in the production process of manufactured goods, and the variety of intermediate goods, respectively. It has to be emphasised that all these expressions can be either > 0, or = 0, or < 0.

Generally speaking, as these equations show, the net effects of the reduction of variable costs, due to an increase of public capital, are not too clear[15]. This can be seen in the following equation, which is the counterpart for variable costs of equation 6.28:

$$\frac{\hat{M}}{\hat{v}} = \frac{a\varepsilon\phi_v + \delta_v - \varepsilon\delta_v(a\phi_v - \phi_n)}{D} \tag{6.33}$$

This equation can be either > 0, or = 0, or < 0. The sufficient condition in order to have $\hat{M} > 0$ is that $a\phi_x - \phi_n < 0$[16].

Holtz-Eakin and Lovely concluded that, in this model's context, the effects of public capital on the manufacturing sector "*are far from direct and clear-cut. Reductions in fixed costs will have far different effects than reduction in variable cost, and the effects of the latter are quite complex*" (Holtz-Eakin and Lovely 1996, p.115).

Similar were their results for the impact of infrastructure on the consumption goods sector. The production of consumption goods would increase (decrease) due to the release (acquirement) of factor bundles from the manufacturing sector. Equations 6.25 and 6.31 show that if fixed costs (*F*) are increased, then the volume of consumption goods will drop. In contrast, an increase of variable costs (v) would have results that are unclear.

[15] See Holtz-Eakin and Lovely (1996), p 114-115, for an analysis of these ambiguities.
[16] Holtz-Eakin and Lovely (1996) point out that this is exactly the opposite of the sufficient condition for F.

6.3 Infrastructural impacts on the non-manufacturing sector of the Greek economy

As already mentioned, Holtz-Eakin has written extensively on how infrastructure affects the productivity of the private sector (Holtz-Eakin 1992a, 1993a, and Holtz-Eakin and Schwartz 1995) He was also one of the prominent figures in the camp advocating that public capital does not have any significant impact on private output. However, all this body of work was restricted to the investigation of this single potential 'channel' of influence (the direct impact via a production function) between infrastructure and development.

Holtz-Eakin and Lovely (1996) in contrast have used the theoretical model presented in the previous section for the study of potentially alternative channels of influence in the relationship. Namely, they calibrate their model for the examination of infrastructure effects on the consumption goods sector (as the majority of the existing empirical research has studied the effects on the manufacturing sector), as well as on of how public capital affects the range of varieties (the range of intermediate goods). For the study of the latter they used the number of manufacturing establishments as a proxy.

The following analysis tries to utilise the theoretical model of Holtz-Eakin and Lovely for the investigation of such alternative channels in the Greek context, placing special emphasis on the spatial dimension. However, there are significant obstacles in undertaking this task, due to limitations of the available data, both at the regional and the national level.

This section assesses the impact of infrastructure on the non-manufacturing sector, which includes both the primary and tertiary sectors. In the next section the analysis focuses on the manufacturing sector of the economy and investigates the role of public capital on the increase or decrease of varieties, using the number of establishments as a proxy for the latter.

Even though there is now a small body of work on the results of public capital on the industrial sector of Greek economy (see Dalamagas 1995, Rovolis and Spence 1995, 1997a, 1997b, 1998, Segoura and Christodoulakis 1997) there is a notable absence (here as elsewhere) of research regarding effects on the non-manufacturing sector. The main reason for this is the absence of some key data regarding private capital investment and employment in sectors other than manufacturing. Thus, the application of production function analysis, not to mention the more data demanding cost function approach, seems impossible in this important part of the economy. However, there is an alternative approach, such as the use of quasi-production functions, which can give some indication for the impact of public capital.

Quasi-production functions have already been used in infrastructure research. In fact one of the most significant pieces of research at the regional level - the Biehl report (1986) for the EU - has used this approach extensively. However, here a slightly different implementation of quasi-production functions has been followed (forced upon by the data limitations), which in no small measure follows and develops upon that of Cutanda and Paricio (1994). These authors, interested in the relationship between public capital and regional economic growth in Spain, estimated a function of the type:

$$Y_i = a + b_1 E_i + b_2 I_i + e \tag{6.35}$$

where:
Y_i is the per capita regional income,
E_i the employment rate in industry,
I_i an infrastructure indicator,
and e the error term.

One of the problems with the empirical analysis of Cutanda and Paricio is that, due to their data limitations, the time dimension they used is restricted to a specific point in time. It is, effectively, a cross sectional analysis.

Here for Greece, a panel data model is used in order to provide the necessary information for both the time and spatial dimensions. More particularly, data for 49 prefectures of Greece were used for the period 1982 to 1991. The prefectures vector is derived from the official Greek prefectures (NUTS III according to the EU classification). However, the industrial data for employment, which are used in the analysis, imposed several limitations. Thus, as a result, it proved necessary to exclude Lefkada, where there was no industrial activity during the period, and to add the statistics for Kephalonia to those of the adjacent prefecture of Zakynthos (for a more extensive analysis, see chapter 4). The data for infrastructure have been purged of purely accounting expenditures (represented by Miscellaneous and Administrative Expenditures sub-categories) and what remains is pure investment in the public capital (as in previous chapters). The various categories of public capital expenditure have been again classified into the two important components of 'productive' and 'social' infrastructure. Total infrastructure investment is the sum of these two categories. The infrastructure capital stocks have been estimated with the way described in chapter 4, and the public capital variable always refers to the previous year (lagged one year).

The output data comprise the regional Gross Domestic Product (GDP). These data were provided by the National Statistical Service of Greece (NSSG) and are supplied with a breakdown into the various sub-categories which comprise the regional GDP. These are Agriculture-Farming-Forestry-Fishery (henceforth Agriculture), Mines, Electricity-Lighting-Water Companies (henceforth Electricity), Constructions, Transportation-Telecommunications (henceforth Transportation), Commerce, Banking-Insurance-Land Estate sectors (henceforth Banking), Housing, Public Administration, Health-Education (henceforth Health), Services (which includes various categories of services), and Manufacturing. As the impact of public capital on the latter has been analysed in detail in chapters 4 and 5, the following analysis focuses only on the infrastructure effects on the other categories of regional GDP.

It has to be noted that all the quasi-production functions of this section, as well as the analysis regarding the returns of variety for the manufacturing sector (next section), have been formulated with regional specific effects and a time trend. These are least squares dummy variable models (LSDV), similar to those described in chapter 4. This means that the error term of equation 6.35 should be written as:

$$e_{it} = \mu_i + v_{it} \tag{6.36}$$

where:

μ_i is the unobservable regional specific effect, and v_{it} is the remainder disturbance (for a further analysis of how the dummy variables, which capture these regional specific effects, are organised see chapter 4, section 4.4). However, the results for these dummy variables are not reported here due to space limitations. Thus, the panel of data used in this analysis has an *N* regional dimension, and a *T* time dimension.

There are three tables of results regarding the effects of public capital on the non-manufacturing sector. Table 6.1 presents the findings for the total of infrastructure taken as a whole, table 6.2 examines only the productive part of public capital, and table 6.3 the social component.

In all these tables a Hausman specification test has been performed. This test can demonstrate if the hypothesis of the exogeneity public capital is valid or not. Usually the question of whether infrastructure investment in a specific geographical area is exogenous or not, is circumvented in empirical work. A potential theoretical justification for this could be that public investment has been decided on by a central state mechanism, without any relation to the regional output. Another reason could be the fact that when the effects of infrastructure on the output of the secondary sector of the economy are examined, the latter can constitute only a rather small part of the regional economy (when the primary and/or the tertiary sectors are the most significant). However, in the case where the whole regional GDP is the dependent variable, there is a strong possibility that GDP disparities are the source of public capital disparities.

The way in which the Hausman specification test is conducted can be found in most econometrics texts[17]. In a nutshell, the test principle is that the regressor (of an original regression), which is to be tested for exogeneity, should be used in an auxiliary regression as the dependent variable, in which the other regressors (of the original regression) are the explanatory variables. The residuals of this auxiliary regression are then used as another regressor in the original regression. If the coefficient of the residuals in this augmented regression is statistically significant, then there is a simultaneity problem.

The first column of Table 6.1, which deals with the total public capital stock, refers to the regional GDP categories, which are the dependent variables for the respective regressions. The second column gives the estimates for the constant term, the third for the labour input (which refers to the employment of the manufacturing sector), the fourth for the infrastructure variable, and the fifth for the time trend. The next three columns give the usual measures of the regressions, the adjusted R square, the error sum squares, and the standard error of the regression, respectively[18]. The last column presents, under the *h* heading, the results for the Hausman specification test of the augmented regression (however, the rest of the results refer to the original regression). As mentioned above, the results for the dummy variables are not reported on here. The 'total' row gives the results for the sum of regional GDP categories (including total manufacturing). The infrastructure coefficient appears to be small in magnitude (0.036) and statistically insignificant. The *h* statistic shows that the hypothesis of exogeneity for public capital cannot be rejected. Some of the categories of regional GDP seem to have large infrastructure coefficients, which are also statistically significant. These are the Agriculture, Banking, Housing, Public Administration, Services, and to some extent the Health GDP categories. The signs of these coefficients in some cases is negative (Agriculture, Health, and Housing). However, for all the cases where the infrastructure variable appears to be statistically significant the *h* statistic shows that the hypothesis of exogeneity for public capital must be rejected. Thus, the overall conclusion from this

[17] See for instance Berndt 1991, pp. 379-380, Cujarati 1995 pp. 670-673, or the original paper of Hausman (1976), and Nakamura and Nakamura paper (1981)). For the application of the test in a panel data analysis context, see, for instance, Baltagi 1995, pp. 68-73).

[18] These measures are from the formulation with a constant term and *n-1* dummy variables.

table is that the infrastructure variable does not seem to have an impact on regional GDP, and this is inferred from the results for the aggregate GDP category and for the individual sub-categories.

Table 6.1 The effect of total public capital (G total) on the GDP of the non-manufacturing sectors of Greece, 1982-1991

Equation for per capital regional income (ln)

GDP Category	Constant	lnL	lnG(total)	time trend	Adjust. R2	SSE	SE	h
TOTAL	20.671	0.031	0.036	0.017	0.995	1.832	0.065	0.036
	(41.217)***	(2.009)**	(1.427)	(5.385)***				(1.426)
AGR	22.938	0.073	-0.154	0.024	0.959	11.606	0.163	-0.154
	(18.171)***	(1.849)*	(-2.404)**	(3.121)***				(-2.400)**
BANK	9.524	-0.079	0.420	0.029	0.961	14.917	0.185	0.420
	(6.655)***	(-1.780)*	(5.801)***	(3.266)***				(5.776)***
COMMER	18.209	0.035	0.048	0.016	0.989	4.291	0.099	0.048
	(23.725)***	(1.456)	(1.245)	(3.294)***				(1.245)
CONSTR	19.507	-0.002	-0.010	0.029	0.983	4.136	0.097	-0.010
	(25.886)***	(-0.084)	(-0.267)	(6.131)***				(-0.267)
HEALTH	19.279	0.030	-0.057	0.063	0.993	2.607	0.077	-0.057
	(32.225)***	(1.635)	(-1.877)*	(17.027)***				(-1.878)*
HOUS	24.744	0.089	-0.333	0.074	0.960	14.396	0.181	-0.333
	(17.600)***	(2.024)**	(-4.681)***	(8.442)***				(-4.681)***
MINES	36.836	-0.322	-0.906	0.004	0.769	1489.66	1.844	-0.906
	(2.576)**	(-0.724)	(-1.252)	(0.043)				(-1.253)
PADMIN	14.916	0.025	0.190	0.022	0.968	12.116	0.166	0.190
	(11.565)***	(0.615)	(2.910)***	(2.764)***				(2.913)***
SERV	11.686	0.041	0.365	0.003	0.988	5.182	0.109	0.365
	(13.855)***	(1.547)	(8.556)***	(0.636)				(8.545)***
TRANSP	18.336	0.038	0.034	0.002	0.997	1.250	0.053	0.034
	(44.261)***	(2.952)***	(1.639)	(0.854)				(1.626)

Note: *t*-statistics in parentheses (and henceforth in all tables)

***Statistically significant at 1% level **Statistically significant at 5% level *Statistically significant at 10% level

In tables 6.2 and 6.3 the total infrastructure variable has been replaced by its productive and social components. The regional GDP categories, as well as the regression tests remain the same. Table 6.2 gives a similar picture to that of table 6.1. The magnitude of the coefficient for public capital, in the regression where the dependent variable is the total regional GDP, is small (0.031) and statistically insignificant. Again the coefficients for public capital are statistically significant, although with different signs, in cases where the GDP sub-categories, Agriculture, Banking, Housing, Public Administration, Services, Health were used as the dependent variable. In all these cases the Hausman specification tests indicated that the infrastructure variable is probably endogenous.

Table 6.2 The effect of productive public capital (G productive) on the GDP of the non-manufacturing sectors of Greece, 1982-1991

Equation for per capital regional income (ln)

GDP Category	Constant	lnL	lnG(prod)	time trend	Adjust. R2	SSE	SE	h
TOTAL	20.785	0.032	0.031	0.017	0.995	1.832	0.065	0.031
	(49.519)***	(2.053)**	(1.440)	(5.756)***				(1.438)
AGR	22.037	0.069	-0.108	0.021	0.959	11.651	0.163	-0.108
	(20.818)***	(1.750)*	(-2.016)**	(2.787)***				(-2.013)**
BANK	11.014	-0.072	0.346	0.033	0.961	14.954	0.185	0.346
	(9.185)***	(-1.615)	(5.699)***	(3.874)***				(5.680)***
COMMER	18.406	0.036	0.039	0.016	0.989	4.292	0.099	0.039
	(28.648)***	(1.500)	(1.185)	(3.606)***				(1.185)
CONSTR	19.551	-0.002	-0.013	0.029	0.983	4.135	0.097	-0.013
	(31.002)***	(-0.080)	(-0.393)	(6.575)***				(-0.394)
HEALTH	19.120	0.030	-0.049	0.063	0.993	2.606	0.077	-0.049
	(38.193)***	(1.594)	(-1.932)*	(17.919)***				(-1.935)*
HOUS	24.084	0.084	-0.302	0.074	0.960	14.276	0.181	-0.302
	(20.555)***	(1.943)*	(-5.079)***	(9.027)***				(-5.078)***
MINES	35.334	-0.332	-0.836	0.008	0.769	1488.53	1.843	-0.836
	(2.953)***	(-0.749)	(-1.379)	(0.090)				(-1.379)
PADMIN	15.001	0.026	0.187	0.020	0.969	12.072	0.166	0.187
	(13.948)***	(0.653)	(3.434)***	(2.619)***				(3.438)***
SERV	13.767	0.050	0.260	0.012	0.987	5.421	0.111	0.260
	(19.067)***	(1.857)*	(7.116)***	(2.323)**				(7.102)***
TRANSP	18.507	0.039	0.026	0.003	0.997	1.252	0.053	0.026
	(53.344)***	(3.018)***	(1.467)	(1.158)				(1.455)

***Statistically significant at 1% level **Statistically significant at 5% level *Statistically significant at 10% level

The situation is not different when the social part of infrastructure is examined. The results, given in table 6.3, show that for the total regional GDP the social infrastructure coefficient is small (0.015) and statistically insignificant. Here, only when the categories of Agriculture, Mines, and Services of regional GDP were used as regressands do the coefficients of social public capital reach high and significant levels.

Nevertheless, as in the two previous tables, the Hausman specification test suggests that there is a concern for the problem of public capital endogeneity.

Table 6.3 The effect of social public capital (G social) on the GDP of the non-manufacturing sectors of Greece, 1982-1991

Equation for per capital regional income (ln)

GDP Category	Constant	lnL	lnG(soc)	time trend	Adjust. R2	SSE	SE	h
TOTAL	21.123	0.032	0.015	0.020	0.995	1.838	0.065	0.015
	(57.333)***	(2.030)**	(0.706)	(13.978)***				(0.705)
AGR	22.382	0.080	-0.141	0.014	0.959	11.565	0.162	-0.141
	(24.221)***	(2.029)**	(-2.711)***	(3.759)***				(-2.710)***
BANK	18.769	-0.041	-0.062	0.081	0.958	16.025	0.191	-0.062
	(17.255)***	(-0.881)	(-1.018)	(18.906)***				(-0.985)
COMMER	19.060	0.038	0.005	0.021	0.989	4.306	0.099	0.005
	(33.805)***	(1.556)	(0.164)	(9.497)***				(0.164)
CONSTR	18.679	-0.008	0.037	0.026	0.983	4.124	0.097	0.037
	(33.852)***	(-0.318)	(1.175)	(11.846)***				(1.163)
HEALTH	18.298	0.027	-0.007	0.057	0.993	2.627	0.077	-0.007
	(41.545)***	(1.450)	(-0.291)	(32.934)***				(-0.278)
HOUS	17.132	0.056	0.066	0.032	0.958	15.074	0.186	0.066
	(16.239)***	(1.242)	(1.109)	(7.671)***				(1.110)
MINES	-10.870	-0.617	1.747	-0.188	0.773	1465.27	1.829	1.747
	(-1.045)	(-1.386)	(2.981)***	(-4.594)***				(2.984)***
PADMIN	17.829	0.032	0.045	0.042	0.968	12.330	0.168	0.045
	(18.685)***	(0.790)	(0.844)	(11.176)***				(0.841)
SERV	14.711	0.035	0.237	0.034	0.987	5.502	0.112	0.237
	(23.082)***	(1.300)	(6.593)***	(13.551)***				(6.569)***
TRANSP	19.121	0.041	-0.007	0.007	0.997	1.257	0.054	-0.007
	(62.758)***	(3.175)***	(-0.395)	(5.441)***				(-0.394)

***Statistically significant at 1% level **Statistically significant at 5% level *Statistically significant at 10% level

The overall conclusion from the analysis of the relationship of the total regional GDP and the total infrastructure is that the latter appears to have no significant impact on the former. This is also true for the productive and social categories of public capital. The breakdown of the regional GDP has not given any indication that infrastructure, in its total, productive, or social form, has a direct productive effect on the private economy whatever the GDP category, if the Hausman specification test results are taken into consideration.

However, it has to be emphasised again that the quasi-production functions utilised here are severely constrained by the data limitations. It is probably the case that the labour input proxy of employment in the manufacturing sector is a poor measure of the employment activity in the specific regional unit in the Greek case. In some Greek prefectures the employment in the primary and tertiary sector is inversely related to that of secondary employment. For this reason, it could be argued that the aforementioned results could be viewed only as partial evidence.

The theoretical part of the Holtz-Eakin and Lovely model, however, assumes that public infrastructure would not have any significant impact on the non-manufacturing part of the economy. In fact their results for the US economy have corroborated this thesis. Thus, the Greek results presented in this section can be viewed as another confirmation of the model's assumption, with the caveat that the quasi-production functions used here cannot describe accurately this specific part of the Greek economy.

6.4 Investigating Alternative Channels of Infrastructure Effects at Different Spatial Levels in Greece

The direct impact of public capital on the manufacturing sector of the Greek economy has been extensively analysed in chapters 4 and 5, at national, regional, sectoral, and urban levels. However, it seems worthwhile to seek for other potential channels by which infrastructure can affect the private economy, perhaps in more subtle ways. The Holtz-Eakin and Lovely (1996) model suggests that there is a variety of such channels at least from a theoretical viewpoint. Their empirical work examined in depth two possible ways by which a change in public capital stock can affect the secondary sector. The first is by altering the scale of production for each manufacturing firm. The second is by influencing the equilibrium number of firms. Thus, their model can help to assess if the public infrastructure affects private manufacturing, either by changing the level or by altering the composition of its productive activity. These issues can be dealt with in turn.

6.4.1 Public capital's effects on the preferred scale of production

The theoretical model described in section 6.2 postulates that the number of varieties of intermediate goods in the economy can be used as a measure of the range of economic activity. The greater the number of these varieties the more dynamic is the state of the economy (see equation 6.4). The empirical counterpart of equation 6.4 is the following equation,

$$\frac{M}{n} = n^{a-1} x_0 \tag{6.37}$$

which has been calibrated by Holtz-Eakin and Lovely using as the left hand side variable the output per manufacturing establishment and the right hand side variables are the number of establishments (as proxy of n) and public infrastructure (changes in infrastructure increase x_0, see section 6.2) and with the variables in logarithmic form. Thus, equation 6.37 becomes:

$$\ln\left(\frac{M}{n}\right) = \ln(n^{a-1}) + \ln(x_0) \tag{6.38}$$

or in working form:

$$\ln\frac{M_{it}}{n_{it}} = (a-1)\ln n_{it} + \ln G_{it} + t + u_{it} \tag{6.39}$$

where:

M_{it} is the Gross Production Value of manufacturing (as a proxy of the finished manufactured goods) in a specific region or sector in time t, n the number of manufacturing establishments (as an index of the range of economic activity),

a the degree of homogeneity in equation 6.37,

G_{it} the infrastructure variable,

t is a time variable,

and e_{it} the error term of the form $e_{it} = \mu_i + v_{it}$,

[where:

μ_i is the unobservable regional or sectoral specific effect,

and v_{it} is the remainder disturbance]

A point that begs clarification is the fact that public capital in the above equation appears to be a pure public good. However, as Holtz-Eakin and Lovely (1996, p. 119, footnote 17) argue "*entering public capital in per-firm units would not affect its coefficient. Instead, only the coefficient on the growth of firms (and our estimate of a) would be affected*".

A similar formulation has been employed for the Greek case. However, here four different datasets were used. The first comprises information on manufacturing (large industry, employing more than 20 persons) for the 49 prefectures. (These data have been used before in chapters 4 and 5 and reference should be made there for a more extensive description.) It has to be remembered that these manufacturing data refer to the total of all industrial sectors, no sectoral breakdown being available. The analysis by Holtz-Eakin and Lovely has had the added luxury of regional data together with a sectoral breakdown.

There are, however, three other datasets at hand, which do have a sectoral dimension. The first provides a sectoral breakdown for Greece as a whole. The second has a similar breakdown for the metropolitan area of Athens, and the last refers to the Rest of Greece. The last mentioned is a derivative set of data, as it is the difference between that for the whole of Greece and the Athens panel (again for more details on these datasets see chapter 5). These data, along with the regional panel, allow analysis of the different channels by which public capital can affect manufacturing sector at four different spatial levels.

Gross Production Value (GPV) has been used as a measure for manufacturing output in tables 6.4 to 6.7, in which are presented the results for the different datasets. Public capital has been introduced again either as total infrastructure (but excluding Miscellaneous and Administrative expenditures as before) or as a breakdown into productive and social infrastructure (again as defined previously). As in all previous cases where panel data analysis has been used, regional dummies were introduced into the regressions to capture the regional specific effects. This constitutes the Least Squares Dummy Variable model. This model and the organisation of the dummy variables designed to capture the regional effects (and similarly the sectoral effects for the sectoral panels) are described in section 4.4. Such an approach was also used by Holtz-Eakin and Lovely in their empirical calibration of the model (Holtz-Eakin et al. 1996).

The results for the regional panel, presented in table 6.4, reveal that public capital has a positive impact on output per firm. This impact is substantial in magnitude (0.383) and is also statistically significant. If total infrastructure is disaggregated into its productive and social components, it appears that the effect of the former is much larger than that of the latter. Productive public capital has a statistically significant coefficient of 0.352, while the respective magnitude for social infrastructure is only 0.041 and statistically insignificant. In all three regressions the variable representing the varieties of production, that is the number of manufacturing establishments, is negative and statistically significant. The respective coefficients for the regressions for total, productive and social infrastructure are -0.662, -0.654, and –0.654 respectively. This implies in turn, an a (as equation 6.39 shows, the estimated coefficient is actually $a-1$) of 0.338, 0.346, and 0.346 degree of homogeneity respectively.

Table 6.4 Infrastructure effects on the scale of production: regional panel for total manufacturing, 1982-1991

Dependent Variable: ln of Output (GPV) per Manufacturing Establishment

Constant	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
11.218	-0.662	0.383			-0.042	0.925	21.047	0.219
(6.608)***	(-13.920)***	(4.475)***			(-3.962)***			
11.901	-0.654		0.352		-0.043	0.926	20.858	0.218
(8.461)***	(-13.849)***		(4.918)***		(-4.334)***			
18.071	-0.654			0.041	0.001	0.922	21.993	0.224
(14.124)***	(-13.323)***			(0.576)	(0.150)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The findings for the sectoral panel of manufacturing for Greece as a whole are given in table, 6.5. Public capital appears to be statistically significant in all cases, and to have extremely high coefficients, namely 0.709 for total infrastructure, 0.655 and 0.892 for the productive and social categories respectively. The results for the establishments variable are, in all three regressions of this table, negative and statistically significant. Actually, they are of the same magnitude (at three digit level), that is –0.557, with a degree of homogeneity of 0.443. The infrastructure results certainly imply that some of the industrial sectors are extremely sensitive to changes of public capital.

Table 6.5 Infrastructure effects on the scale of production: Greece panel for sectors, 1982-1991

Dependent Variable: ln of Output (GPV) per Manufacturing Establishment

Constant	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
1.041	-0.557	0.709			-0.057	0.987	2.713	0.124
(0.197)	(-4.937)***	(3.382)***			(-2.849)***			
2.580	-0.557		0.655		-0.057	0.987	2.713	0.124
(0.534)	(-4.937)***		(3.390)***		(-2.851)***			
-2.319	-0.557			0.892	-0.053	0.987	2.716	0.124
(-0.365)	(-4.938)***			(3.345)***	(-2.782)***			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The sectoral results for the metropolitan area of Athens are in sharp contrast to those obtained for the national sectoral panel. As table 6.6 shows, none of the variables is statistically significant. This is also the case for total, productive and social public capital. Totally different is the picture for the panel as it refers to the manufacturing sectors of the Rest of Greece. Table 6.7 shows that the Rest of Greece economy appears to have high negative results for the number of manufacturing enterprises variable. These coefficients are -0.505, -0.505, and -0.502 for the regressions with the three types of public capital, implying a degree of homogeneity (*a*) of 0.495, 0.495, and 0.498 respectively. The coefficient for total infrastructure is high (0.985) and statistically significant. The respective results for the productive and social infrastructure categories are 0.909 and 1.251, again statistically significant at the one percent level.

Table 6.6 Infrastructure effects on the scale of production: Athens panel for sectors, 1982-1991

Dependent Variable: ln of Output per Manufacturing Establishment

Constant	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
4.205	-0.090	0.515			-0.014	9.330	10.099	0.245
(0.411)	(-0.637)	(1.186)			(-0.425)			
2.556	-0.083		0.596		-0.021	0.933	10.050	0.245
(0.277)	(-0.588)		(1.496)		(-0.680)			
11.948	-0.100			0.195	0.010	0.933	10.173	0.246
(1.155)	(-0.708)			(0.423)	(0.310)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.7 Infrastructure effects on the scale of production: Rest of Greece panel for sectors, 1982-1991

Dependent Variable: ln of Output (GPV) per Manufacturing Establishment

Constant	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
-6.041	-0.505	0.985			-0.082	0.983	3.880	0.148
(-0.963)	(-4.648)***	(3.937)***			(-3.421)***			
-3.875	-0.505		0.909		-0.082	0.983	3.880	0.148
(-0.677)	(-4.653)***		(3.941)***		(-3.421)***			
-10.995	-0.502			1.251	-0.078	0.983	3.881	0.148
(-1.458)	(-4.619)***			(3.932)***	(-3.387)***			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

6.4.2 The effect of public capital on total manufacturing output

The Holtz-Eakin and Lovely (1996) results relating to output per manufacturing establishment showed that public infrastructure in the United States had only a small, if any, effect on output per firm. In order to pursue this point further, they studied the impact of infrastructure on total manufacturing output, controlling for the private inputs of production and the number of firms. This strategy resulted the following form of equation:

$$Q = \frac{K}{n} + \frac{L}{n} + n + G \tag{6.40}$$

where:
Q is total manufacturing output (GPV),
K/n is private capital per firm,
L/n is labour per firm,
n is the number of firms,
and G is public infrastructure capital.

Even though in the case of Greece infrastructure capital seems to play a significant role in the determination of the output per manufacturing establishment, it is still useful to extend the analysis in this context as per Holtz-Eakin and Lovely. The results would then corroborate or refute the findings of the previous section. Equation 6.40 changes for the Greek model to:

$$Q_{it} = \frac{K_{it}}{n_{it}} + \frac{L_{it}}{n_{it}} + n_{it} + G_{it} + t + u_{it} \tag{6.41}$$

(notation as in previous equations)

Again there are four different levels of spatial analysis.

The estimations for the regional panel are given in table 6.8. The coefficient for total public capital, in the first regression of the table, is positive and statistically significant. Its magnitude is high (0.254), as is also the case for the coefficient of labour. However, the coefficient for private capital is small (0.046) and statistically significant only at ten percent level. The degree of homogeneity *a* (see section 6.2) is the magnitude of the estimated coefficient of the manufacturing establishments (this coefficient corresponds directly to *a*, in contrast to the previous section where the estimated coefficient was *a-1*). Here, *a* is equal to 0.761 (statistically significant) and is larger than the respective figure obtained in the previous set of regressions. The next two regressions present the results for the breakdown of public capital into productive and social categories respectively. It is interesting that at regional level productive infrastructure seems to account for practically all of the impact of total public capital. The results for this type of infrastructure are almost identical to those for the total. However, it seems that the social component has practically zero impact, as its coefficient is small and statistically insignificant (-0.048).

Table 6.8 Infrastructure effects on total output: Regional panel for total manufacturing, 1982-1991

Dependent Variable: ln of Total Manufacturing Output (GPV)

Constant	lnK	lnL	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adj. R2	SSE	SE
9.253	0.046	0.742	0.761	0.254			-0.026	0.990	13.824	0.178
(6.650)***	(1.695)*	(14.597)***	(15.677)***	(3.573)***			(-2.982)***			
9.401	0.041	0.742	0.762		0.253		-0.029	0.990	13.661	0.177
(8.078)***	(1.519)	(14.698)***	(15.875)***		(4.256)***		(-3.534)***			
14.779	0.062	0.760	0.793			-0.048	0.005	0.990	14.207	0.181
(12.843)***	(2.304)**	(14.674)***	(16.072)***			(-0.822)	(0.918)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The results for the sectoral panel for the whole of Greece are not essentially much different (table 6.9). In the regression incorporating total infrastructure the coefficient for private capital appears to be statistically insignificant, that for labour is more or less the same magnitude (0.722 and statistically significant) as for the regional panel, and similarly for the manufacturing establishment variable (0.785 and statistically significant). The estimate for infrastructure is, nevertheless, much higher in magnitude (0.630 and statistically significant). The same can be said for the findings for the regression utilising productive public capital. Its coefficient is again higher than the respective estimate at regional level (0.583 and statistically significant for the sectoral panel). A crucial difference from the regional analysis can be found if the results for regional and sectoral social infrastructure regressions are compared. At the regional level the coefficient for social public capital is not statistically significant, while when sectors are considered it is both significant and high (0.789) - seemingly more so than is the case for productive infrastructure. The cost function analysis results have shown that social infrastructure does have a positive effect in reducing private costs at the sectoral level. Thus, both the model results and those of the cost analyses suggest that some sectors are highly affected by social public capital. This effect cannot detected by the regional (prefectural) panel where manufacturing industry as a whole is examined. If there were available sectoral data at regional level, this discrepancy (between sectoral and prefectural results) would be probably solved.

Table 6.9 Infrastructure effects on total output: Greece panel for sectors, 1982-1991

Dependent Variable: ln of Total Manufacturing Output (GPV)

Constant	lnK	lnL	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adj. R2	SSE	SE
-0.848	-0.015	0.722	0.785	0.630			-0.047	0.988	2.318	0.115
(-0.154)	(-0.143)	(5.195)***	(5.589)***	(3.183)***			(-2.398)**			
0.498	-0.014	0.722	0.786		0.583		-0.047	0.988	2.317	0.115
(0.098)	(-0.140)	(5.196)***	(5.592)***		(3.194)***		(-2.402)**			
-3.717	-0.017	0.723	0.783			0.789	-0.043	0.988	2.321	0.115
(-0.577)	(-0.169)	(5.201)***	(5.570)***			(3.139)***	(-2.311)**			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Even more interesting is a comparison of the results for the two regional-sectoral panels – those for the metropolitan area of Athens panel (table 6.10) and the Rest of Greece panel (table 6.11). The results for Athens, in all three regressions for total, productive and social public capital, generate an insignificant coefficient for public capital. This is in contrast with all other results for the different spatial levels. The estimates for labour approximate roughly similar levels (positive and statistically significant) to the respective results for the regional and other sectoral panels. In contrast, the coefficients for the manufacturing establishments variable are much higher in magnitude than for any other panel. In all three regressions for Athens these estimates are around 1.6, which implies that the number of manufacturing firms generates a greater volume of industrial output. But more important for this research is the finding that, for Athens, infrastructure in all its guises seems to play no role, as in all the regressions its estimates are statistically insignificant. One potential explanation involves the fact that the Athens economy is much more advanced in comparison with that of the rest of Greece. These results seem to corroborate, at first sight, the argument that infrastructure investment has a smaller effect in more advanced economies that already endowed with a sufficient infrastructure capacity (see for instance Holtz-Eakin 1990). Conversely, there is the other possibility that in reality the industry of the main metropolitan area of the country, in fact, uses the infrastructure stock of whole of Greece.

Table 6.10 Infrastructure effects on total output: Athens panel for sectors, 1982-1991

Dependent Variable: ln of Total Manufacturing Output (GPV)

Constant	lnK	lnL	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adj. R2	SSE	SE
-7.072	0.665	0.781	1.603	0.363			-0.019	0.971	7.450	0.212
(-0.767)	(4.414)***	(4.952)***	(10.383)***	(0.963)			(-0.637)			
-7.326	0.665	0.774	1.604		0.382		-0.021	0.971	7.437	0.212
(-0.874)	(4.419)***	(4.892)***	(10.398)***		(1.099)		(-0.748)			
-3.750	0.663	0.794	1.600			0.231	-0.008	0.971	7.476	0.212
(-0.402)	(4.394)***	(5.043)***	(10.349)***			(0.582)	(-0.273)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

The final table of this set (6.11) presents the results for the panel that refer to a panel of industrial sectors for the Rest of Greece. The results of this panel appear to determine the respective findings for the sectoral panel for Greece as whole (table 6.9). The estimates for private capital are statistically insignificant in all three types of regression, while the coefficients for labour and manufacturing establishments are of high magnitude, positive, and significant. The coefficients for public capital, although positive and significant, are of even higher magnitude than the respective estimates for Greece as a Whole. Again here, social infrastructure appears to have a bigger impact than productive public capital.

Table 6.11 Infrastructure effects on total output: Rest of Greece panel for sectors, 1982-1991

Dependent Variable: ln of Total Manufacturing Output (GPV)

Constant	lnK	lnL	lnEstabl	lnG(total)	lnG(prod)	lnG(social)	time trend	Adj. R2	SSE	SE
-5.944	0.013	0.852	0.806	0.797			-0.064	0.989	2.782	0.126
(-1.041)	(0.137)	(6.856)***	(7.526)***	(3.694)***			(-3.011)***			
-4.232	0.013	0.852	0.806		0.738		-0.063	0.989	2.780	0.126
(-0.806)	(0.136)	(6.862)***	(7.526)***		(3.707)***		(-3.018)***			
-9.721	0.012	0.852	0.807			1.003	-0.059	0.989	2.786	0.126
(-1.435)	(0.127)	(6.845)***	(7.533)***			(3.653)***	(-2.933)***			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Comparing these panels clearly shows that public capital is significant at the regional (prefectural) level when manufacturing is considered in total. However, while this is also the case for sectors in Greece nationwide and the nation excluding Athens it is most certainly not the case for the metropolitan area of Athens. (Some of these issues will be reconsidered in the conclusion to the thesis.)

6.4.3 Public capital's effects on the equilibrium number of manufacturing establishment

Another potential way in which public capital can influence the private economy, in the context of the model in hand, is its impact on the (equilibrium) number of manufacturing establishments. The simplest method for the examination of such an effect is via regression. The dependent variable is the logarithm of the number of manufacturing establishments, and the independent variable is the logarithm of the public infrastructure capital stock. The latter is again introduced as three forms (total, productive, and social) in each of the four spatial levels of reference. Again, the regressions have included a constant term, a time trend, and a set of (*N-1*) dummy variables capturing the regional or sectoral specific effects (not reported on here due to space limitations). Thus, the working equation becomes:

$$n_{it} = G_{it} + t + u_{it} \tag{6.42}$$

(notation as in previous equations)

The results of tables 6.12 to 6.15 show that there is no direct impact of public capital on the number of establishments, as the public capital coefficients are statistically insignificant in all these regressions. This is true for all spatial levels. However, as Holtz-Eakin and Lovely have argued, there is the danger that such a regression "*fails to control for the resources available to the manufacturing sector*" (1996, p. 120).

Table 6.12 Infrastructure effects on the equilibrium number of firms (regression based infrastructure and time): Regional panel for total manufacturing, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
-0.978	0.104			-0.004	0.976	21.276	0.220
(-0.574)	(1.208)			(-0.388)			
0.448		0.032		0.004	0.976	21.337	0.221
(0.315)		(0.445)		(0.374)			
-2.836			0.218	-0.003	0.977	20.869	0.218
(-2.291)**			(3.168)***	(-0.582)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.13 Infrastructure effects on the equilibrium number of firms (regression based infrastructure and time): Greece panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
7.432	-0.130			-0.004	0.990	1.205	0.082
(2.139)**	(-0.939)			(-0.336)			
7.139		-0.120		-0.005	0.990	1.205	0.082
(2.255)**		(-0.937)		(-0.347)			
8.053			-0.164	-0.005	0.990	1.205	0.082
(1.928)*			(-0.929)	(-0.412)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.14 Infrastructure effects on the equilibrium number of firms (regression based infrastructure and time): Athens panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
8.784	-0.212			-0.029	0.979	3.027	0.134
(1.584)	(-0.897)			(-1.619)			
9.525		-0.248		-0.025	0.979	3.018	0.134
(1.911)*		(-1.146)		(-1.503)			
5.443			-0.073	-0.039	0.979	3.040	0.134
(0.968)			(-0.290)	(-2.238)**			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.15 Infrastructure effects on the equilibrium number of firms (regression based infrastructure and time): Rest of Greece panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
4.954	-0.072			0.009	0.986	1.857	0.102
(1.149)	(-0.420)			(0.567)			
4.734		-0.064		0.009	0.986	1.857	0.102
(1.205)		(-0.405)		(0.554)			
5.795			-0.112	0.010	0.986	1.856	0.102
(1.118)			(-0.511)	(0.665)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

In order to circumvent this problem, these authors used a regression similar to the previous one, but with the addition of the private inputs of production, private capital, and labour. This method has also been followed here and the results for these augmented regressions are given in tables 6.16 to 6.19. The form of this equation becomes:

$$n_{it} = K_{it} + L_{it} + G_{it} + t + u_{it} \qquad (6.43)$$

(notation as in previous equations)

However, even this augmented regression generally fails to produce significant results for the infrastructure variable. The only exceptions are the cases for social capital in the regional panel where a positive relationship holds (table 6.16) and for productive public capital in the metropolitan area of Athens, where the coefficient is negative (table 6.18). It has to be noted, nevertheless, that both these coefficients are statistically significant only at the ten percent level. However, perhaps the salient point is that generally the coefficients are negative.

Table 6.16 Infrastructure effects on the equilibrium number of firms (augmented regression): Regional panel for total manufacturing, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnK	lnL	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
-2.502	0.098	0.536	-0.054			0.007	0.983	15.095	0.186
(-1.729)*	(3.510)***	(11.555)***	(-0.730)			(0.722)			
-2.013	0.101	0.536		-0.083		0.011	0.983	15.053	0.186
(-1.655)*	(3.631)***	(11.585)***		(-1.326)		(1.246)			
-5.334	0.097	0.519			0.104	-0.005	0.983	15.009	0.185
(-4.625)***	(3.559)***	(11.038)***			(1.740)*	(-0.966)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.17 Infrastructure effects on the equilibrium number of firms (augmented regression): Greece panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnK	lnL	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
5.286	-0.075	0.595	-0.174			0.008	0.993	0.851	0.070
(1.600)	(-1.220)	(8.384)***	(-1.462)			(0.710)			
4.891	-0.075	0.595		-0.160		0.008	0.993	0.851	0.070
(1.599)	(-1.220)	(8.383)***		(-1.458)		(0.701)			
6.114	-0.075	0.595			-0.219	0.007	0.993	0.851	0.070
(1.582)	(-1.211)	(8.382)***			(-1.452)	(0.661)			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.18 Infrastructure effects on the equilibrium number of firms (augmented regression): Athens panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnK	lnL	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
1.778	0.205	0.525	-0.234			-0.011	0.988	1.783	0.103
(0.395)	(2.862)***	(8.039)***	(-1.281)			(-0.774)			
3.008	0.203	0.528		-0.292		-0.006	0.988	1.768	0.103
(0.739)	(2.839)***	(8.113)***		(-1.742)*		(-0.432)			
-2.868	0.210	0.521			-0.040	-0.026	0.987	1.800	0.104
(-0.629)	(2.917)***	(7.948)***			(-0.208)	(-1.830)*			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

Table 6.19 Infrastructure effects on the equilibrium number of firms (augmented regression): Rest of Greece panel for sectors, 1982-1991

Dependent Variable: ln of Number of Manufacturing Establishments

Constant	lnK	lnL	lnG(total)	lnG(prod)	lnG(social)	time trend	Adjust. R2	SSE	SE
5.147	-0.082	0.585	-0.186			0.022	0.991	1.208	0.083
(1.379)	(-1.287)	(8.504)***	(-1.315)			(1.588)			
4.667	-0.081	0.585		-0.169		0.022	0.991	1.208	0.083
(1.360)	(-1.283)	(8.500)***		(-1.295)		(1.570)			
6.520	-0.082	0.585			-0.254	0.022	0.991	1.206	0.083
(1.476)	(-1.296)	(8.522)***			(-1.418)	(1.702)*			

*** Statistically significant at 1% level, ** Statistically significant at 5% level, * Statistically significant at 10% level

It seems that public infrastructure does not affect the equilibrium number of firms, at least in this model context. There are, however, examples of other research focused on firm entry and exit in Greek industrial sector, in which public capital appears to be a significant factor of firm creation. These results, as well as comments, criticisms and potential extensions of this model are discussed in the next section.

6.5 Conclusions

The proliferation of empirical research on the effects of public capital investment on the private sector of the economy has provided a substantial body of work. This is based mainly on production function analysis, or alternatively on the duality theory and cost function approach. These approaches can be useful in assessing the role of infrastructure and can be used as a tool for the planning of public investment policies. Having said that, there still remains the problem of an analytical theoretical basis outlining the mechanisms by which public capital generates, or not, these specific effects. A few models by which these mechanisms can be sketched have recently become available. But few of them have been empirically tested for any verification or refutation of their theoretical assumptions.

One exception is the important paper on the US economy by Holtz-Eakin and Lovely (1996). The basic premises of this model have been utilised here for an analysis of the Greek case. The model's empirical calibration distinguishes between two main effects of infrastructure on the economy - the impact on the non-manufacturing part on the one hand and on the manufacturing sector on the other.

However, there are significant differences between the US and the Greek empirical research based on the model. In the former, cross-sectional data were used for four years, whereas in the Greek case the time dimension of the panel data is ten years. Furthermore, there are no available data for the Greek case that permit a proper empirical modelling of the non-manufacturing part of the economy and to circumvent this problem quasi-production functions were used.

The basic equation was calibrated not only for the aggregate measure of the private non-manufacturing sector output, which was the regional GDP, but also for its breakdown to regional sub-categories. Three measures of public infrastructure capital were used, total infrastructure, and its two categories - productive and social public capital. The results showed that there is no significant effect on the total regional GDP, no matter the type of infrastructure proxy in use. There are, however, some sub-categories of regional GDP, for which public capital at first sight seems to have a significant impact. However, for these categories there is the technical problem of the endogeneity of public infrastructure in the equations.

The analysis of the effects of infrastructure on the manufacturing sector of the economy has also been conducted at four different spatial levels. First, a panel of the total (large scale) manufacturing of the Greek prefectures is used; second, there is a sectoral breakdown of the manufacturing for Greece as a whole; third, comes a sectoral breakdown for the metropolitan area of Athens; and finally, the fourth level offers a sectoral breakdown for the Rest of Greece.

The empirical calibration tried to examine the two ways by which the theoretical model assumes that public capital affects the manufacturing sector. The first possibility is that changes of infrastructure provision alter the preferred scale of production for the firms of the manufacturing sector. The empirical counterpart of this possibility was the examination of the impact of public capital and the number of manufacturing establishments on the output per manufacturing establishment. The results showed that total public capital plays a significant positive role at all spatial levels, with the exception of the metropolitan area of Athens. The productive infrastructure coefficients are similarly significant positive, again with the exception of Athens. However, the picture is not clear for the case of social public capital. At the regional level, where the total of manufacturing sectors is considered, social infrastructure appears not to play any important role. The same is true for the sectoral breakdown for the area of Athens. Nevertheless, for the sectoral breakdown for Greece as a whole, and for the Greece excluding the Athens area, there is a statistically significant impact of high magnitude.

Following Holtz-Eakin and Lovely (1996), the above results were double-checked by a second set of regressions, in which it was assumed that public capital should influence the total manufacturing output via its impact on output per firm and the number of varieties. The results for these latter regressions corroborate those obtained earlier.

The second channel by which infrastructural change affects private manufacturing, in the context of this model is the concomitant changes in the equilibrium number of manufacturing establishments. The direct regression of the number of manufacturing establishments on the public capital variable (either in its total, productive, or social form) has shown that there is no such direct impact, whatever the spatial level. The next step was to augment these regressions with the private inputs of production. Once again the results obtained generally showed that there was little significant impact of the infrastructure variables.

One conclusion that can be drawn from comparing these results for Greece with the findings from the US research is that for the more developed economy infrastructure works more via its effects on the composition of the manufacturing activity, whereas in the Greek case it seems to affect more directly the level of this activity. However, it has to be kept in mind that the US case refers to a huge economy in comparison to the Greek one, and that the US empirical work is based on four cross-sectional surveys articulated into a panel, while the Greek panel has a significantly longer time dimension. In any case, both of these empirical works show that public capital seems to have little if any impact on the non-manufacturing part of the economy. However, the results for the Greek case must be viewed with the caveat that crucial data for this part of the analysis were unavailable, and that it was conducted in a rather indirect way (quasi-production functions).

Finally, it must be noted that the whole analysis was conducted within the analytical framework set by the Holtz-Eakin and Lovely (1996) model. This means that the results are as good as the model's assumptions, and must be viewed in this spirit. For instance, the results for the impact of public capital on the equilibrium number of firms must not be construed as an attempt to evaluate the infrastructural role on new firm creation. There is now an existing body of work on this topic for Greece, and some of this research has incorporated the infrastructure variable into the analysis[19]. The results of this empirical work have shown that public capital, does indeed play a positive role in new firm creation, with a significant time lag (see Fotopoulos 1998). This implies that the model used here has not allowed for such lagged impact of infrastructure on the equilibrium number of firms.

[19] For a summary of the existing bibliography on the topic, see Fotopoulos (1998); for a different perspective on the subject, see also Katseli (1990) and Papandreou (1989).

Chapter 7
Conclusions

7.1 Infrastructure and economic development in Greece – the principal question

The main question that this thesis has attempted to answer concerns the relationship between infrastructure and economic development. Even a cursory look at recent literature reveals that there is yet to be found an uncontested theoretical and applied framework for the empirical analysis of this relationship that enjoys an overall consensus. This problem is accentuated once the parameter of 'space' enters the picture. There is a strong possibility that public capital investment does not affect all regions to the same degree and in the same way. As the empirical analysis of the Greek case has shown, differences on the degree of development of local economies can result in different infrastructure effects.

A common thread, at the level of empirical analysis, in this research was the application of panel data analysis. Even though this approach was dictated by the lack of time series data with sufficient time length at regional level, it has provided the empirical analysis with the necessary geographical information for the infrastructure effects, which, as will be argued later in this chapter, is essential for a proper examination of these impacts.

The main difference between previous attempts to assess the impact of public infrastructure capital on productivity and economic development from the recent 'wave' of research, spawned by the work of Aschauer, is that the latter approach has made possible to examine that impact at a *macro* level, whether this is a national economy or a regional unit. There are many examples analysing the effects of specific infrastructure projects or attempts at a theorisation of the role of public capital in Greece (see for instance Skayannis 1990, 1994). However, there are only two examples of research utilising the new analytical framework. Dalamagas (1995), and Segoura and Christodoulakis (1997) have tried to analyse the effects of public infrastructure by using production and cost function analyses, based on time-series data for Greece as a whole. Both these pieces of empirical work have contributed towards a better understanding of the Greek case. Nevertheless, it has to be pointed out that there are two inherent problems in both these research projects.

The first refers to the nature of the time-series data. The longest time-series dataset of the two (used by Dalamagas and covering the period from 1950 to 1992) provides only 42 observations[1], which pales in comparison to the richness of information provided by the panel datasets[2] (for instance, the regional panel used here has a time dimension from 1982 to 1992, and a spatial dimension of 49 prefectures, which amounts to 539 observations) generally used in this type of analysis. In this case, information is restricted in a twofold way: first, in terms of the number of observations made. Second, in terms of the quality of information provided by the geographical dimension in the prefectural panel, and the information about the different effects at different industrial sectors (at a specific geographical scale) in the sectoral panels. As it will be discussed later in this chapter, the geographical/sectoral dimensions seem to be crucial in the analysis of the infrastructure effects.

A second problem with the previous two examples of this type of research undertaken in a Greek context is that both of them have used a, more or less, *broad* definition for public infrastructure (including the telecommunications and energy companies). The present research has been able to build and improve upon this most valuable experience. It was argued in chapter 3, that the adoption of a *narrower* definition for public infrastructure in this thesis makes the comparison of its results to similar research from other countries easier. In most studies the telecommunications and energy investment is excluded from definitions of public infrastructure since these usually are in the hands of the private sector. Having said that, though, one of the problems of recent infrastructure research is that different specifications can lead to different results, even if the same dataset is used (for a more extensive analysis, see chapter 2). There can be little

[1] Even fewer degrees of freedom are provided by the dataset used by Segoura and Christodoulakis, which covers the periods 1963 to 1977 and 1980 to 1990 (the interim years 1978 and 1979 are missing).
[2] For some of the advantages of panel data analysis (as well as of some of the problems) see Appendix I.

doubting that the exact definition of what constitutes infrastructure in the various attempts to empiricise the relationship is vitally important to the final result.

7.2 Infrastructure and economic development in Greece – the major findings.

7.2.1 The evolution of infrastructure spending and private capital investment.

This thesis has used the investment of the Public Investment Programme (PIPR) as a proxy for infrastructure capacity in Greece. The PIPR was introduced in 1952 with the aim of providing Greece with the necessary public capital stock for a modern economy, as the existing one was in poor condition after the forties (in itself, the result of the Second World War and the Greek Civil War). The PIPR provided -and still does- public investment in several categories of fixed capital (see tables 3.4 and 3.5 in chapter 3). These categories have been classified under three major headings for the needs of this research. One class was comprised of the 'productive' categories, a second by the 'social' categories, and the third included the Administrative and Miscellaneous expenditures of the PIPR, which did not materialise as actual investment.

An analysis of the temporal evolution of these categories has shown that during the late seventies - early eighties the actual investment of the PIPR (the sum of the productive and social categories) had fallen significantly from its 1976 level (in real-deflated terms) to recover during the late eighties and early nineties. The Administrative and Miscellaneous category doubled its 1976 level during the eighties (reaching almost three times this level by 1981), only to fall significantly during the nineties. Whereas the productive category has remained stable or even increased by the end of the period examined (1976-1992), it is the social part of the PIPR that has been permanently reduced (since 1981, it stands at around 15 percent of the total expenditure, when in 1976 it represented 24 percent).

One of the main problems in analysing the regional effects of public investment in Greece is that even though the PIPR investment expenditures are available in a prefectural (NUTS III) breakdown, part of the PIPR is either allocated to a higher spatial level (NUTS II), or has not been allocated to a specific regional unit at all (referring to Greece as a whole for accounting reasons). This *non-spatial* part of the PIPR amounts to more than 45 percent of the total programme. However, if the Administrative and Miscellaneous categories are excluded, this falls to around 28 percent. The implication is that the regional panel used in this thesis somewhat underestimates the real infrastructure stock. Nevertheless, in the case of the sectoral panels, either those used for Greece as a whole, or for the analyses at the 'metropolitan area of Athens' and 'Rest of Greece' regional levels, the estimated stocks do include all the public infrastructure investment.

There are significant inequalities in the regional distribution of infrastructure capital amongst the Greek prefectures. If the absolute overall spending in public capital investment is the criterion by which the Greek prefectures are classified, then the three prefectures containing the major urban centres (Athens, Thessaloniki, and Achaia), along with the border prefecture of Evros, have concentrated by far the higher percentages of public investment. The same pattern of spatial distribution was observed for the productive part of the PIPR, whereas for the social part, the concentration of such investment in prefectures containing the major urban centres is even more accentuated. However, if investment per inhabitant is examined, a different pattern appears, and some of the most remote prefectures of the country seem to be the main beneficiaries of investment decision making viewed this way.

The data used to represent the private sector relate to relatively large-scale manufacturing industry and this covers more than 90 percent of the total manufacturing sector in Greece by whatever measure chosen. A salient feature of these data is that private investment during the eighties has fallen sometimes even by one quarter its 1976 level (in constant prices of course; see for this point, table 4.2, column 5).

7.2.2 The impact of infrastructure on manufacturing production

The main tools of analysis in the recent resurgence of infrastructure research are production functions. In this family of functions, the most popular one is the Cobb-Douglas specification. This type of production function has been utilised here extensively - though not exclusively - to analyse the national and regional effects of infrastructure investment.

Chapter 4 presented several different calibrations of the Cobb-Douglas production function. The norm in infrastructure literature is to obtain, as a first step, the results for a generic Cobb-Douglas, where the public capital variable has not been introduced. At the next stage, the infrastructure variable is then added to the Cobb-Douglas equation.

However, the exact operational form of the production function is far from an undisputed procedure. A great part the academic debate has dealt with the most adequate empirical calibration. In this analysis, apart from the private inputs as well as the infrastructure variable in its different guises, a time trend and the capacity utilisation rate were also included. The latter was added into the equation in order to control the influence of the business cycle. Ford and Poret (1991) have argued for the importance of the inclusion of this term (see chapter 4 for this point).

Several alternative formulations of the Cobb-Douglas, with and without the inclusion of the public infrastructure variable, have been tested. The straightforward conclusion here is that the formulation with the infrastructure capital is the most successful variation, in comparison to alternative ones excluding public capital, or including it but estimated in terms of first differences. Another econometric test (RESET) was performed in order to secure that the Cobb-Douglas calibration is not inconsistent with the empirical data. The results of this test were again favoured of the formulation with the infrastructure variable.

The main result from the empirical analysis in this research is that there is indeed a positive and significant relationship between the public capital variable and the private sector's industrial output. As mentioned in chapters 2 and 4, the estimated elasticities for the production inputs give the percentage change in output if the respective input has changed, for instance, by one percent. The estimated coefficient for public infrastructure was 0.20 for Greece as a whole (see table 4.10). This result closely approximates the results from similar research in other countries that have been undertaken for a wide variety of time periods: table 4.1 in chapter 4 shows that the results of Aschauer, Baltagi and Pinnoi, Eisner, and Munnell for the United States are near to this estimate[3]. Mera has estimated exactly the same figure for the role of Japanese infrastructure (see table 4.1 for these references). Similar are the estimations for the Spanish case. Bajo-Rubio et al. (1993) have discovered a 0.19 coefficient for public capital, while the estimations arising from the research of Mas et al. (1993, 1994, and 1996 respectively) vary from 0.21, through 0.24, to 0.08.

The only point of reference for the Greek infrastructure capital that is directly comparable to the findings of this thesis is the Cobb-Douglas production function estimated by Segoura and Christodoulakis (1997). With the caveat already mentioned (that they used a time-series dataset and an all-encompassing definition for public capital) their estimation is extremely high (0.42 for infrastructure variable; see Segoura et al. 1997, table 1). The only other piece of work for the Greek case, that of Dalamagas (1995), is not directly comparable as it has employed a *translog* formulation and variables such as energy and the public deficit.

Another point that the academic debate has focused on is the way in which panel datasets, in econometrics terms, should be properly analysed. In an effort to refute the Aschauer-Munnell *pro*-infrastructure thesis, Holtz-Eakin has argued that if panel analysis has to be employed, then it is imperative to use the right econometric techniques in order to obtain unbiased and consistent results. More specifically, he argued that it is essential to take into consideration the regional specific effects (provided that the panel is based on spatial units)[4]. It is reassuring to observe that in chapter 4 (where the analysis is based on the regional panel) the introduction of the dummy variables, which capture the regional specific effects, has produced results showing that infrastructure has a significant impact both statistically and in terms of actual magnitude.

The production function was also used for a temporal analysis. The ten-year period of the panel was disaggregated into two different panels each comprising a sub-

[3] However, it has to be kept in mind that table 4.1 reports also some pieces of research for the US where the estimated coefficient is almost zero.
[4] The key references on this point are Munnell (1990b), Holtz-Eakin (1993c), Eisner (1991); for a more extensive analysis see chapter 2.

period of five years. The results showed that the public capital variable, either as total infrastructure or as the productive and social categories, have no significant impact. This is a demonstration of the notion that infrastructure effects can really only be detected over long time periods.

Another part of the analysis is that which considers the type of returns to scale[5] of the Cobb-Douglas production function. The results obtained (see table 4.9) were rather ambiguous, as the constrained (to have constant returns to scale) versions, with or without the infrastructure variable, produced similar results to the unconstrained versions.

The next step in the production analysis was to analyse the public capital impact over the sub-national territory Greece. In this respect, three different spatial levels were used. The first regarded a division of the prefectures into two smaller panels creating effectively one panel for the 'north' and one for the 'south' of Greece. The results showed that the overall infrastructure investment has had a much larger impact (twofold) on southern rather than northern Greece.

A second level of analysis concerned three non-spatially contiguous groupings (panels) of the prefectures according to their overall level of manufacturing output (high, intermediate, and low). The results showed that infrastructure has had its largest impact on the lowest output group of prefectures, followed by the highest output cluster. It has to be mentioned, however, that the difference in magnitude was fivefold between these two classes (see table 4.12).

In the third level of spatial analysis are the prefectures themselves. These were used to construct regional panels that correspond, more or less, to the Greek regions of the NUTS II level. The results for the infrastructure variable were statistically insignificant for all but one region (the Ionian Islands). One potential explanation is that the smaller the spatial case the harder it is to detect the infrastructure effect (see chapters 2 and 4). It seems, however, that these results have more to do with the reduced degrees of freedom in the NUTS II panels, than with the actual effect of public capital. An indication corroborating this argument is the fact that apart from the infrastructure

[5] This is an important question, as the type of the returns to scale reveals the type of technology of the Cobb-Douglas equation (see chapter 4.6).

variable, the private capital variable coefficients also appeared to be statistically insignificant.

The Cobb-Douglas function was also used for the investigation of potential regional network effects of infrastructure capital. The aforementioned regional NUTS II panels were again used[6], but the public capital stocks were estimated taking into consideration the infrastructure capital of the adjacent prefectures. It seems that if there are such network effects, they are only captured by the national and the north-south panels.

All this analysis has been conducted not only for public capital as a whole, but also for the productive and social categories that make it up. The calibration of the Cobb-Douglas function at the national level showed that almost all of the impact estimated for infrastructure as a whole can be attributed to the effect of the productive component. The coefficient for this category was statistically significant, with a magnitude of 0.17, while the coefficient for the social category was only 0.06 and statistically insignificant (see table 4.6 AAA). The results for the north-south divide showed that for the north the findings for the two categories are almost the same as those for Greece as a whole (see table 4.13). These results are in accordance with the empirical findings from similar research in other countries (see table 2.1).

However, for the south of Greece, the results are less straightforward as they are statistically significant only at 10 percent level, even though both coefficients for productive and social categories are substantially positive. The empirical findings for the NUTS II level regions are even less clear. There are some regions that have statistically significant coefficients for the two public capital categories. From these coefficients, all elasticities regarding the productive category are positive, while those for the social type are mixed (for a more thorough analysis see section 4.7, in chapter 4).

[6] The 'Greece as a whole', and North and South panels were not used as it is supposed that the large spatial aggregations of prefectures capture any network effects (see chapter 4).

7.2.3 The impact of infrastructure on the non-manufacturing part of the economy

Due to data limitations it has not been possible to extend the production function approach analysis to the non-manufacturing part of the private economy. For similar reasons, it was also impossible to implement the cost function approach for these activities. The main deficiency of the data is that there are no available estimations for the private capital investment/stocks, or employment remuneration, or number of workers for, at least, some of the non-manufacturing sectors. In order to circumvent this problem, quasi-production functions similar to those employed by Cutanda and Paricio for Spain (1994) were used (employed in the context of the economic model developed in chapter 6).

Panel data analysis was the method selected used once again, this time based on a prefectural dataset. The dependent variable in the equations was regional Gross Domestic Product (GDP), which apart from its total value was disaggregated to ten sectoral sub-categories. The employment rate in the industrial sector has been used as a proxy for the prefectural employment, which along with the infrastructure variable (in total, productive, or social forms), and a time trend formed the explanatory variables[7]. The overall result that arises from these quasi-production functions is that public capital investment, irrespective of its guise, has no significant effect on either the total regional GDP, or on any of its sub-categories. It has to be noted that even in cases where some of the estimates for public capital appeared to be statistically significant, these coefficients were rejected on the basis of a Hausman test for the exogeneity of infrastructure variable (see chapter 6 for a more thorough presentation). This means that, based on the results of this test, the possibility that it is changes in GDP that determines the infrastructure investment (and not the other way around) cannot be rejected.

[7] As in the analysis for the manufacturing sector, a least squares dummy variable model was used.

7.2.4 The impact of infrastructure on manufacturing costs

The production function approach is the most widely used method in modern infrastructure effects literature (see chapter 2). However, as explained in chapters 2 and 5, this dominance is less a result of the theoretical advantages of the production function analytical framework, and more a product of the ease of estimation and results interpretation that this framework provides. The main alternative in public capital research is cost function analysis, which, despite being more data demanding and producing results that are less straightforward to interpret, uses more flexible functional forms, and can shed more light to the production and cost structure of the economic unit under investigation (whether this be a firm, a sector, a region, or an economy as a whole).

The general principle of the cost function approach and the duality theory that underpins it is that there is a dual cost function to its primal production counterpart. Dalamagas (1995), and Segoura and Christodoulakis (1997) in their analyses for the infrastructure capital at national level have also used cost functions. In both these pieces of research the selected form for the cost function was the translog specification. The overall conclusion from the Dalamagas analysis is that public infrastructure is labour and private capital saving, and energy using (which is the only intermediate input that he adds into the cost function). Segoura and Christodoulakis, on the other hand, have argued that public capital is labour and intermediate inputs saving, and private capital using. As argued previously, the results of these earlier - national level - pieces of research are not directly comparable to those of this thesis[8], though they ought to be directly comparable with each other, as the time period and their methodologies are similar (with the notable exception of the intermediate inputs treatment). However, it seems that there is only a small area of agreement regarding their main findings.

This thesis has used a generalised Cobb-Douglas cost function, similar to that employed by Nadiri and Mamuneas (1994). Four different datasets (panels) were used in order to capture all the nuances of the infrastructure impact on different spatial levels for the Greek industry. The first panel is based on the prefectural data that were used for the production function analysis, augmented with some necessary additional variables. The second panel refers to sectoral data (two-digit level) for Greece as a whole. The only

[8] They were time-series analyses, with a broad definition of infrastructure.

area/region for which these sectoral data are available, in addition to those at national level, is the metropolitan area of Athens. Thus, these data constituted the third panel of the cost analysis. Subtracting the Athens data from those at national level generates the last panel, which can be referred to as the industry for the Rest of Greece.

The system of equations calibrated for the cost function analysis has been tested against several alternative specifications for all four different datasets (without regional/sectoral dummy variables, constant returns of scale, and a variant in which public capital was restricted to have zero effect). These specifications were compared with the use of a log-likelihood ratio test. As argued earlier in this section, the cost function analysis results are not easy to interpret, at least directly. The estimated coefficients are used at a second stage to compute several 'derivative' measures of infrastructure impact on private costs. These are a) the cost elasticity with respect to public capital, b) the 'factor bias effect' (which has been estimated over the share of the private inputs), and c) the private input demand elasticity with respect to infrastructure (which is the sum of the cost elasticities and factor bias effect). An additional estimated measure was the 'shadow value' of public capital, which can be interpreted as a gauge of the willingness of the private sector to pay for an additional unit of infrastructure services.

The basic conclusion from the analysis based on the regional (prefectural) data is that the productive part of public capital does have an impact on the private costs, while its social counterpart does not. The estimated private input demand elasticities for the impact of productive infrastructure showed that it saves labour and intermediate inputs, and uses private capital. There is no clear geographical pattern for these elasticities, but, in general, prefectures which have higher levels of a particular private input (private capital, labour, intermediate inputs) tend to have a higher private input demand elasticities. It seems, however, that the higher shadow values for public capital belong to prefectures that are near to the two major urban centres of Greece (Athens, and Thessaloniki). Additionally, the Magnisia prefecture (which includes the industrial area of Volos, probably the most important in the country) also has a high shadow value.

The second level of cost analysis regards the sectoral panel for the manufacturing industry of Greece as a whole. This panel contains all twenty two-digit sectors. A notable difference from the regional (prefectural) results was that both productive and social infrastructure appeared to have an impact on private costs (with the latter category indeed and unusually having a larger effect). The measures of that impact showed that both productive and social categories of infrastructure save labour and private capital (they are substitutes for these inputs), and use intermediate inputs (they are complements). Thus, it seems that even when the results regarding the labour input have the same direction for the regional and sectoral panel (this is a strong point of stability for all results), the results for private capital and intermediate inputs have the reverse direction.

The international literature has provided several pieces of research in which the direction of relationship between infrastructure and private inputs is similar to either the regional or the sectoral results (but there are also differences as well; see chapter 2 table 2.2). For instance, Conrad and Seitz (1994), Lynde and Richmond (1992), Seitz (1994), Seitz and Licht (1995) have found that infrastructure is a substitute for labour, and a complement to private capital. On the other hand, Morrison and Schwartz (1996) have found that infrastructure is a substitute for private capital in the short run. However, this relationship has the opposite direction in the long run. As far as the difference in the results from the Greek panels is concerned, it can be argued that the regional (prefectural) panel differs substantially from the sectoral panel for Greece as a whole (as well as from the other sectoral panels - Athens, and the Rest of Greece). The regional panel contains information for spatial differences of manufacturing, without any sectoral dimension, while for the sectoral analysis there is information for the industrial sectors, but not for their spatial differences. As argued in chapter 5, this problem could have been circumvented if the National Statistical Service of Greece had been able to make available sectoral data at prefectural level. The only geographical area for which such data are available is that of Athens.

The results for the Athens panel are notable in the sense that it is the only spatial level of analysis in which the productive part of public capital does not have a significant impact on private costs (as it is rejected by the log-likelihood ratio test). On the other hand, the social category does indeed have a positive effect. This may be an indication that some sectors are sensitive to cost reductions by better public administration or health services, for which social infrastructure is a proxy. Regarding the relationship between public capital and the private inputs, the results for Athens have shown that they have the same direction as in the sectoral analysis for Greece as a whole. However, the estimated measures revealed that the magnitude of the infrastructure impact was smaller in the Athens area.

The last sectoral panel refers to the Rest of Greece. The results for both productive and social parts of public capital are similar to those for Greece as a whole. Thus, labour and private capital are substitutes for infrastructure, while the latter has a complementary relationship to intermediate inputs. The absolute magnitudes of the estimated measures (of infrastructure impact on private costs) are higher than those for the national level, for both public capital categories.

7.2.5 The impact of infrastructure on manufacturing through indirect channels

Standard infrastructure research has focused on the analysis of the production, and, to a lesser degree, cost effects of public capital (see chapter 2). There is the possibility, nevertheless, that infrastructure investment could affect the private sector of the economy in other, more subtle, ways. There are very few pieces of empirical work in which such alternative channels have been investigated. The work of Holtz-Eakin and Lovely (1996) is one such promising example, and for this reason their theoretical model has been used here for the examination of the Greek case.

Holtz-Eakin and Lovely constructed a model for the economy that provides the theoretical underpinning for these alternative channels. In a nutshell, they argued that infrastructure capital investment does not seem to have a significant direct impact on the production process of either the non-manufacturing, or the manufacturing parts of the economy (according, at least to their results summarised in chapter 2). Nevertheless, there is strong evidence (at least for the United States) that infrastructure affects manufacturing industry in two indirect ways. The first is by changing the scale of production of individual firms (by only a small degree in the US case) and the second is by having an impact on the equilibrium number of the manufacturing firms.

The empirical findings for the manufacturing part of the Greek economy are different from the respective results for the US obtained by Holtz-Eakin when the production function approach is used. The results for Greece showed a positive impact of public capital, while Holtz-Eakin found no significant effect. For the non-manufacturing sectors there is no clear evidence that there is a significant impact of public capital (as argued extensively in chapter 6, and earlier in this chapter[9]), and thus, the US and Greek results are in line. Chapter 6 also attempted to explore the alternative channels (which the production function approach cannot reveal) of the impact of public capital on the manufacturing part of the economy.

The impact of infrastructure on the scale of production of manufacturing firms was investigated by examining the effect of the number of manufacturing establishments and public capital stock on the gross production value per manufacturing establishment. The results for the regional panel showed that infrastructure does have a significant positive impact, and that impact is almost solely due to the productive component of public capital. The estimated impact from the sectoral panel for Greece as whole is even higher, and here the social category also has a significant positive impact, even higher than its productive counterpart. The analysis from the two available sectoral panels with a regional dimension (Athens and the Rest of Greece), revealed that the effect on the Athens economy was not statistically significant. Thus, the results for Greece as a whole seem due only to the effects occurring in the Rest of Greece.

These results were double-checked using Holtz-Eakin and Lovely's stratagem to regress the gross manufacturing output on the private capital and labour per firm, the number of establishments, and infrastructure capital. The results for all spatial levels (regional and sectoral panels) corroborate the results from the previous regressions. One of the most important conclusions is that as far as the metropolitan area of Athens is concerned, public infrastructure does not have a significant, if any, effect. This may be an indication that manufacturing activity in the capital is 'qualitatively' different in the sense that it does not depend on infrastructure provision for its production process. Possibly this is an indirect confirmation of the basic Holtz-Eakin's argument that public capital has no significant impact on the private sector. Athens represents a significant part of the nation's industry, along with some of the most productive part of the labour force. It also stands for a significant part of the overall infrastructure capacity of the country.

[9] It appeared that infrastructure had a significant impact on some non-manufacturing sectors, but these cases were rejected on the basis of a Hausman specification test.

Thus, since Athens is the most economically advanced area of the country, it is possible that here infrastructure does not play such an important role as it does in other parts of the country. The only potential counter-argument may be that the Athens economy 'uses' not just the Athenian infrastructure but also the adjacent infrastructure stock, or possibly the infrastructure capacity of Greece as a whole.

The second channel by which public capital affects manufacturing according to the Holtz-Eakin and Lovely model is through its impact on the equilibrium number of the manufacturing firms. Two empirical formulations were used, one assessing directly the impact of infrastructure on the number of firms, and the other adding the private input factors of production. The results showed that only social infrastructure at the regional level (prefectural panel) plays a positive role. It has to be noted that these results are based on the theorisation of this particular model. Recent research has shown that there is a significant time lag of the public capital impact on the manufacturing openings (see Fotopoulos 1998), and perhaps the present study somewhat underestimates the real infrastructure effects on the equilibrium number of the manufacturing firms.

7.3 Infrastructure and economic development in Greece – the policy implications of the main findings

The basic conclusion from the literature review is that the theoretical and practical problems of infrastructure research are yet to be resolved. It seems that the '*positive effects*' camp has shown more empirical results in their favour, however, the opposite side is not without good arguments and supporting evidence (see chapter 2). It may be characteristic of the current state of the debate the fact that even Holtz-Eakin, one of the key figures of the '*no effects*' side, has recently advocated that public capital has an indirect positive impact on the economy (see Holtz-Eakin and Lovely, 1996).

In any case, it can be safely argued that the public capital and regional development relationship is a complex one, especially as the infrastructure effects can be different at different spatial levels. The different impact is due to the specific conditions and level of development of a particular regional economy. This argument is also a warning for caution over the extension of empirical results either from another country[10], or from a more aggregate level. The use of empirical findings from a national study based on aggregate time series analysis for policy recommendations at the regional level, for example, is potentially misleading. As for international comparisons, of course, countries can have a totally different social and economic structures and levels of development and this makes cross-national comparison problematic.

The empirical results from the production function analysis confirm at first sight the argument, raised especially in the US debate, that the larger the spatial scale the larger the estimated infrastructure impact (probably due to spillover effects). However, this conclusion for the Greek case may be the result of the reduction in the degrees of freedom of the regional panels[11]. The results from the sectoral panels in cost function analysis have shown that if there is sufficient information in terms of the econometrics, there can be detected a significant infrastructure impact even at a small spatial scale. One example of this feature is the case of the metropolitan area of Athens and social public capital.

For these reasons (the complexity of the relationship of infrastructure and development, and the nuances that the spatial dimension adds to the problem) that the geography of public capital investment *must* be seriously considered in any infrastructure assessment. Even the estimation of the public capital impact at the national level should be based on a dataset that contains information at the lowest spatial level possible. In an ideal world, this geographical information should be coupled with the disaggregated data regarding the sectoral composition of the economy under examination (regardless of whether or not this concerns the manufacturing or non-manufacturing parts of the economy).

The main conclusion from the descriptive analysis in chapter 3 is that despite the fact that the real investment in public capital has increased or decreased according to a political cycle, it has remained a constant source of investment for the economy. It has to be noted that within the same period, the manufacturing sector experienced a severe

[10] Often there are economists or politicians who advocate in favour of some specific policy based on its fruitful application in other countries, or even worse on how well a theoretical model of an economy works with such simulated policy. However, in reality good economic policy should be the art of contextual analysis.

[11] This problem has been addressed recently in econometrics theory as 'micronumerosity'. For a brief discussion and some key references, see Gujarati 1995, chapter 10.

crisis, of which the most salient characteristic was the fall in private investment (see chapter 4). The public investment, however, was not distributed equally to the Greek prefectures according to the several measures of regional inequalities used in chapter 3.

The effect of public infrastructure in private production, which has been estimated in chapter 4 with the use of Cobb-Douglas production functions showed that there is a significant positive impact. This can be attributed solely to its productive component. This result was confirmed by the cost function analysis at the regional level. At the sectoral level, however, the social category seems to have a significant role in reducing private costs of production. The theoretical model used in chapter 6 showed that there is no significant impact of public capital in the non-manufacturing sectors and further corroborate the positive impact on manufacturing industry (even though there seems to be no significant relation to the total number of manufacturing firms).

These results concerning infrastructure investment pose some serious questions about public policies for the development of the national economy and its regional components.

(a) Has public infrastructure provision been used as tool of economic growth and regional planning?

(b) Were the various government administrations aware of the different impact of the infrastructure categories?

(c) Was the infrastructure investment policy complementary to the industrial policy?

(d) What would be the 'ideal' mix of public infrastructure investment at national and regional level, and would be the achievement of these 'targets' result in conflicts (regarding the use of limited financial resources and potential contradictory effects)?

One significant obstacle in answering these questions is that all of them have a degree of normative[12] statement in them – most planning questions do. This makes answers difficult if the policy objectives are not clearly specified. However, as Hausman has argued, positive and normative issues are intermingled in economics (1992, p. 114).

[12] For definition on the term see, for instance, Lipsey (1989).

Thus, some policy recommendations and observations perhaps may not be considered here to be out of line.

The Greek administrations could argue that there has always been a coherent public investment policy. This is true, at least to a certain degree, for some of the infrastructure categories[13]. Thus, despite the influence of the political cycle there seems to have been a constant flow of public investment during the period under examination. This, however, can also be one of the major problems with public capital policy, and this applies not only to Greece. As there is a general perception that the implementation of public works is something 'positive' for the economy (it can be seen as a materialised proof for the 'work' of a government), then infrastructure policy may well be sometimes driven by 'inertia'. The fact that some of the infrastructure categories have constantly spends over time is often just due to the fact that in the previous year the spend was also high. The same phenomenon can be observed for the spatial distribution of these categories.

A policy maker should be informed about both the short and long run potential impacts of each specific type of public capital investment as well as the complexity of these potential results. (The next section proposes that one of the first aims of future research should be the further dissagregation of infrastructure categories.) For instance, as it has been shown in the empirical analysis in this thesis that productive infrastructure capital has a significant impact at the regional level. However, its social counterpart does not, either in terms of the production process or the cost structure of the manufacturing sector. Based on these results the policy maker may well conclude, depending on objectives, that under an optimum policy resources should be directed from the social category to productive infrastructure.

Nevertheless, as the cost function analysis has shown, at all spatial levels regarding the industrial sectors, social infrastructure does seem to have an effect in reducing private costs. Thus, what is needed is a balance between regional (the need to promote the whole industry in a specific prefecture) and sectoral (the need to promote a specific sector in the whole country) objectives.

[13] This has been demonstrated in chapter 3.

Another question regarding the policy targets relates to some of the cost analysis findings. A point of stability of the cost results, regardless the type of panel used or the spatial level, is that all categories of public capital appear to reduce the demand for labour input. In cost terms this is an advantageous effect. It could be more positive if it is assumed that a more advanced type of industry would be more capital intensive. However, it could be argued that if the long run effect of public capital investment in an area leads to a less labour intensive industrial structure, this subsequently would result in a reduction of the local employment. It is obvious that the decision for the increase or not of the labour reducing infrastructure investment hinges on the long term targets of the regional or national policy maker.

The right mix of infrastructure categories and the overall spending on public capital depends on the balance between local, regional, and national targets for the economy. At the same time it has to be taken into serious consideration the fact that Greece is not a remote island, but has neighbouring countries, as well as partners in the European Union. Some of the infrastructure categories, for instance transport, health, tourism, education, to mention but a few, could (or should) be seen as a part of a larger sum or network. It must be kept in mind that a part of the Greek infrastructure stock in recent years has been constructed with the financial aid of the European Union.

Relative to the development of policy about financing infrastructure is the US debate/dispute as to whether investment should be for the creation of additional infrastructure stock or for construction of modern systems of fees/tolls of charging infrastructure users. The latter could subsequently fund the replacement of the worn public capital. This issue is related to the reduction of the planning role of the state, and to fiscal austerity programmes that many countries, including Greece, have followed. A comprehensive infrastructure policy in Greece should aim to combine both of these two objectives. Certainly there are areas in which the existing infrastructure stock is overused (for instance, the dominant role of private car for mass transportation in Athens has lead to increased need for improved roads etc., as well as negative external economies). Thus, it may well be a sensible aspect of infrastructure policy to introduce fees in order to reduce these negative externalities. In other less developed areas, however, it is clearly necessary to increase the already existing stock of public capital.

7.4 Infrastructure and economic development in Greece – the limitations and analytical lessons to be learned

It is hoped that this study may have contributed some new insight into the investigation of the public capital's impact on economic growth at national, regional, and urban levels. However, there are many significant limitations and shortcomings, which have to be acknowledged. These limitations can be classified under four general headings. The first refers to the general methodological framework in which the empirical analysis was conducted. The second concerns the use of differentiated levels of analysis within the methodological framework itself regarding the type of data used. A third problem stems from the 'nature' and inherent problems of the data employed. The last limitation of the thesis is that due to the character of the project several potentially valuable research paths have not (yet) been explored.

As it was argued in chapter 1, the empirical research of this thesis has been based on theoretical paradigms and quantitative techniques of mainstream neo-classical economics and economic geography. The resurgence of public capital research in the late eighties and in the nineties has been based on these accepted tools of empirical research and this has helped to put public economic activity, and especially infrastructure investment, back onto the political and theoretical agenda, most certainly in the US[14]. However, by using a completely different theoretical approach, it would be possible to dismiss much of this body of work, including research projects such as this thesis, on the grounds of empiricism and 'chaotic conceptions'[15]. Due to space limitations, is not possible to present the methodological debate for economics and economic geography. The interested reader can find a good summary of relevant arguments in Hausman (1992), and Johnston (1986), for each discipline respectively.

Harvey's view on public fixed capital[16] incorporates the role of infrastructure into the 'big picture' of the process of capital accumulation. It also links public infrastructure with a theory of class struggle. Such a theorisation emanates from a totally different set of initial assumptions about how society and economy operate, how commodity value is

[14] See, for instance, Clinton (1993) and Clinton and Gore (1992).
[15] For an analysis of an alternative methodological framework, as well as the term 'chaotic conceptions' see Sayer (1992).
[16] For a summary of Harvey's arguments see chapter 1.

created, or how fixed investment is incorporated in space. The recent resurgence in infrastructure research is based on altogether different premises, and possibly lacks such a clear perspective of the mechanism by which fixed public investment affects growth. It is, however, and despite its shortcomings, a useful tool in order to assess and appraise the specific impact of public capital in a country, region, or city.

This study, nevertheless, has some limitations even within the quantitative analytical framework. There are several levels of analysis, in regard to the nature of data used, by which the impact of infrastructure can be evaluated with statistical/econometric methods. One option is the use of secondary data, which can refer to the urban, regional, or national spatial levels (or even allow international comparisons). This approach was used here.

There is, of course, another option that involves the use of data acquired through questionnaires designed specifically for infrastructure assessment. An example of this kind of research is the analysis of Diamond and Spence (1989) designed to assess the impact of infrastructure on British industry. Such data can be tailored to the specific needs of analysis and, thus, provide insight into some of the effects of public capital that would not normally be revealed by secondary data. Unfortunately, this type of analysis has not been pursued here in the main due to constraints on resources. Another potential type of research, closely linked to the aforementioned questionnaire approach, is to examine the effects of public capital on a specific industry or industrial sector. The previous constraints prohibited again this type of research. These 'micro'-approaches, though, have important potential for future research (see next section).

The third major category of limitations of this study stems from the secondary nature of the employed data. The regional dataset is restricted to the total of manufacturing industry, as there is no published sectoral breakdown at regional levels in Greece (by the NSSG). On the other hand, there are two available sectoral datasets, one for Greece as a whole, and one for the metropolitan area of Athens. On the basis of these two, a third regional sectoral set was derived that for the Rest of Greece. However, in other countries sectoral datasets at regional level do exist. This is true not only for the United States, where data are available at fine regional scales, but also for smaller countries like Spain (see Moreno 1998). The existence of similar datasets for Greece, even at NUTS II level, would have provided great opportunities to examine the regional effects of infrastructure on the manufacturing industry in more depth.

In addition, the lack of regional estimations for the private sector capital stocks, for investment, and employment for the non-manufacturing sector has made impossible the use of the production and cost function analytical frameworks in the fashion used for the secondary sector. There is, though, an analysis for non-manufacturing activity that attempts to use quasi-production functions (see chapter 6). However, the results for this part of the economy should be read with the caveat of the restrictive assumptions that have had to be made.

The data limitations have not only restricted the spatial-sectoral dimensions of this study, but also its time dimension. Unfortunately, the data for both public capital, manufacturing industry (especially at the prefectural level), and the non-manufacturing sector before the late eighties are of poor quality or just non-existent. If panel data analysis had not been used, then it would be impossible to use time-series analysis (due to the limited number of observations) to examine the regional effects of infrastructure in this way. However, a longer time dimension would have given the opportunity to examine these effects in greater depth.

Another data limitation regards the regional estimation of infrastructure investment. Some of the public capital categories are not allocated (accounted) at prefectural level (see chapter 3). This means that public capital stocks at the prefectural level in this study underestimate the real infrastructure capacity. This problem did not occur in the estimation of the stocks for the sectoral panels, as for Greece as whole and for the metropolitan area of Athens all public investment was taken under consideration.

There is a last category of limitations of the thesis that is due mainly to the time and length restrictions such a project entails. Most of the following shortcomings (along with the limitations already discussed) can be the starting point for future research and will be returned to. The present thesis has not been able to cover all of the potentially fertile ground. A catalogue of these theoretical and empirical possibilities would include experimentation with time-lags of infrastructure effects; a deeper analysis of the infrastructure categories; dynamic modelling of infrastructure investment; incorporation of public capital into elaborate models of economic growth at national and regional levels; fiscal and financial aspects of infrastructure investment; maintenance-repair-management of public capital and infrastructure fees; technology aspects of the actual infrastructure investment; privatisation and quasi-public ownership of infrastructure stocks. All these are potential areas of future research and are more extensively addressed in the following section.

7.5 Infrastructure and economic development in Greece – the potential for future research

There are many aspects of infrastructure investment effects that have not been investigated deeply enough in this study. The most interesting of the extensions of this research are briefly discussed in this section and for reasons of convenience have been classified into several broad categories. This categorisation has been made here only to facilitate the presentation of the arguments and by no means constitutes a proper methodological classification. The following proposed areas for research, with the possible exception of the first theoretical category, can be explored not only in the Greek context, but could also be fruitful new areas of research for other countries as well.

The first major category for potential future research is in the theoretical domain. As it was mentioned earlier, the recent literature on infrastructure effects has utilised the mainstream paradigms of economics and economic geography. Despite the recent development of theoretical models of national or regional economies in which public capital has been incorporated as one of the key variables (see chapter 2 for a description of some of these models), the 'mechanics' of how infrastructure affects the economy are still unclear. This is even truer if the spatial dimension is added into such models. Even though chapter 6 has tried to shed some light on the empirical results for Greece, at a theoretical level much work is still to be done.

Alternative theorisation for the role of public fixed capital, particularly Harvey's work (see chapter 1, and previous section in this chapter) has attempted to accentuate space as one of the key factors of social change. However, Harvey has not worked specifically on infrastructure investment and the points of his argument are scattered in his work. An interesting, yet underrated, alternative theoretical framework for economic geography is that provided by Sheppard and Barnes (1990). Even though they have also not worked specifically on infrastructure, they have stressed the importance of fixed public investment in transport infrastructure in reducing production costs in their modelling[17].

In this category of potential theoretical advancement lies a potential link of infrastructure research with New-Keynesian economics[18]. This strand of macroeconomics has tried to explain the 'stickiness' of prices in the economy, in the short-run. Some of the main arguments in favour of the non-flexibility of commodities prices include the costs to price adjustments (the so-called 'menu costs' in macroeconomic jargon), which are linked to the problem of externalities to price adjustments (called 'aggregate-demand externalities', and which are represented by the benefits occurring for one firm from price reductions of other firms), and the 'staggering' way in which the overall level of wages and prices adjust. Given that many studies from various countries (including this research) have shown that infrastructure investment has a significant impact on the private sector costs, it would be interesting to examine the potential role of public capital on price reductions. As infrastructure capacity is difficult to change significantly in the short run, it is possible that bottlenecks in infrastructure provision could result in higher production costs. If these costs constitute a significant part of the overall costs of the firm, infrastructure underprovision can be an additional source of price rigidity, and negative 'aggregate-demand externalities'.

A second category for future investigation can be the several aspects of public capital research which either have been neglected or have not yet been properly explored, at least within the Greek context, and have as a common thread the creation and maintenance of the infrastructure stock. An interesting topic, which begs for further examination, is the finance of infrastructure investment and its fiscal effects. This topic can be directly linked to some of the previous arguments for a better theorisation, and especially to the macroeconomic debate (that New-Keynesian economics are part of).

[17] For this point see Sheppard and Barnes (1990), especially chapter 13.
[18] For an introductory presentation of the New-Keynesian ideas, as well as the main Neo-Classical arguments on macroeconomic analysis see Mankiw (1997). For a critique of both these dominant schools of thought see Palley (1996).

As infrastructure investment is a large part of public expenditure, it is obvious that the way this investment is financed can have a significant impact on the aggregate demand of the economy and private saving, as well as on other significant macroeconomic variables. Dalamagas (1995) has provided a discussion, at least to some extent, of the fiscal dimension of public investment in Greece. However, there are many unanswered questions in this field. A relevant query for regional analysis is the fiscal dimension for infrastructure projects conducted by local governments. Even though in the Greek case the Public Investment Programme finances the great bulk of infrastructure investment at this level, it would be interesting to examine in the future the financing of at least a sample of local government infrastructure projects.

One relevant area for infrastructure finance is the maintenance and repair of the existing stock of infrastructure. As it has been argued in chapter 2, Holtz-Eakin (1992; 1993a; 1993c) has proposed that it would be better if the money spent on construction projects for new infrastructure in the US were used for the development of systems which would charge infrastructure users. This, as it was discussed earlier in this chapter, may be a rather extreme policy measure especially for countries in a lower stage of economic development, like Greece. However, the field of infrastructure maintenance could well prove to be one of the most significant for future research, since fiscal problems (and austerity packages) still plague many countries, again like Greece.

It is these problems that have led many governments to the privatisation of a significant part of their infrastructure capacity, especially in the telecommunications, energy, and transport areas. Greece has not been an exception to this trend and that was one of the reasons for which the public capital of the publicly owned (and privatised in the immediate future) telecommunications and energy companies in Greece has been excluded from this study (for some of the other reasons see chapter 3). In any case, the privatisation of public capital stock and public utilities is a field of research of its own, and it would be enticing to study the reasons for and the ways in which these private companies have been privatised in Greece. The interested reader can find some additional bibliography on these topics in Appendix V.

Another category for future research is the exploration of new research methods for the already existing data. For instance, there are few examples in the bibliography to date on infrastructure research investigating the short run effects of public capital investment (see for example Moreno 1998, or Morrison and Schwartz 1992). It is possible that there will be some differences in the short and long run effects of public capital, and that these may be of great importance, especially for policymaking. Policymakers may also be interested in simulation results from alternative temporal or spatial allocation of public capital investment. Some interesting examples towards this direction of research can be found in Ohkawara and Yamano for the Japanese regions (1997), or the Economic and Social Cohesion Laboratory report from LSE about the impact of projects financed by the EU Cohesion Fund (1997).

In this last study, an extensive use of Vector Auto-regression (VAR) models can also be found. Despite the fact that VAR techniques have sometimes been criticised (see chapter 2 for some references on this point), this approach can prove to be a useful tool of analysis, especially for the dynamic modelling of infrastructure effects. The combination of VAR techniques with panel data analysis would be an additional improvement (see Holtz-Eakin, Newey, and Rosen 1988).

Another type of econometric analysis from which public capital regional research can benefit is the investigation of the presence of spatial autocorrelation. A recent example on the topic in the infrastructure research context comes from the US (Kelejian and Robinson 1997). The analysis, and especially the empirical work based on the prefectural-regional data, presented in the thesis can be extended, time permitting, to incorporate an investigation for spatial autocorrelation.

The investigation of the space parameter, however, can be even more explicit. A whole category of future research can be comprised by potential spatial comparisons of infrastructure studies at different geographical levels. The Greek infrastructure capacity can be examined as a part of the overall capacity of the geographical area in which Greece belongs to (i.e. the Balkans), and/or as a part of a wider study of the infrastructure impact in the European Union (or even Europe in general). The examination of the impact of investment in some types of public capital (transportation networks, for instance) in the Balkans could well prove to be of great importance for the future economic development of this area.

In conjunction with the macro-spatial research, analysis at micro-geographical level can also be fruitful for future research in the Greek context. The economic, social, and environmental effects of specific infrastructure projects could be monitored on a regular basis, possibly best at the level of local government. An additional area of future research is the use of attitudinal questionnaires and the replication of work similar to that conducted by Diamond and Spence for British industry (1989). It is more than likely that the Greek Ministry of Public Works, or Industry, would benefit by such an analysis in the planning of their investment policy.

However, the most important future research for both national and regional analyses of infrastructure effects is a further breakdown of infrastructure investment to its categories. The disaggregation used in this study was dictated by the space and time constraints of a research project like this. Nevertheless, even the production and social categories used in this research are composites of more elementary sub-categories (see chapter 3). It is possible that some of the categories bundled together under the headings productive or social public capital might yield different effects. For instance, productive infrastructure contains the Agriculture, Forestry and Fishery, Industry, Energy and Handicrafts, Irrigation, Research and Technology, Special Works, Transportation, Water/Sewage Works, and Prefectural Works/Programmes. There is no guarantee that public investment in the Forestry and Fishery category would have the same, if any, impact on the manufacturing sector, as the investment in the Industry, Energy and Handicrafts, or Transportation categories.

The same breakdown to sub-categories is also necessary for the social infrastructure category with one additional point for future research. It may be possible that, as indicated in chapter 2, the services from these categories are not merely the result of investment in fixed capital (for instance, school buildings or hospitals), but of their combination with the human resources (for instance, the services of teachers or doctors). Thus, it may well be necessary to add the respective public spending in these categories to public investment on fixed capital. The best-case scenario would be to have the public spending for these social categories at a prefectural level. In this way, it would be possible to replicate the whole analysis conducted in this study for each category using panel data analysis based on the prefectural data.

Notwithstanding the caveats and future research possibilities discussed in the last two parts of the conclusion to this thesis it is hoped that the findings and work that it contains has added some insight into better understanding this important dimension of the economy of Greece.

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Appendix I:

The Use of Panel Data: Advantages and Limitations

In the eighties, as Hsiao argued in his seminal book *Analysis of Panel Data* (1986), a new source of data enriched empirical research in economics and related subjects – panel data analysis. Essentially, this involves the pooling of cross-section observations over several time periods. These observations can refer to firms, households, regions, or even countries. If, for instance, a researcher wanted to analyse the production process of a specific country, and the available data covered a period of ten years, say 1981 to 1991, the problem of the restricted number of observations (just ten) would have to be confronted. The data for the estimated equation for a Cobb-Douglas production function with two inputs, private capital (*K*), and labour (*L*), and output (*Q*), would be as follows:

$$Q_{81} = A + K_{81} + L_{81} + e_{81}$$

$$Q_{82} = A + K_{82} + L_{82} + e_{82}$$

....

....

$$Q_{91} = A + K_{91} + L_{81} + e_{81}$$

However, if there were data available for the same time period for the regions of this country (say 3 regions: region 1, region 2, and region 3), then it would be possible to pool the data for the regions over the period 1981-1991. In this way the dataset would have three times more observations in comparison with purely national data. The panel data for the estimated equation then would be:

$$Q_{region1,81} = A + K_{region1,81} + L_{region1,81} + e_{region1,81}$$

$$Q_{region1,82} = A + K_{region1,82} + L_{region1,82} + e_{region1,82}$$

....

....

$$Q_{region1,91} = A + K_{region1,91} + L_{region1,91} + e_{region1,91}$$

$$Q_{region2,81} = A + K_{region2,81} + L_{region2,81} + e_{region2,81}$$

$$Q_{region2,82} = A + K_{region2,82} + L_{region2,82} + e_{region2,82}$$

....

....

$$Q_{region2,91} = A + K_{region2,91} + L_{region2,91} + e_{region2,91}$$

$$Q_{region3,81} = A + K_{region3,81} + L_{region3,81} + e_{region3,81}$$

$$Q_{region3,82} = A + K_{region3,82} + L_{region3,82} + e_{region3,82}$$

....

....

$$Q_{region3,91} = A + K_{region3,91} + L_{region3,91} + e_{region3,91}$$

The panel data regressions can be written compactly as:

$$y_{it} = \alpha + X_{it}^{'}\beta + u_{it}$$

where, subscript i denotes the cross-section dimension (e.g. firm, region, country), t the time-series dimension, y_{it} is the dependent variable, X the ith observation on M explanatory variables. α is a scalar, and β is of M x 1 dimension. Finally, u_{it} is the disturbance term. As Baltagi observed, "most of the panel data applications utilize a one-way error component model for the disturbances, with

$$u_{it} = \mu_i + v_{it}$$

where μ_i denotes the unobservable individual specific effect and v_{it} denotes the remainder disturbance" (1995, p. 9).

Panel data analysis has some considerable advantages in comparison with pure time-series and cross-section studies. These can be summarised as follows (this list is based mainly on Baltagi 1995 and Hsiao 1986, but also on Klevmarken 1989 and Solon 1989):

1. Controlling for *individual heterogeneity*. "Panel data suggest that individuals, firms, states or countries are heterogeneous. Time series and cross-section studies not controlling for this heterogeneity run the risk of obtaining biased results" (Baltagi, p. 3).
2. Panel data help in *reducing estimation bias*. This is true for *omitted variable* bias, bias induced by the *dynamic structure of the model*, and/or *simultaneity* bias (Hsiao, pp. 215-218).
3. Panel data *increase the degrees of freedom* and the *variability* of the data, and, thus, *lessening the problem of multicollinearity*. (see Baltagi p. 4).
4. Panel data reduce also the potential biases from the aggregation of data (in time-series analysis). (see Baltagi pp. 5-6).
5. Panel data can *describe better* than cross-sectional studies *the dynamic nature* of social relationships, and *allow the construction of more complicated behavioural models* than purely time-series or cross-section data. (see Baltagi pp. 4-5).

One of the main disadvantages of panel data analysis is the fact that it is not always easy to construct such a dataset (with the use of a questionnaire), or that disaggregated data (at firm or regional, for instance, level) are not always available. Also too short a time-series dimension of the panel dataset can still pose some estimation problems. Even so, even though the estimation of panel data is more difficult in terms of practical computation, panel data analysis has provided a most powerful tool for quantitative research in the last two decades.

Appendix II:

Correspondence of Public Investment Programme 1976-80 to 1981-92 categories

In the following table, the 1976-1980 categories of Public Investment Programme (in the fourth column) correspond to the respective 1981-1992 categories (in the third column). Column 2 presents the categories used in this research (column 1 offers their classification according to productive, social, or operational expenditure types of public investment).

Infr. Type	Categories used in this research	1981-1992	1976-1980
Misc+Adm	Administrative Expenditures	Administrative Expenditures	Administrative Expenditures
Productive	Agriculture	Agriculture	Agriculture
Productive	Borderline Programme*		Borderline Programmes Special Programme for Evros
Social	Education	Education	School Buildings Higher Education Rest Education
Productive	Forest/Fishery	Forest/Fishery	Forest Fishery
Social	Health/Welfare	Health/Welfare	Health Welfare
Social	Housing	Housing	Housing
Productive	Industry/Energy/Handicraft	Industry/Energy/Handicraft	Industry/Energy/Handicraft
Productive	Irrigation	Irrigation	Irrig. Progr. Ministry of Agriculture Irrig. Progr. Ministry of Public Works
Misc+Adm	Miscellaneous*	Miscellaneous	Miscellaneous Mines etc.
Productive	Prefectural works*+	Prefectural works OTA(Local Government) Prog. Pref. Pr. financed by the MIP* Prefectural Programmes	Prefectural works Prefectural Programmes
Social	Public Administration	Public Administration	Public Administration
Productive	Research and Technology*	Research and Technology	Committee of Atomic Energy Research Institutions Technical Co-operation
Productive	Special Works*+	Special Works Special works Athens/Thessaloniki	Special Works Special works Athens/Thessaloniki
Social	Tourism/Museums/Monuments	Tourism/Museums/Monuments	Tourism Museums
Productive	Transportation*	Railways	Railways Aviation (Civil) Roads-Bridges Ports Urban Transportation Athens Works
Productive	Water/Sewage*	Water/Sewage	Water Sewage

* Research categories which include several 1976-1980 categories, + Research categories which include several 1981-1992 categories

Appendix III:
Zellner's Seemingly Unrelated Regression (SUR) Estimator

The seemingly unrelated regression method (SUR) can be described if it is assumed that the objective is to estimate the coefficients of a system of equations as follows (composed, for instance, of 3 equations, written compactly in matrix algebra):

$$y_1 = X_1 b_1 + e_1$$
$$y_2 = X_2 b_2 + e_2$$
$$y_3 = X_3 b_3 + e_3$$

The disturbance (*e*) variances are supposed to be constant over time, but different for each equation. These variances would be, $\sigma_1^2, \sigma_2^2, \sigma_3^2$, or, following Judge et al.'s (1988, p. 446) notation $\sigma_{11}, \sigma_{22}, \sigma_{33}$. Two disturbances in different equations (for instance, in equations 1 and 2), but at the same time period, will be correlated, if contemporaneous correlation exists. Thus, the covariance for equations 1 and 2 would be:

$$\operatorname{cov}\operatorname{ar}(e_{1t} e_{2t}) = E[e_{1t} e_{2t}] = \sigma_{12}, \qquad \text{for a given time period } t.$$

Two disturbances in different equations, and for different time periods (for instance, equation 1 in time period *t*, and equation 2 in time period *t+1*) are uncorrelated:

$$\operatorname{cov}\operatorname{ar}(e_{1,t} e_{2,t+1}) = E[e_{1,t} e_{2,t+1}] = 0, \qquad \text{for time periods } t \text{ and } t+1.$$

The covariance matrix of the joint disturbances would be:

$$\Omega = E[ee'] = \begin{bmatrix} \sigma_{11} I & \sigma_{12} I & \sigma_{13} I \\ \sigma_{12} I & \sigma_{22} I & \sigma_{23} I \\ \sigma_{13} I & \sigma_{23} I & \sigma_{33} I \end{bmatrix},$$

$$\text{or} \qquad = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{12} & \sigma_{22} & \sigma_{23} \\ \sigma_{13} & \sigma_{23} & \sigma_{33} \end{bmatrix} \otimes I_T$$

This can be written even more compactly as, $\Sigma \otimes I_T$, where Σ represents the first matrix, symbol $\otimes$ denotes the Kronecker product, *I* an identity matrix, and the subscript *T* the time dimension (for an analysis of this notation see Judge et al. 1988).

Consistent estimates of the variances and covariances of matrix Σ can be computed by the formula:

$$\hat{\sigma}_{ij} = \frac{1}{T}\hat{e}_i'\hat{e}_j = \frac{1}{T}\sum_{t=1}^{T}\hat{e}_{it}\hat{e}_{jt}\,, \qquad \text{(AII-1)}$$

$$\text{where } \hat{e}_i = y_i - X_i b_i \qquad \text{(AII-2)}$$

(see Judge et al. 1988, pp. 451-452, for a discussion on the divisor T).

If $\hat{\Sigma}$ is the matrix with the estimated variances and covariances, then Zellner's SUR estimator would be:

$$\hat{\hat{\beta}} = [X'(\hat{\Sigma}^{-1} \otimes I)X]^{-1}X'(\hat{\Sigma}^{-1} \otimes I)y \qquad \text{(AII-3)}$$

Another method to estimate β is to use successive iterations (starting with equations AII-1 and AII-3). Thus, new estimates for the variances and covariances can be computed. These estimates will be:

$$\hat{\hat{\sigma}}_{ij} = T^{-1}(y_i - X_i\hat{\hat{\beta}}_i)'(y_i - X_i\hat{\hat{\beta}}_i) \qquad \text{(AII-4)}$$

where, $\hat{\hat{\beta}}' = (\hat{\hat{\beta}}_1', \hat{\hat{\beta}}_2', \ldots, \hat{\hat{\beta}}_M')$. Then, with $\hat{\hat{\sigma}}_{ij}$ a new estimator for β (that is $\hat{\hat{\hat{\beta}}}$) can be estimated and so on, until convergence. As Judge et al. (1988) argue "*when the random errors follow a multivariate normal distribution this estimator will be the maximum likelihood estimator*" (p. 452).

Appendix IV:
Two digit Sectors and three digit sectors in Greek manufacturing

The following breakdown is based on the sectoral nomenclature in English as provided by the National Statistical Service of Greece.

2-digit Sectors	3-digit Sub-sectors
20 Food and Kindred Products	201 Meat Products
	202 Dairy Products
	203 Canned, Frozen, & Pres. Fruits, Vegetables, & Food Spec.
	204 Fats and Oils
	205 Grain Mill Products
	206 Bakery Products
	207 Sugar
	208 Chocolate and Confectionery Products
	209 Miscellaneous Food Preparations and Kindred Products
21 Beverages	211 Alcoholic Drinks and Alcohol
	212 Wines
	213 Beer
	214 Non-alcoholic Drinks, Mineral Water
22 Tobacco Manufactures	221 Tobacco
	222 Cigarettes and Cigars
23 Textile Mill Products	231 Manmade and Natural Wool Fibre and Fabrics
	232 Manmade and Natural Cotton Fibre and Fabrics
	233 Manmade & Natural Silk Fibre and Fabrics, & Nylon Fibre
	234 Manmade Fibre and Fabrics, except Nylon
	235 Jute, Linen and Canvas and Related Products
	236 Knitting Mills
	237 Colouring, Printing and Finishing Plants
	238 Threads and Yarns
	239 Miscellaneous Textiles
24 Apparel and Other Textile Products	241 Shoe Making
	242 Shoe Repair
	243 Apparel
	244 Clothing and Other Textile Goods
25 Lumber, Wood and Cork Products	251 Sawmills and Planing Mills
	252 Construction Wood Works
	253 Wood Containers and Small Wood Goods
	259 Cork and Cork Products
26 Furniture and Fixtures	261 Wood Household Furniture
	262 Metal Household Furniture
27 Paper and Allied Products	271 Pulp and Paper Mills
	272 Paper Products
28 Printing and Publishing	281 Printing & Edit. of Newspapers, Journals, Books & Pamphlets
	282 Miscellaneous Printing Works

2-digit Sectors	3-digit Sub-sectors
29 Leather, Leather Products and Furs	291 Leather Plants
	292 Fur and Fur Products, Except Apparel
	293 Manmade & Natural Leather Prod., Except Apparel & Shoes
30 Rubber and Miscellaneous Plastics Products	301 Rubber Plants
	302 Miscellaneous Plastics Products
31 Chemicals and Allied Products	311 Acids, Salts and Fertilisers
	312 Plastics Materials and Resins, Manmade Fibres
	313 Other Primary Chemical Plants
	314 Paints, Printing Inks and Allied Products
	315 Pharmaceuticals
	316 Cosmetics, Perfumes and Toilet Preparations
	317 Soaps and Detergents
	319 Miscellaneous Chemicals Products
32 Petroleum and Coal Products	321 Petroleum Refining
	322 Coal Products and Lignite
	329 Petroleum By-products
33 Non-metallic Minerals and Allied Products	331 Minerals and Earths for Structures
	332 Glass and Glass Products
	333 Clay, Porcelain and Related Products
	334 Cements
	335 Lime, Gypsum and Related Products
	336 Cement Products
	337 Marble and Marble Products
	338 Asbestos Products
	339 Miscellaneous Non-Metallic Minerals Products
34 Primary Metal Industries	341 Iron
	342 Other Metals
35 Fabricated Metal Products, except for Mach. Equip.	351 Iron Tubes
	352 Chains, Wire Springs, Nails and Related Products
	353 Metal Structures
	354 Metal Tools
	355 Household Metal Appliances
	356 Cast Iron Products
	357 Copper and Lead Products
	358 Aluminium Products
	359 Miscell. Metal Products, except Machinery & Transport Equip.
36 Machinery Except Electrical	361 Internal Combustion Engines
	362 Air Conditioning Machines
	363 Agricultural Machinery
	364 Machinery for Roads, Quarries and Structures
	365 Machinery for the Food, Beverages & Tobacco Industries
	366 Machinery for the Textile, Wood and Metal Industries
	367 Pumps, Blowers and Industrial Spraying Machinery
	368 Office Equipment and Balances
	369 Machinery and Repair non specifically Named

2-digit Sectors	3-digit Sub-sectors
37 Electric and Electronic Equipment	371 Electrical Machinery
	372 Transformers and Dry Electrical Elements
	373 Electrical Coil Windings and Electrical Wiring
	374 Lamps and Lighting Fixtures
	375 Other Electrical Materials
	376 Telecommunications, Materials and Hearing Devices
	377 Electrical Scientific Instruments
	378 Other Electrical Apparatuses
	379 Repair of Electrical Equipment
38 Transportation Equipment	381 Boats and Repair
	382 Rail Materials
	383 Cars
	384 Car Repair
	385 Motorcycles and Bikes
	386 Repair of Motorcycles and Bikes
	387 Repair of Aeroplanes
	389 Other Transportation Equipment
39 Miscellaneous Manufacturing Establishments	391 Medical Instruments, Measuring & Control Instruments
	392 Photographic and Optical Products
	393 Repair of Photographic and Optical Products
	394 Watches and Cosmetics
	395 Repair of Watches
	396 Musical Instruments
	397 Toys and Athletics Products
	398 Manmade Teeth
	399 Miscellaneous Plants

Appendix V:

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