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ESSAYS ON COST OVERRUNS IN INFRASTRUCTURE PROVISION

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To Alda

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Summary

This thesis comprises three papers that represent three autonomous chapters. The linking "fil rouge" between the essays is the investigation of the issue of efficiency in the execution of public works. Particularly, the focus is on the analysis of cost overruns in infrastructure provision.

The efficient execution of public works can be defined in terms of time of completion and final costs. From existing research, we know that construction cost overruns are systematic and potentially substantial in public infrastructure provision (Flyvbjerg et al., 2002, 2003, Odeck 2004, Cantarelli et al., 2012). This can imply, among other effects, adverse impacts on the growth of local economies and social benefits (Flyvbjerg et al., 2002; Ganuza, 2007; Lewis and Bajari, 2011; Guccio et al., 2012 and 2014).

The main objective of this work is to contribute to the existing literature, providing a further advance to the understanding of the nature of cost overruns as well as of their main determinants, and to the measurement of their impact on the Italian infrastructure provision. To this purpose, in the first part of the thesis, a systematic review of the published empirical literature on the determinants of cost overruns is carried out, highlighting differences in conceptual definitions, empirical approaches, study designs and characteristics. All the revised papers are then summarized by quantitative and qualitative methodologies and critically analyzed. The second part of the thesis encloses two empirical papers that focus on the Italian public procurement system as a case study. In both, I try to explore, empirically, some the reasons for cost overruns in infrastructure provision in Italy that are not extensively investigated by previous literature. More specifically, by looking at the expansion of cost overruns throughout the entire life-cycle of the project, in the first paper, I try to fill a gap in the existing literature on the topic. I

was, thus, able to identify some phases that are more critical than others in generating project extra costs and to disentangle their own contribution to the final extra cost. In the second paper, I focus on the design phase and analyse its impact on the efficiency of the Italian public works. Studying the evolution of the Italian regulatory framework in this sector, I find evidence supporting the regulator's choices as emerging by the new Code of public works.

Chapter 1 – The determinants of cost overruns in transport infrastructure provision: A systematic literature review[1]

In this chapter, I conduct a systematic literature review of those papers published in peer-review journals in the period 2000-2016 and assessing empirically the determinants of cost overruns in the provision of transport infrastructure.

In the last years, several researches have paid attention to this issue with the aim to assess the magnitude and the determinants of cost overruns in the transportation sector. However, empirical findings are scattered among different strands of literature, ranging from the fields of construction engineering and management to that of applied economics. Compared to previous literature reviews, this work has no equal in terms of comprehensiveness of the papers reviewed, methodology and focus. In particular, the objective of the review is to identify the differences existing in: (i) the conceptualization and definition of cost overruns; (ii) the estimated costs; (iii) the methods applied in the empirical investigations; (iv) the determinants used in the estimation and their impact on cost overruns.

To this purpose, as suggested by Littell et al. (2008), I follow standardized, transparent and replicable procedures. Therefore, the systematic literature review is organized along three main stages: (i) explanatory literature research; (ii) literature review; (iii) analysis, reporting and discussion. In the first stage (i), the formal protocol-driven search strategy is applied to the scientific database SCOPUS that, compared to other social sciences resources, allows for broader coverage of peer-reviewed journals and a reasonably cleaner definition of subject areas. Accordingly, the beginning of the research implies the definition of

[1] In conducting this research, I am largely in debt with Marina Cavalieri (University of Catania) and Calogero Guccio (University of Catania).

keywords, the construction of search strings, and the choice of the criteria of inclusion/exclusion. The second stage (ii) consists of a descriptive and content analysis of all the selected papers. Thus, a descriptive statistical analysis is conducted to provide a summary view of the selected papers. Finally, in the last stage (iii), each of the selected papers is reviewed and studied in depth. Specifically, each article is read in parallel by two researchers, plus a third one in the case of uncertainty. Starting from a total number of 945 papers, the final list comprises 25 papers, plus another one that meets the inclusion criteria through snowballing. Consequently, the studies included in the review are 26.

The 26 papers are critically evaluated in terms of cost overrun definition, measurement and determinants. The differences mainly reflect the various theoretical approaches and perspectives used in the literature to investigate the issue of inefficiency in infrastructure provision. Indeed, according to the applied economic literature, the critical elements of the procurement process represent the main reasons for the inefficiency in the execution of the projects, whose context is characterised by contract incompleteness, asymmetric information and lack of powered incentives (Estache et al., 2009). These determinants are consistent with the relationship between cost escalation and (i) bidder behaviour; (ii) auction formats; (iii) other factors that influence the likelihood of contract renegotiation (size, duration, etc.). Differently, the construction engineering/managerial literature mainly looks at the project organisation and management. It attributes the existence of cost overruns to the following problems: underestimation of project costs with respect to the project budget (underestimation problem); occurrence of unforeseen technical and environmental events (scope changes, technical reasons, characteristics of a given geographical area, etc.); specific features of the project (typology, size and projects), etc.

Chapter 2 - On the magnitude of cost overruns throughout the project life-cycle: An assessment for the Italian public works contracts

The cost-growth phenomenon has been attributed to several sources arisen in the different stages along the life-cycle of the project. However, most of the empirical literature share a common aspect: it mainly focuses on cost overruns in the

execution phase of the project, thus neglecting what happens throughout the entire life-cycle of it. Only few papers have paid specific attention to this issues (Chong and Hopkins, 2016; Cantarelli et al., 2012; Terril, 2016).

Following the approach of the managerial literature, the primary object of this chapter is to understand how cost overruns of Italian public works evolve through the various phases of the project life-cycle and to disentangle the role of each project phase in determining the overall final cost overrun. For doing this, the magnitude of cost overruns is estimated in the different phases of the process of realisation of the public works, to determine the impact of each stage to the overall final performance (in terms of cost overruns) of the project. Based on the previous literature, I distinguish four stages of the project life-cycle: (i) project conception and administrative planning; (ii) project design and engineering cost estimates; (iii) contractor selection; and (iv) execution and project closeout.

Employing a dataset of Italian transport infrastructure projects for roads, started and completed during the period 2000-2013, I try to reconstruct the expenditure flows over the entire project life-cycle, from the financing and the start of the work, the awarded and the execution of the contract, up to the completion and testing of the work. To assess the cost evolution by project phase, I distinguish between the costs of physical execution and all the other costs. Thus, I am able to compute several indexes connected with the project life-cycle: (i) indexes for the physical execution; (ii) indexes for the whole provision of the public work.

Some interesting results regard the behaviour of the contracting authority. On average, I find that total cost overruns in the execution phase assume a negative value and that the final coverage is around 26% higher than the actual cost of the project. Therefore, the contracting authorities seem to systematically overestimate the extent of the final costs. This behaviour is more pronounced for financial coverage. From a policy point of view, the results arising from the paper can be relevant for restraining the growth of cost overruns in the execution stage, suggesting the adoption of more stringent rules in the budgeting and financial coverage of the projects.

Chapter 3 – Assessing the role of design phase on cost overruns and time delay: evidence from public works in Italy[2]

The design phase is recognized as one of the possible determinants of inefficiency in public works execution, but empirical evidence on the topic remains scarce. This chapter aims to contribute to the existing literature, widening the understanding of the relationship between the choices taken in the design phase and the renegotiation of public contracts in Italy. The reasons for the low performance of Italian public works can reflect the inefficiencies of the Italian regulatory framework, the characteristics of the procurement system (i.e., contractor selection mechanisms, contractual forms, inefficient types of contracts) as well as problems related to the project design, its management and delivery.

To address the objective of this chapter, I investigate the role of the internal and external designer on the performance in public works execution as measured by cost overruns and time delays. Before the empirical analysis, an overview of the evolution of the role of the design phase within the Italian regulatory framework is provided. The link between Italian laws on public works and design phase is very strong. It has changed over time, giving rise to different behaviours of the procurer, who can strategically play on the use (and abuse) of a specific type of contract – Design & Build – and the choice to either outsource the design activity or maintain a design in-house. This section retraces the evolution of the regulatory approach until the last Decree n.50/2016, which has transposed the last EU directives aimed to increase the efficiency of the public procurement system.

Using a large dataset of public works awarded in Italy between 2008 and 2014, I test the relationship between different choices taken in the design phase and the performance of public works execution. The findings show that the presence of an external designer is statistically associated with a higher cost and time renegotiation. This issue is especially critical for small municipalities that are less efficient than public companies. The former also has a much higher likelihood to choose an external designer, probably because of the more relevant presence of unskilled and inadequate internal technical offices. Moreover, the capability and the experience of the bureaucratic structures, influenced by the size and the

[2] This chapter is the result of a joint work with Livio Ferrante (University of Catania).

economic conditions of the local governments, can affect bureaucratic performance and contribute to the inefficiency in the execution of public works. Concerning the use of Design & Build contracts, it appears to be negatively associated with extra costs.

In conclusion, due to the large decentralisation of the public procurement system and the presence of a complex and often contradictory regulatory framework, the Italian public procurement sector is an ideal case-study to analyse the relationship between the choices taken in the design phase and cost overrun and time delays. From the public policy perspective, in the light of the New Code of public works (decree n.50/2016), the findings from this paper seem to support the regulator's decision to improve the quality and the performance of public works by introducing a system of qualification of contracting authorities, which takes into account the type, the experience and the endowment of technical personnel. On the contrary, the empirical evidence does not support the regulator's choice to weaken the strategic role that the contracting authority should play in the design phase, putting on the same ground the involvement of either an internal or an external designer.

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Chapter 1

The determinants of cost overruns in transport infrastructure provision: A systematic literature review

Abstract

Cost overruns are an endemic feature of transport infrastructure provision all over the world. In the last decades, a considerable amount of studies has been devoted to assessing the magnitude and determinants of cost overruns in the transportation sector. However, empirical findings are scattered among different strands of literature, ranging from the fields of construction engineering and management to that of applied economics. To shed light on the determinants of cost overruns in the execution of transport infrastructure projects, we conduct a systematic review of the empirical literature on the topic. Of the 945 articles retrieved, 26 articles published between the years 2000 and 2016 meet our inclusion criteria. For them, we describe the different empirical approaches, provide a classification of the determinants employed in the analyses and summarise their impact on cost overruns. Finally, we discuss some directions and concerns for further research in the field.

Keywords: cost overruns; transportation infrastructure; performance; determinants; systematic literature review.

JEL: H54

1. Introduction

The performance of infrastructure provision is a worldwide concern implying not only economic inefficiency (i.e., waste of public resources) but also a negative impact on social welfare (Lewis and Bajari, 2011). In fact, the efficient provision of infrastructure, as well as the capability to deliver the planned benefits, are severely affected by execution problems. The most well-known expressions of inefficiency are cost overruns and time delays that are commonly considered to strongly affect the execution of infrastructure projects in most countries (Flyvberg, 2005; Estache et al., 2009).

Over the last decades, many empirical studies have focused on the evaluation of cost overruns, looking at the issue from manifold points of view and in different contexts. Indeed, the phenomenon of the increasing planned costs of public projects has been widely studied by different scientific disciplines, particularly construction engineering and management but also applied economics.

In this paper, we conduct a systematic literature review of the articles published in peer-reviewed journals in the period 2000-2016, to assess the determinants of cost overruns in the provision of transport infrastructure empirically. In particular, we aim at identifying the differences existing in: (*i*) the conceptualisation and definition of cost overruns; (*ii*) the estimated costs; (*iii*) the methods applied in the empirical investigation; (*iv*) the determinants used in the estimation and their impact on cost overruns.

The approach applied in this study follows a systematic quantitative analysis, namely a research method used for a systematic, quantitative description of the content of the literature in a particular field or on one specific subject (Pickering and Byrne, 2014). For this purpose, as suggested by Littell et al. (2008), standardised, transparent and replicable procedures must be followed. We define a formal protocol-driven search strategy applied to a scientific database. Our initial bibliographic "metadata" are drawn from the SCOPUS database. In fact, compared to other resources for social sciences such as the Social Science Citation Index, EconLit and Google Scholar, SCOPUS allows for broader coverage of peer-reviewed journals and a reasonably cleaner definition of subject areas. Furthermore, it includes relatively good coverage of citation data in scholarly journals that enable to assess

the influence of a given author/article/journal in the literature through citation analysis.

Our systematic review focuses on those studies that not only report the magnitude of cost overruns but also attempt to investigate the underlying causes empirically. As for the time span of the analysis, we limit the reviewed literature to that published since the year 2000. Indeed, previous literature mostly refers to single-case studies or is based on too small samples to allow for robust statistical analyses and to provide reliable results (e.g., Morris and Hough, 1987; Pickrell 1992; Reichelt and Lyneis, 1999).

The present work is not the first one to review the existing literature on the performance and characteristics of projects provision. Some previous attempts have been made to analyse the same issue (Cantarelli et al., 2010a; Hu et al., 2013; Ahiaga-Dagbui et al., 2017). However, though worth mentioning, none of them comes close to ours regarding comprehensiveness of the literature reviewed, methodology and focus.

The remainder of the paper is organized as follows. Section 2 presents our background and the method applied in the systematic literature review, also showing preliminary results on bibliographic "metadata". Section 3 provides a more analytic assessment of the determinants of cost overruns in the provision of infrastructure, looking at the problem from multiple points of view and in different contexts. Section 4 offers a unified picture of the variables used in the literature as proxies for the determinants of cost overruns. Finally, Section 5 critically discusses the main findings arising from this review and suggests directions for future research investigations.

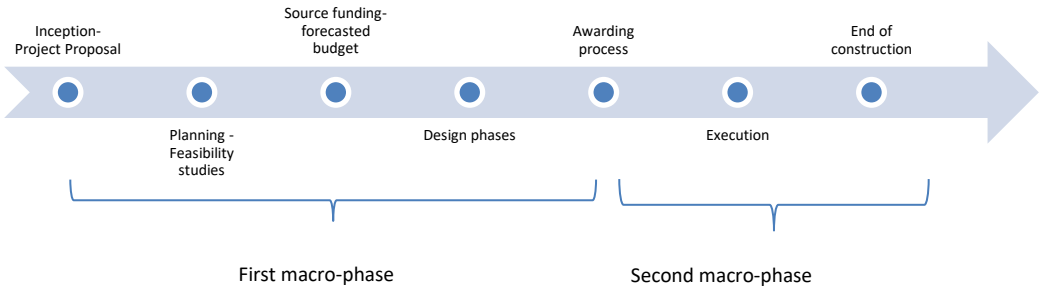
2. Background and method

2.1 Setting the stage

Evidence from existing research confirms that construction cost overruns are systematic and potentially substantial in traditional public infrastructure procurement (Flyvbjerg et al. 2002, 2003, Odeck 2004, Cantarelli et al. 2012b). The cost-growth phenomenon has been attributed to several sources arisen in the different stages

along the life-cycle of the project. Analyzing the entire project cycle (see Fig. 1), various cost estimates can be made at the various steps of the process, i.e., project planning, decision to build, tendering, contracting (and possible later renegotiations) and so on. At each step, factors can be identified that leave room for variation in forecasted costs thus affecting the overall efficiency of the project (Cantarelli et al. 2012b).

Figure 1 – Typical life-cycle of an infrastructure project



Source: our elaboration

Ideally, the project life-cycle can be divided into two macro-phases: (i) the first phase, with reduced visibility, whose steps range from the project proposal to the awarding phase and (ii) the second phase, which includes the contract execution and the work realisation until the end of the construction process. The first part of the project life-cycle path requires more time than costs, using few financial resources although the design and the awarding processes are both important in determining the final cost of infrastructure projects; the second part of the path needs both time and financial resources as agreed in the contractual arrangements with the provider. The contracts usually provide some forms of renegotiation of the agreed time and cost to take into account the future contingencies during the execution phase. Furthermore, cost estimates at each successive stage typically benefit from a smaller number of options, more significant details of the design, higher accuracy of the quantities, and more precise information about unit prices. Therefore, the accurateness of the estimated costs is better over time (Flyvbjerg et al. 2002, 2003). However, variation in cost estimates is not the only factor to influence the magnitude

of cost overruns. Indeed, cost overruns can be the result of estimation errors, voluntary or deriving from the strategic and opportunistic behaviors of bidders in tendering contracts - with variation in the cost performance of contracts - (Flyvbjerg et al. 2002; 2007), or can be due to scope changes (Ahiaga-Dagbui and Smith 2014) and reworks after the completion of the infrastructure work (Love et al., 2005).

Therefore, to provide a more in-depth comprehension of the determinants of cost overruns in the execution phase, in this review we limit the scope of the analysis by excluding papers related to infrastructure changes or reworks after project completion.

2.2 Method

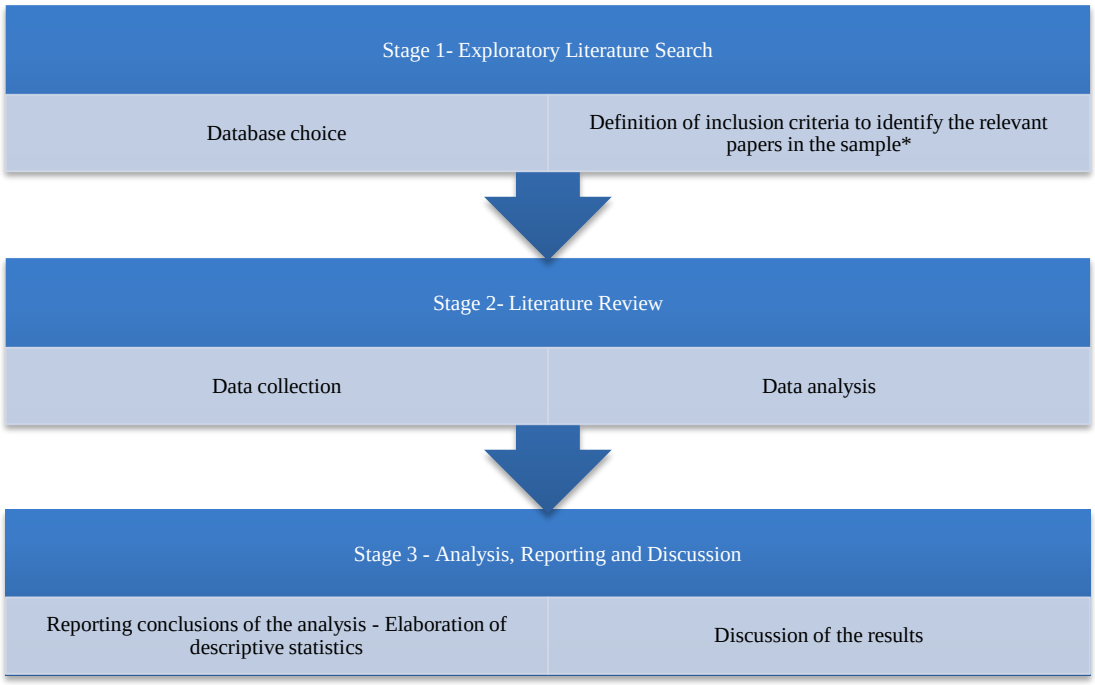
As previously mentioned, the approach employed in this study is that of a systematic quantitative literature review. As pointed out by Greenalgh (1997) a systematic review of the literature is an overview of the main studies that use explicit and reproducible methods of identification. To this purpose, several methodological approaches have been proposed in the literature (e.g. Tranfield et al., 2003; Petticrew and Roberts, 2006; Littell et al., 2008; Pickering and Byrne, 2014). Generally speaking, three broad methodological techniques exist to conduct a literature review: meta-analysis, qualitative or narrative review, and systematic review. A meta-analysis is an approach whereby empirical studies on a given subject are collected and analysed statistically. In this perspective, a meta-analysis is considered effective as long as the extracted studies have comparable research designs. The latter often involves data conversion and sophisticated statistical procedures. In contrast, a qualitative review is a less rigid approach, employing several methods, mainly narrative, that make it more malleable and, hence, comprehensive. The third approach, the one applied in this study, is a research method used for systematic, quantitative description of the content of the literature in a particular field or on a particular subject (Pickering and Byrne, 2014). For this purpose, as suggested by Littell et al. (2008), standardised, transparent and replicable procedures must be followed.

More specifically, our systematic literature review is organized into three main stages. In the first stage, we choose the database to be investigated (e.g., Scopus,

EconLit, the Social Science Citation Index, Google Scholar), review the selected database using the search strings, and select the papers to be analysed in detail. This stage implies the identification of keywords, the construction of search strings, and the choice of the criteria of inclusion/exclusion.

The second stage consists of a descriptive and content analysis of the selected papers. In this stage, a descriptive statistical analysis is conducted to provide a summary view of the selected papers. Afterwards, in the last stage, the selected papers are reviewed and studied in depth one by one, to analyse the existing differences in the definition of cost overruns, in the emerging determinants and in their related impact. Figure 2 shows the main steps involved in our systematic literature review process.

Figure 2 – Main **s**teps of the literature search and identification of studies



**Note:* Criteria for filters include: period; keywords and search strings; choice of subject areas; criteria of inclusion/exclusion;

Source: our elaboration

2.3 Database choice and exploratory literature overview

A number of different online bibliographic databases include articles in peer-reviewed journals (and in some cases other types of publications) and, thus, could be potentially used to perform our systematic review. At least, these include EconLit, the Social Science Citation Index (SSCI), Google Scholar and SCOPUS. These resources vary along some critical dimensions, one fundamental being whether the database employs a classification system that allows balancing two opposing goals: 1) obtaining a broad coverage of those journals where is plausible that papers on our topic are published; 2) making a reasonable distinction among the various publication subjects. For its irrelevance in terms of overall journal coverage, we exclude Google Scholar. The SSCI covers primarily journal articles, and it is limited to about 2,500 social science journals[3]. EconLit covers about 1,000 journals but it is mainly restricted to economic subjects[4]. The SCOPUS database includes over 21,000 peer-reviewed journals that cover virtually all disciplines, as well as books and conference papers[5]. Therefore, by choosing the SCOPUS database, we feel confident to get a significant share of the publications representing the different strands of the literature investigating the topic of cost overruns in transport infrastructure provision. In fact, the SCOPUS database ranges from the general field of transportation to the applied economic disciplines. Furthermore, it provides a reasonably precise definition of the subject areas and includes relatively good coverage of citation data in scholar journals that enable to assess the influence of a given author/article/journal in the literature through citation analysis. Finally, compared to the SCOPUS database, both the SSCI and EconLit have limited coverage of publications. Thus, we select the SCOPUS database as the source of our bibliographic "metadata" on publications assessing the determinant factors of cost overruns in the provision of transport infrastructure.

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[3] Further details on the SCCI coverage can be found at: http://thomsonreuters.com/en/products-services/scholarly-scientific-research/scholarly-search-and-discovery/social-sciences-citation-index.html.

[4] EconLit also includes books, book chapters and doctoral dissertations beginning with the 1987. Further details on the EconLit coverage can be found at: https://www.aeaweb.org/econlit/content.

[5] More details on the SCOPUS database can be found at: https://www.elsevier.com/solutions/scopus/content.

Finally, in this stage, we identify the criteria for the filters used to select the paper sample. In the first searches, we test different combinations of keywords, attempting to define the better criteria to obtain a general overview of research contributions in the literature. This is an important step to understand the distribution of papers on cost overruns in different academic areas and its evolution over time. The filters used in our work concern: (i) the time period; (ii) the objective of the study; (iii) the choice of the keywords and search strings; (iv) the subject area; (iv) the criteria for inclusion/exclusion of papers.

2.4 Data collection

The second stage of our systematic literature review process begins with the data collection. We employ the keywords more often used in the literature: "Cost overruns" and its variant "Adaptation costs"[6]. To safeguard the quality of the review and to enable an efficient synthesis, we limit our search to articles published in the English language, in peer-reviewed journals, over the period 2000-2016. Furthermore, we select as a general subject area "Social Sciences & Humanities". Although this choice could run some risks of omissions, we are, however, confident that our publication coverage is quite substantial[7].

In a first search, we find 945 papers that, however, cover a too broad range of topics and subjects[8]. Therefore, we limit our search on the following sub-subjects: Business, Management and Accounting; Social Sciences; Engineering; Environmental Science; Economics, Econometrics and Finance; Decision Sciences. The refined search results consist of 796 papers with the following distribution:

[6] The use of keywords such as "cost overrun*" OR "adaptation cost*" make it possible to select papers containing the main variants of the topics.

[7] We also conduct some pilot examinations in other general subject areas in the SCOPUS database (i.e. Life Sciences; Health Sciences; Physical Sciences), providing further support to our choices.

[8] Publication results by subject area are: Business, Management and Accounting (519); Social Sciences (368); Engineering (292); Environmental Science (175); Economics, Econometrics and Finance (165); Decision Sciences (97); Energy (27); Computer Science (23); Arts and Humanities (19); Earth and Planetary Sciences (18); Agricultural and Biological Sciences (10); Mathematics (10); Medicine (9); Psychology (6); Biochemistry, Genetics and Molecular Biology (1); Chemical Engineering (1); Multidisciplinary (1). It should be noted that the SCOPUS database uses a multi-subject attribute classification. Thus, the same paper might be classified in more than one subject area.

Business, Management and Accounting (485); Social Sciences (287); Engineering (268); Economics, Econometrics and Finance (149); Environmental Science (141); Decision Sciences (80)[9]. To further refine our search, we employ the keywords in the SCOPUS metadata. However, since keywords are usually chosen by authors on the basis of their tastes, unsurprisingly they are highly heterogeneous and, in several cases, their use results in a substantial loss of bibliographic data.

Thus, to provide a reasonable identification of the relevant literature, we further refine our initial sample using information available in the abstract, with the objective of excluding the papers without adherence to the present research and without available full paper. More specifically, reading each abstract when available, we are able to exclude from our sample those publications that explicitly refer to cost overruns in projects different from transport ones (e.g., mega-events, power plant projects, software projects, pharmaceutical projects, residential constructions, etc.). Furthermore, we omit papers that are clearly out of the goals of our systematic review[10]. Additionally, due to their contract peculiarities, we also exclude articles that refer to public-private partnerships or private finance initiatives in infrastructure provision including transports[11]. Finally, we disregard documents with no available abstract and/or those that do not report in the abstract whether an empirical analysis is conducted and/or do not provide evidence of empirical findings. However, we apply the benefit of the doubt rule whenever, by reading the abstract, we are not able to explicitly exclude the paper from our sample[12].

This further refinement identifies 62 articles that potentially refer to cost overruns in transportation infrastructure provision, whose full texts are retrieved and further reviewed for eligibility in the final analysis.

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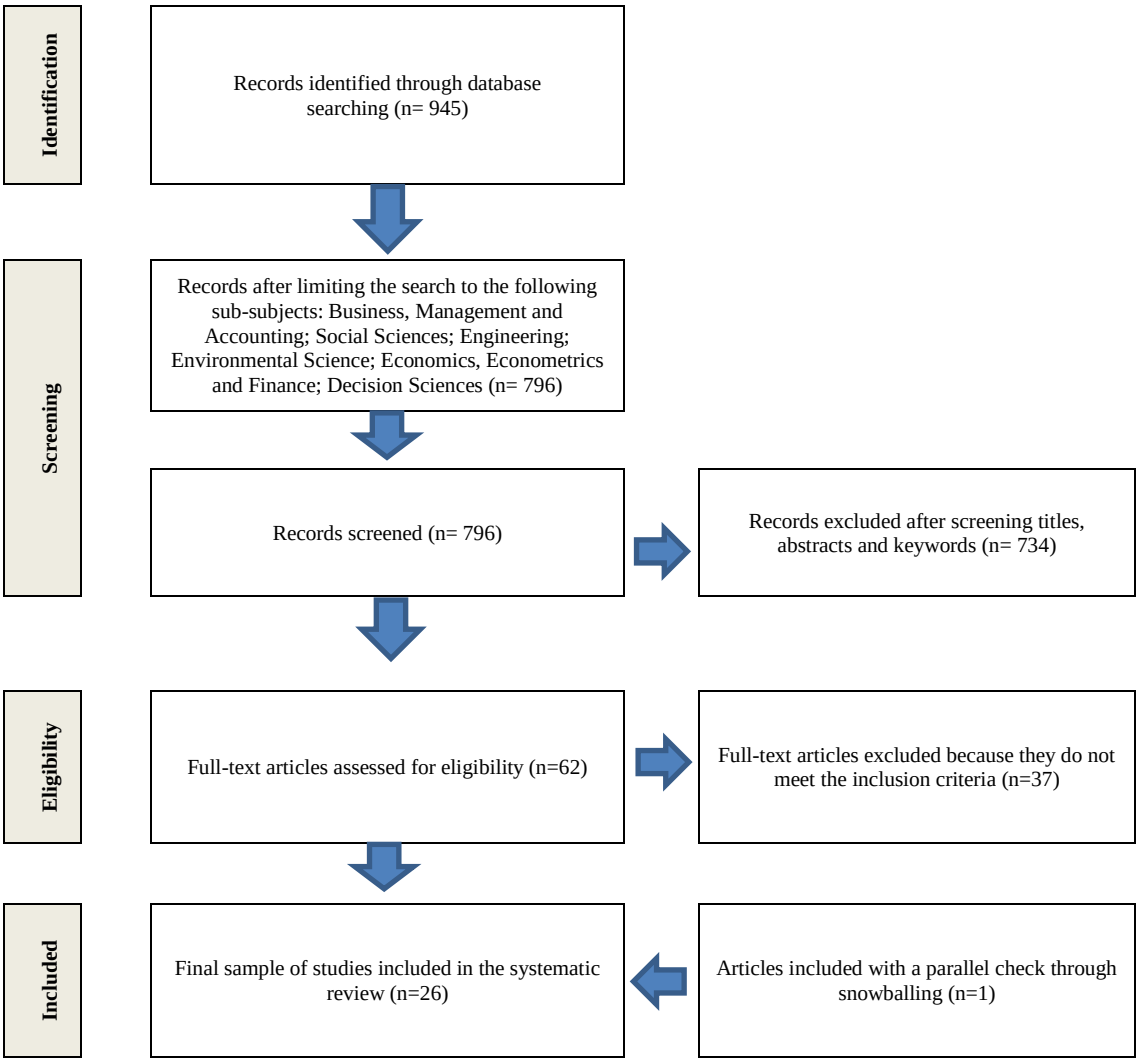
[9] Again, given the fact that the SCOPUS database employs a multi-subject attribute classification, the same paper might be classified in more than one subject.

[10] Among these are those articles that in the abstract: refer to adaptation cost connected to climate change or environmental waste; propose theoretical models without new empirical findings; report or analyze different measures of the perception magnitude of cost overruns and their determinants using survey of experimental data; employ only predictive or forecasting models in specific project assessments, including risk management and cost-benefit analysis; merely present a review of previous papers; etc..

[11] For a review of the economic implications of these contracts in transportation projects see Button (2016).

[12] Abstracts are read in parallel by two researchers, plus a third one in case of uncertainty.

Figure 3 – PRISMA flow diagram of the systematic literature review



Source: our elaboration

These papers are distributed according to the following sub-subjects: Business, Management and Accounting (31); Social Sciences (24); Engineering (21); Economics, Econometrics, and Finance (15); Decision Sciences (7); Environmental Science (5). Additionally, considering the journals in which they are published, we find a relatively broad dispersion but with the core of works being published in leading transportation journals[13].

[13] Considering only the journals with two or more publication, our database refers to the following distribution: Journal of Construction Engineering and Management (7); Transport Policy (7); International Journal of Project Management (5); Engineering Construction and Architectural Management (5); European Journal of Transport and Infrastructure Research

As a final assessment of our systematic review, we analyse in detail each paper. All the articles are read in parallel by two researchers, plus a third one in the case of uncertainty. Furthermore, since our formal protocol-driven search strategy and our choice of the SCOPUS database may fail to find important references on the topic, we implement a parallel check through snowballing, using the reference list in each paper and checking the citations by a generic search engine (i.e. Google Scholar). With this search, we are able to identify an additional paper that meets our inclusion criteria. Therefore, the papers selected for the subsequent phase of descriptive analysis are 26. Figure 3 reports the PRISMA flow diagram of our systematic review.

3. Results

3.1 General overview: evolution of the literature and main contributions

This section is devoted to describing the data included in the study sample. In the next Section, we provide a broader discussion of the contents and the empirical findings stemming from the papers in the sample. Descriptive statistics based on the sample data are presented to provide an initial overview of the analysed literature. Table 1 lists the journals included in our sample. The journals whose main focus is on transport issues (*i.e.* Transport Policy, Transport Reviews, Transportation Research A and B, Transport Planning and Technology and Journal of Transport Geography) are also those where the highest percentage of selected articles are published (46.2%). Interestingly, Table 1 shows that a relevant portion of the articles referring to cost overruns for transportation projects are published in journals with a broader scope related to either planning (26.9%) or economic (26.9%) issues.

Table 2 provides the rank of the leading journals in our sample, by subject field (i.e. with a focus on either transport or planning or economics) and according to the SCImago Journal Rank (SJR)[14]. As shown in the table, journals with a focus on

(3); Journal of Financial Management of Property and Construction (3); Journal of Management in Engineering (3); Transportation Research Part A Policy and Practice (2); Applied Economics (2); Journal of the American Planning Association (2); Transport Reviews (2).

[14] SJR is a size-independent indicator of journals' scientific prestige that ranks scholarly journals based on citation weighting schemes and eigenvector centrality. Within SJR, citations are weighted by the prestige of a journal. Subject field, quality, and reputation of

transport rank first in the list, indicating that for this category the topic concerning the determinants of cost overruns is a hot one. Furthermore, looking at the most cited papers in our sample (Table 3), with the only exception of the work by Bajari et al. (2014), all other works are published in journals with a focus on either transport or planning. Details regarding the 26 retrieved paper are provided in Table A.1 in the Appendix.

Table 1 - Main journals in terms of percentage of papers in the sample

Journals	**% papers in the sample**
Transport Policy (6)	23.1%
Transport Reviews (2)	7.7%
Transportation Research Part A Policy And Practice (1)	3.8%
Transportation Research Part B Methodological (1)	3.8%
Transport Planning and Technology (1)	3.8%
Journal of Transport Geography (1)	3.8%
% of articles in journals with a focus on transport	***46.2%***
Journal of Construction Engineering and Management (3)	11.5%
Australasian Journal of Construction Economics and Building (1)	3.8%
Journal of Management in Engineering (1)	3.8%
Journal of The American Planning Association (1)	3.8%
Environment and Planning B Planning and Design (1)	3.8%
% of articles in journals with a focus on planning	***26.9%***
Applied Economics (2)	7.7%
American Economic Review (1)	3.8%
Review of Industrial Organization (1)	3.8%
Economics Letters (1)	3.8%
European Journal of Political Economy (1)	3.8%
International Tax and Public Finance (1)	3.8%
% of articles in journals with a focus on economics	***26.9%***

Source: our elaboration on the SCOPUS database.
Note: Numbers in parentheses represent the papers in the sample

the journal have a direct effect on the value of a citation. For more information on Journal Metrics and the use of SJR, see: www.journalmetrics.com.

Table 2 – Sample journal ranking

Journals	**SCImago journal rank**
Journals with a focus on transport	
Transportation Research Part B Methodological	3.905
Transportation Research Part A Policy And Practice	1.810
Transport Reviews	1.635
Journal of Transport Geography	1.734
Transport Policy	1.347
Transport Planning and Technology	0.459
Journals with a focus on planning	
Journal of the American Planning Association	1.560
Journal of Construction Engineering and Management	1.219
Journal of Management in Engineering	1.060
Environment and Planning B Planning and Design	0.582
Australasian Journal of Construction Economics and Building	*n.a.*
Journals with a focus on economics	
American Economic Review	8.048
European Journal of Political Economy	0.956
International Tax and Public Finance	0.799
Review of Industrial Organization	0.526
Economics Letters	0.612
Applied Economics	0.441

Source: our elaboration on the SCOPUS database.

Table 3 – Most cited papers in terms of total citations (TC) and average citations per year (TC/years since publication).

Top 10 articles	**TC in SCOPUS**	**TC/year**
Flyvbjerg, B., Holm, M.S., Buhl, S. (2002)	476	34.0
Flyvbjerg, B., Skamris Holm, M.K., Buhl, S.L. (2004)	163	13.6
Odeck, J. (2004)	82	6.8
Flyvbjerg, B. (2007)	45	5.0
Creedy, G.D., Skitmore, M., Wong, J.K.W. (2010)	28	4.7
Bajari, P., Houghton, S., Tadelis, S. (2014)	21	10.5
Cantarelli, C.C., Molin, E.J.E., Van Wee, B., Flyvbjerg, B. (2012)	19	4.8
Cantarelli, C.C., Van Wee, B., Molin, E.J.E., Flyvbjerg, B. (2012)	18	4.5
Bhargava, A., Anastasopoulos, P.C., Labi, S., Sinha, K.C., Mannering, F.L. (2010)	16	2.7
Gkritza, K., Labi, S. (2008)	15	1.9
Top journals by article citations		
Journals with a focus on transport		
Transport Reviews (2)	164	6.9
Transport Policy (6)	128	4.5
Journals with a focus on planning		
Journal of The American Planning Association (1)	476	34.0
Journal of Construction Engineering and Management (3)	59	3.1
Journals with a focus on economics		
American Economic Review (1)	21	10.5
Applied Economics (2)	10	1.3

Source: our elaboration on SCOPUS database.
Note: Numbers in parentheses represent the papers in the sample.

In the next Section, we discuss the different definitions of cost overruns adopted in the papers of our sample while in the subsequent Section we analyse the methods employed to identify the main determinants of cost overruns.

3.2 On the definition of cost overruns

By reviewing the identified sample of empirical works on cost overruns in infrastructure provision, two issues are noteworthy: the definition of cost overruns and the identification of their determinant factors. In this Section, we try to look at each of these issues through the lens of either the applied economic or the construction engineering/managerial literature. The goal here is to bring out the main differences between the two strands of research. Starting from the consideration that there is neither unambiguous way nor international convention to refer to the

phenomenon, marked differences exist in the way cost overruns are defined and, hence, operationalized in the relevant literature. From a merely terminological point of view, the economic literature refers to cost overruns as "adaptation costs". Here, the focus is on the ex-post modification of the project's plans and specifications when the initial contract design is endogenously incomplete. The term has been used by Bajari et al. (2014), who define adaptation costs as "any costs that are incurred above and beyond the direct production costs of the project", whereas the direct production costs - the other source of the cost increases following a modification of the initial plan - are "the direct costs of the additional work". On a similar line, Guccio et al. (2012a: 1894) refer to adaptation costs as the cost of adapting post-award changes.

Furthermore, Bajari et al. (2014: 1294) make a distinction between "direct" and "indirect" adaptation costs. Direct adaptation costs are due to disruption of the initially planned work, which affects the contractual obligations, giving rise to disputes and, hence, increased legal costs. On the contrary, indirect adaptation costs are due to resources devoted to contract renegotiation and dispute resolution. Behind both these two typologies of adaptation costs, there is the contractual incompleteness that leads to adjustments, extra works and claims for deductions if work is not completed on time or if it fails to meet the agreed specifications.

Operationally, the above-defined adaptation costs are generally computed as the difference between actual, or final costs, and the contract costs as a ratio of the contract costs, whereas the latter are those representing the value of the winning bid (Guccio et al., 2012a; Iimi, 2013; Jung, 2016). Similarly, Decarolis and Palumbo (2015: 77) refer to price renegotiation (i.e., the extra cost of renegotiation) and compute it as "the percentage change of the final price paid to the contractor relative to the awarding price". Slightly differently, Bucciol et al. (2013: 37) define cost overruns as the difference between "the final price at the end of the works and the price winning the auction, as a ratio of the reserve price" (which could be different from the awarding price).

A different empirical strategy has been proposed by Guccio et al. (2012b). The authors argue that considering distinctly cost overruns and time delays does not allow evaluating the overall performance of the procurer in carrying out the contract. Hence, they propose the use of a benchmarking approach by defining a frontier

envelopment surface for all contracts in the sample, employing linear programming techniques (namely, Data Envelopment Analysis - Charnes et al. 1978). More specifically, Guccio et al. (2012b) assume that for the given targets of time and costs agreed in the contract; the best performers should be considered those that, *ceteris paribus*, minimise the actual time and costs[15].

Concerning the construction and engineering/managerial literature, though "cost overruns" is the term usually encountered, there is no commonly accepted point of reference from where this should be measured. The use of different reference points contributes to explain the existing significant variation in estimates of cost overruns in the transportation sector. In their studies, Flyvbjerg and his colleagues (Flyvbjerg et al. 2002 and 2004; Cantarelli et al., 2010b and 2012a,b,c) opt for a policy-centric approach, using the cost estimates that are approved at the time of the decision to realize the project. More specifically, they define cost overruns as "actual costs minus estimated costs in percent of estimated costs", where the actual costs are "real, accounted construction costs determined at the time of project completion" (Flyvbjerg et al., 2002: 281) while the estimated costs are those either budgeted or forecasted at the time of the ("formal" or "real") decision to build. Contrary to the previous literature, here the focus is on decision making, that is to say on the inaccuracy of early cost information at the time decision makers decide the budget allocation and give the go-ahead to build the project.

3.3 The determinants of cost overruns

Some relevant differences also exist in the way the two strands of literature analyse the determinants of cost overruns in the execution of transportation projects empirically. These divergences can be primarily traced back to the different theoretical approaches and perspectives used to investigate the issue of inefficiency in infrastructure provision, which is reflected in a not-always concordant definition

[15] Finocchiaro Castro et al., (2014) apply the approach proposed by Guccio et al. (2012b) to investigate the role of the quality of local environment on public contracts performance. They find that the characteristics of the local area where the public works are executed, as captured by different dimensions (such as, social capital and corruption), are significantly associated with the outcome in the execution of public works, even after controlling for all other relevant factors.

of cost overruns (see above) and often result in different conclusions. The approach followed by the economic literature leads back the cause of the inefficiency in the execution of projects to the critical elements of the procurement process in a context characterized by incomplete contracts, asymmetric information and lack of powered incentives (Estache et al., 2009).

Differently, the construction engineering/managerial literature seeks the determinants of cost overruns above all in the project organization and management, which is likely to determine the following problems: underestimation of project costs with respect to the project budget (underestimation problem); occurrence of unforeseen technical and environmental events (scope changes, technical reasons, characteristics of a given geographical area, etc.); specific features of the project (typology, size and projects), etc.

In the following, we analyze each of the two strands of literature with regard to the determinants of cost overruns, trying to highlight the main differences and similarities.

3.3.1 Applied economic literature

The applied economic literature on infrastructure provision is mainly focused on public procurement and includes several studies whose objective is to evaluate empirically the performance of public contracts execution with respect to cost overruns and/or time delays. Rooted in the theoretical assumptions of the incomplete contract theory (Hart and Holmstrom, 1987; Hart, 1995 and 2003; among others), this research strand pays attention to the characteristics of the procurement process, finding results consistent with the relationship between cost escalation and (i) bidder behaviour, (ii) auction formats and (iii) likelihood of contract renegotiation.

A part of this literature focuses on the strategic role of auctioneers in the procurement process. The room for ex-post opportunistic behaviors is assumed to depend on relevant factors such as the characteristics of bidding actors (e.g. the buyer's technical expertise on both the features of the work to be procured and the tendering organization and management), the degree of tendering competition, the characteristics of the procured work (mainly, its complexity) (Bajari et al., 2014;

Immi 2013). Indeed, if the contractual design is incomplete and the project is complex, an auction may lead to an adverse selection problem (Bajari et al., 2014). In such a situation, the bidder who is the most aware of the contractual blanks could benefit from a higher likelihood of being selected. By anticipating the advantages that could take from situations that are unforeseen in the contract, the bidder will not hesitate to propose an unrealistically low price. This type of bidding behaviour (known as a low-balling strategy) is expected to jeopardise the most important objective of tendering, that is to say, allocative efficiency. Analysing this problem and the related endogeneity issue with regard to the transport infrastructure procurement, Iimi (2013) assessed empirically that bidders are likely to anticipate ex-post contract adjustments and take advantage of the low-balling strategy, causing a vicious circle of low-balling and renegotiation that results in actual cost overruns and project delays.

The empirical work of Bajari et al. (2014) finds a relationship between opportunistic bidder behaviour and incomplete contract. They show that bidders respond strategically to contractual incompleteness and that adaptation costs are an important determinant of the observed bids. Moreover, they provide further evidence that adaptation costs are one of the drawbacks of the traditional competitive bidding system. These pieces of empirical evidence are consistent with the theoretical work of Bajari and Tadelis (2001), where it is argued that adaptation costs are a key determinant of contract forms and award mechanisms in private sector construction. The authors note that in the private sector, open competitive bidding for fixed-price contracts is not so frequent because it is perceived to create high adaptation costs.

As for the way auction design may affect cost overruns, Bucciol et al. (2013) consider a sample of small road and building maintenance public projects procured in the Italian Veneto region in the years between 2004 and 2006, when the regional law enabled procurers to choose the rules for the auction from a variety of different mechanisms in terms of format (i.e. first price or average bid format)[16] and entry

[16] Under an average bid auction mechanism (Iannou and Leu, 1993), the winning bid is the one closest to the average of all the bids, and the contractor receives its asked price. An average bid format is considered by the theoretical literature better suited to avoid the adverse selection problem arising in a first price auction when the contractor fails to meet its obligations and, hence, downloads on the procurer large cost overruns. However, when bidders collude, even an average bid auction may not prove to be effective in preventing adverse selection (Albano et al., 2006).

requirements (i.e. open to all qualified firms or restricted only to invited ones). They find that cost overruns are smaller under the Italian average bid format, but only when this format is combined with restricted entry.

Some authors investigate the relationship between cost overruns and the renegotiation of the contract. Among these, Bajari et al. (2014) try to estimate the ex-post adaptation costs resulting from incomplete contracts. After developing a stylized model to incorporate expected changes in payments and adaptation costs into the bids ex-ante, they apply the theoretical framework to a panel dataset of highway procurement in the state of California. They find that adaptation and changes are the major determinants of bid costs in the construction industry and relevant potential sources of inefficiency. Differently, from the previous literature, they also reach the conclusion that adaptation costs (both direct and indirect) seem to impose more distortions and frictions than rents from private information and market power, and unbalanced (strategically skewed) bidding: adaptation costs account for 7.5-14% of the winning bid. Moreover, they find that the contractual incompleteness that leads to adjustments, extra work, and deductions are positively correlated with the direct costs from disrupting the normal flow of work (i.e., direct adaptation costs) and the indirect costs of renegotiation (i.e. indirect adaptation costs).

Based on these findings, in a quite complementary work Jung (2016) examines the direct effects of incomplete contracts (i.e., contracts requiring upon completion extra originally unspecified work) on procurement costs. He considers a dataset of road construction projects procured by the Vermont Agency of Transportation in the period 2004-2009. The results show that there is a significant cost difference between projects that are renegotiated for extra work and those that are not. Following Iimi et al. (2014), renegotiation imposes various transaction costs, among which are adaptation costs due to legal disputes over ex-post extra-work and workflow disruptions. In line with the abovementioned studies, DeCarolis and Palumbo (2015) empirically test the effect of design and build (D&B) contracts on time and cost renegotiations. Using a dataset of contracts for public works (including roads) awarded in Italy between 2000 and 2007, the authors find that the use of D&B contracts causes greater cost renegotiations but cost overruns decrease when the design is externalized to a third party. Renegotiations are economically relevant,

averaging to about 6% for prices and 70% for delay, though the two measures are nearly uncorrelated.

3.3.2 Construction engineering/managerial literature

Though sharing the same overall technical approach in the investigation of the determinants of cost overruns, the construction engineering/managerial literature presents a quite heterogeneous panorama regarding empirical results. These differences are due to factors such as the study context, the type of analysis and the applied methodology. However, as previously mentioned, the main reason behind the not always overlapping results lays in a different way to actually measure cost overruns, more specifically in a non-coherent identification of the reference time point at which to calculate the estimated costs.

In the studies by Cantarelli et al. (2012a) and Cantarelli et al. (2012c) some considerations are presented about the differences of results within this strand of literature. The provided explanations include differences in:

- the use of the time of the formal decision to build and the actual opening year as the basis for the estimated and actual costs, respectively;
- the use of either nominal or real prices;
- the way to handle data;
- the sample size;
- the geographical area, linked to different economies;
- the project type, namely complexity, and management.

By focusing on the divergence between estimated (forecasted) and actual costs, the construction engineering/managerial literature generally identifies in the former one of the main sources of project cost escalation. They agree that cost estimates represent a significant parameter of a project, being the basis for cost control during project delivery and, above all, the driving force of project achievement. Notwithstanding, planners tend to underestimate the costs in the first phases of the project life-cycle, thus resulting in inaccurate cost forecasts and potential biases. Indeed, cost underestimation and deception in decision making for transportation

infrastructure is the objective of a body of researchers aiming at understanding the practices used to decide whether such projects should be built or not (Flyvbjerg et al., 2002). Regarding project size as a potential determinant of cost overruns, Odeck (2004) and Cantarelli et al. (2012a) reach different conclusions. In particular, by investigating Norwegian road projects, the former author shows that cost overruns are more predominant among smaller projects than larger ones.

Other studies indicate that often project sponsors routinely ignore, hide, or otherwise leave out significant project costs and risks to make total costs appear low and, hence, to obtain the support by taxpayers for the approval (a 'salami' strategy) (Flyvbjerg, 2005). Similarly, project promoters may also introduce potential risks in a different moment of project realisation so as to make costs appear low as long as possible (Flyvbjerg et al., 2002). Possible explanations for this deliberate intention to underestimate costs are grouped in: (1) technical, (2) economic, (3) psychological, and (4) political (Cantarelli et al. 2010a).

As far as technical reasons are concerned, a degree of uncertainty exists when designing a project because of unforeseen events that could occur during the execution of the work. Therefore, adaptation costs may be due to technical reasons (factual errors, not deliberately made) such as price rises, scope changes, poor project design and implementation, and rough estimations.

However, cost underestimation is not always the result of honest behaviour. From a self-interest point of view, as long as a project goes forward, it creates work for engineers and construction firms, and many stakeholders are likely to increase their earnings. From a public interest point of view, project promoters and forecasters may deliberately underestimate costs in order to incentivise public officials to cut costs and, hence, to save on public resources (Flyvbjerg et al., 2002). In the case of public works, underestimating the costs of a given project is likely to result in an artificially high benefit-cost ratio for that project. This not only gives way to a project despite the fact that is not economically viable but also divert resources from alternative projects that would have yielded higher returns had the actual costs of both projects been known.

Psychological explanations can also be provided to explain biases in forecasts. One of these is the so-called "optimism bias", which leads project promoters and forecasters to underestimate project costs, due to the tendency to exaggerate their

own talents concerning the degree of control over events during the project design. As a result, they make decisions based on delusional optimism rather than on a rational weighing of gains, losses, and probabilities (Lovallo and Kahneman, 2003). In short, they overestimate benefits and underestimate costs.

With regard to the political explanations, an optimistic design of a work may represent an instrument for changing priorities across different projects, for producing short-term political benefits - as arising from the possibility of increasing the number of public works to be started - even if, in the medium-long term, they will be delayed or even not completed, because of financial problems.

Few studies try to test this political behaviour, interpreting the effect of overestimating the net benefits of projects in terms of lying (Flyvbjerg et al., 2002). Indeed, real difficulties exist in investigating the role of political/psychological factors on cost overruns empirically. This fact is well summarized in Table A.1, where technical explanations are among the most investigated determinants of cost overruns for transportation projects while empirical analyses accounting for psychological and political-economic reasons are less frequent.

More recent surveys find other aspects that may influence cost overruns. By investigating the occurrence of unforeseen technical and environmental events, Verweij et al. (2015) focus on the relationship between cost overruns and contract changes. They find that scope changes and technical necessities are the most significant reasons for contract changes in transportation infrastructure projects. Moreover, smaller projects are found to have higher relative contract change costs, especially those due to omissions in the contract. Even the geographical area could play a role in cost overruns. The study by Canterelli et al. (2012a) tests this relationship. They outline that geographical location matters for project performance, to a varying degree according to project type.

In the construction engineering/managerial literature on cost overruns, few studies have considered the relationship between cost overruns and the different project phases. In this respect, they are apparently quite close to the applied economic studies, though the former neglect to investigate the nature of the procurement process. Among these, Odeck (2004), first, and Cantarelli et al. (2012a), later, study at which stage/es projects are more vulnerable to cost increases. Between the initial forecasted budget of construction costs and the start of construction, several

estimates are made and refined before the final approval. Odeck (2004) thus suggests that the reference point for determining a cost overrun should be at the detailed planning stage where design, specification, and final cost are determined. Cantarelli et al. (2012b) make a distinction between preconstruction phase (the period between the formal decision to build and the start of construction) and construction phase (the period between the start of construction and the start of operation "opening"). Summing up, the authors show that the frequency - as well as the magnitude - of cost overruns in pre-construction phase are significantly higher than in the construction phase, as project plans become more detailed and costs can be better estimated over time.

4. A unified picture of the determinants of cost overruns

To provide a more in-depth picture of the determinants of cost overruns in our literature sample, the data of the 26 papers were collected in a spreadsheet indicating information on the category of determinants and variables used as a proxy to find them. Further, we divided the reviewed papers into two categories on the basis of two strands of literature: economic literature and construction engineering-managerial literature.

In the following step, we categorized the determinants in ten items regards the relative specific areas (i.e. bidding process, elements of contract, work, regulations, characteristics of the project, environmental factors, political-economic factors, technical reasons, psychological factors, behavioural factors). Given the huge number of variables involved in the empirical studies, to obtain an easily managed of the determinants, we operationalize them using the corresponding code of study. Thus, the results consist to collocate the different variables used as a proxy for the determinants using the code of the relative paper. The code of identification corresponds to the ID number in the table A.1 in the Appendix A.

Our systematic literature review revealed a great variety of determinants and the variables used for their operationalisation. Many studies used several variables to identify one determinant. In such case, the identification code was repeated for some times equal to the number of variables involved.

To assess the impact of the evidence of each reviewed study, we considered the non-marked operationalisation to record a positive effect of the variables on cost overruns and used a negative sign (-) to represent no impacts on cost overruns.

As reported in Table B.1 in Appendix B, from the systematic analysis of the 26 paper, we recorded 125 occurrences of variables to proxy 24 type of determinants grouped into 10 categories. The number of determinants investigated from each study was contained between a minimum of one and a maximum of nine with on average a number of three.

The two strands of literature focus on the determinants of cost overruns in different ways. The distribution of occurrences reflects the different approach used from the two literature. The applied economic studies reviewed pay more attention to public procurement aspects individuating 8 determinants using 56 variables. The managerial studies find 16 determinants that regard the specifics of the project and other factor linked to manager behaviour and management of the project using 69 variables. This can suggest that economic studies are focused on a little number of determinants investigated more in deeply. The managerial studies, instead, use a large number of determinants, focusing their attention on the project. The main determinants are the "Strategical/Opportunistic bidder behaviour" and the "Complexity of work" indicated by 9 studies. The more investigated managerial determinants are the Type of project indicated by 11 studies, followed by the issue of Underestimation of cost with 10 studies. The category "Characteristic of the project" is most investigated and mainly from construction engineering-managerial literature.

The point of contact of the two strands of literature are represented by the partial overlapped of the interest for "Type and Size of project", "Characteristic of work", "Change orders – Scope change and Complexity of work". Conversely, other determinants seem more specific of each approach.

5. Concluding remarks

This study synthesised a large and diverse body of literature analysing the determinants of cost overruns in infrastructure provision. Our systematic review focused on those studies that not only report the magnitude of cost overruns but attempt to investigate the underlying causes empirically. As for the time span of our

analysis, we limit the reviewed literature to that published since the year 2000. Of the 945 articles retrieved, 26 articles met our inclusion criteria. In our review we described the different empirical approaches, provide a classification for the determinants employed in the analyses and summarise their impact on cost overruns.

Not surprisingly, a large body of identified studies are published on transportation and managerial/planning journals. However, we find a significant and increasing attention also in applied economics journal.

We find relevant differences in the two approaches both in the definition of cost overruns and in the identification of their determinant factors. Furthermore, our review provides a succinct guide to the various determinants of cost overruns and their operationalisation using different variables as a proxy.

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Appendix A

Table A.1 – Details of the selected studies on the determinants of cost overruns in transport infrastructure provision

ID	Author (year)	Country/ies	Sample	Objective	Methodology	Definition of cost overrun	Results/conclusions
1	Bajari et. al. (2014)	California-U.S.A.	819 highway paving projects with a total awarded value of $2.21 billion; a total of 3,661 bids submitted by 349 general contractors, procured by Caltrans from 1999 through 2005.	To measure the economic costs of ex-post adaptations that result from incomplete contracts which force the buyer and supplier to negotiate adaptations both to the scope of work and to compensation and which may result in considerable discrepancies between the winning bid and the final payment.	Reduced form regressions and a structural empirical model with a semiparametric estimation method.	Adaptation costs are all costs that are incurred above and beyond the direct production costs of the project. Distinguishing between two kinds of adaptation costs: • *direct adaptation costs*, due to changes that disrupt the initially planned work; • *indirect adaptation costs*, due to resources devoted to contract renegotiation and dispute resolution.	Renegotiation imposes significant adaptation costs and shows that adaptation costs account for 7.5–14% of the winning bid. Reduced form regressions suggest that bidders respond strategically to contractual incompleteness and that adaptation costs are an important determinant of their bids and a significant potential source of inefficiency.
2	Bhargava et al. (2010)	Indiana (US)	1,862 highway projects implemented from 1995 to 2001 by the Indiana Department of Transportation.	To investigate the factors affecting time delay and cost overrun against the background of their simultaneous relationship overruns	Three-stage least-squares regression analysis	Difference between the as-built project cost and the winning bid amount	Evidence of a simultaneous relationship between cost overruns and time delays. The contract size, project duration, expected weather conditions, and results of the contract bidding process are some of the factors that are found to be statistically significant in the models. However, the strength of these relationships varies by project type.
3	Bucciol et al. (2013)	Italy	Fixed reserve price contracts up to one million euros, held in the Italian Veneto region between the years 2004 and 2006 and completed by the end of March 2009, procured by Italian Observatory for Public Contracts. Mainly regarding road works (40%) and building maintenance (29%).	To study the correlation between the cost overrun and some features of the auction format and entry mechanism.	Non-parametric tests and Heckman regression.	Difference between the final price at the end of the works and the price winning the auction, as a ratio to the reserve price.	Cost overruns are smaller under the Italian average bid format, but only when this format is combined with restricted entry.
4	Cantarelli et al. (2012a)	17 countries plus 2	78 large-scale (> € 20 million) transport	To establish the extent to which	Descriptive statistics; non-parametric tests;	Divergence between estimated at the time of decision and the costs at	Geographical location matters for project performance, to a varying degree according to

		categories (South Europe and other developing countries)	infrastructure projects completed after the year 1980. 728 international projects	project cost performance differs with geographical location.	simple linear regression analysis	the actual opening year (i.e. year in which operations begin)	project type. As geography often relates to other characteristics like the decision-making style, the system of governance, and the culture in countries, it may indicate whether and which of these factors may play a role in project performance between countries.
5	Cantarelli et al. (2012c)	The Netherlands	78 large-scale (> € 20 million) transport infrastructure projects completed after the year 1980	To investigate whether project type, project size and the implementation phase are relevant for the variance in cost overruns and whether these variables can explain the differences in cost performance between Dutch projects and other worldwide findings	Descriptive statistics; non-parametric tests; simple linear regression analysis	Divergence between estimated (i.e. budgeted, or forecasted, construction costs at the time of formal decision to build) and actual (i.e. real, accounted construction costs determined at the time of project completion) costs	Project type matters in explaining cost overruns: road projects are particularly vulnerable. Small projects have the largest average percentage cost overruns but, in terms of total overrun, large projects have a larger share. The length of the implementation phase and especially the length of the pre-construction phase are important determinants of cost overruns. Political-economic explanations seem the most likely. Determinants for cost overruns in the Netherlands differ from worldwide findings.
6	Cantarelli et al. (2010b)	The Netherlands	Two railway projects: the Betuweroute and the the HSL-South	To empirically investigate whether lock in has actually taken place in a project and, if it has, whether it has influenced the performance of the project	Case study analyses	Divergence between estimated (i.e. budgeted, or forecasted, construction costs at the time of either 'formal' or 'real' decision to build) and actual (i.e. real, accounted construction costs determined at the time of project completion) costs	Lock in can appear at both the decision making and the project levels, and it can lead to cost overruns through methodology and practice
7	Chong and Hopkins (2016)	13 developing countries: Burkina Faso, Cape Verde, El Salvador, etc.	48 completed MCC's road construction projects whose funds were authorized between 2005 and 2010.	To quantify cost evolution in MCC road construction, analyse causes of cost evolution, and identify targeted interventions to minimize variability in international development donor road projects	Descriptive statistics and simple linear regression analyses	Divergence between either funding authorization (FA) or engineer's (EE) estimates and final cost (FC)	Mean increase between FA and FC = 135%. Most uncertainty during the design phase: mean increase between FA and EE ~ 100%. Compact signing date, competitive bidding strategies, road length (project size), and design-works variation matter in explaining cost changes. Evidence of underestimation of FA estimates and contractor underbidding
8	Creedy et al. (2010)	Queensland (US)	231 highway projects published in the Roads Implementation Program documents of the Queensland Department of Main Roads over the	to identify the factors that influence significant project cost overruns for the owner and to propose an analytical model	Descriptive analysis, factor analysis, expert elicitation, nominal group technique, stepwise multivariate regression analysis,	Difference between the owner's actual project cost and programmed cost	Of particular concern for cost overruns are changes in project designs and scope changes during project development. Among the various explanatory factors considered (project type, indexed cost, geographic location, project delivery method, etc.), the

			financial years from 1995–1996 to 2002–2003	that correlates project attributes to the level of their cost overruns and owner project risks relating to decision-to-build budgets			regression analysis shows a weak correlation between the size of highway projects, as measured in the indexed programmed cost and the size of cost overruns.
9	Decarolis and Palumbo (2015)	Italy	All contracts awarded between 2000 and 2007 and completed by August 2011 provided by Italian Authority for Public Contracts.	To study price and time renegotiations and a causal analysis of the effect of D&B contract on the renegotiation.	A graphical and a regression-based approach.	Extra cost of renegotiation: the percentage change of the final price paid to the contractor relative to the awarding price.	The results show that price renegotiations are larger than 5% involve 46% of the contracts, while time renegotiations larger than 5% involve 83% of the contracts. Renegotiations are economically relevant averaging around 6% for prices and 70% for time. Moreover, correlations of opposite sign result: • the reserve price might be negatively associated with extra time because penalties for delays are proportional to the contract value. • Its positive association with price renegotiations can be explain because of more appealing for contractors to renegotiate larger contracts. About the relationship between Design & build contracts (D&B) and renegotiation: • D&B contract causes greater cost renegotiations; Cost overruns decrease when the design is externalized to a third party relative to D&B contract.
10	Eliasson and Fosgerau (2013)	Sweden	461 road and rail investments that competed for inclusion in the Swedish transport investment plan 2010-2021	To investigate whether cost overruns and demand shortfalls are due to misrepresentation (i.e. deception) or selection	Simulations	Divergence between estimated and actual costs	Bias in cost underestimation may arise simply as a 'selection bias', without there being any bias at all in predictions ex ante. Such a selection bias is bound to arise whenever ex ante predictions are related to the decisions whether to implement projects.
11	Finocchiaro et al. (2014)	Italy	3,113 interventions for roads and highways, whose engineering estimated costs range from 150,000 euros to 5 million euros, awarded in the period 2000-2004 and completed by 2005 in	To benchmark the efficiency of public work contracts' execution in order to evaluate the effects of environmental factors on the performance in infrastructure	Nonparametric estimation method (DEA) and parametric method (SFA).	Based on benchmarking approach defined by Guccio et al. (2012a and b)	The empirical analyses show that lower efficiency in public contracts execution is associated with greater corruption in the area where the infrastructure provision is localised.

			Italy.	provision. The authors investigate the association between the efficiency of infrastructure provision and the level of corruption.			
12	Flyvbjerg (2007)	20 nations and 5 continents (Europe, North America and other)	258 high-speed rail and conventional rail, bridge, tunnel and road projects	To assess economic risks in terms of cost and revenue in urban rail projects.	Descriptive statistics, analysis of variance and non-parametric tests.	Divergence between forecasted construction costs at the time of decision to build and actual costs.	No significant difference for cost escalation between high-speed rail and ordinary rail, which is very large. This combined with high standard deviation led to a high level of uncertainty and risk regarding forecasts of costs. Type of project and error of underestimating costs affect cost escalation.
13	Flyvbjerg et al. (2004)	20 nations and 5 continents (Europe, North America and other)	258 rail, bridge, tunnel and road projects	To test whether cost escalation is affected by: 1) length of the project-implementation phase; 2) size of the project; 3) type of the project ownership	Simple linear regression analysis	Divergence between forecasted construction costs at the time of decision to build and actual costs	Cost escalation was strongly dependent on the length of the implementation phase. For bridges and tunnels, larger projects have larger percentage of cost escalation. The data do not support the oft-seen claim that public ownership is problematic per se and private ownership is a main source of efficiency in curbing cost escalation. The type of accountability matters more to cost escalation than type of ownership.
14	Flyvbjerg et al. (2002)	20 nations and 5 continents (Europe, North America and other)	258 rail, bridge, tunnel and road projects	To examine four kinds of explanation of cost underestimation: technical, economic, psychological, and political	Descriptive statistics and non-parametric tests	Divergence between estimated (defined as budgeted, or forecasted, construction costs at the time of decision to build) and actual costs	Cost underestimation cannot be explained by error and is best explained by strategic misrepresentation, i.e., lying
15	Gamez and Touran (2010)	Over 60 developing countries	A sample 89 and a subset of 65 transportation projects sponsored by the World Bank	To develop a better understanding of the performance of these large infrastructure projects in developing countries.	Descriptive statistics, analysis of variance, simple linear regression analysis	Difference between actual and budgeted (defined as the original estimate or forecast at the time of decision to build a project) costs	No evidence of either systematic underestimation of costs or learning effect. Project duration does not affect the performance with respect to cost and delay.
16	Gkritza and Labi (2008)	Indiana (US)	1,957 project contracts distributed at various locations across the six highway administration districts in Indiana over the period 1996-2001	To investigate the frequency and magnitude of the problem of cost discrepancies on the basis of key	Multistep econometric approach	Difference between the as-built project cost final amount and the contract award amount.	Contract award amount and specified contract period are influential factors of cost overruns. A nonlinear relationship is found between the cost overrun amount and the contract award amount. For relatively small projects (up to $6 million in contract award Amount), increasing

				characteristics of the bidding process, project, and the environment			contract award amounts lead to decreasing cost overruns while for relatively large projects (over $6 million increasing contract award amounts) lead to increasing cost overruns.
17	Guccio et al. (2012a)	Italy	3,113 interventions for roads and highways, whose engineering estimated costs range from 150,000 euros to 5 million euros, awarded in the period 2000-2004 and completed by 2005 in Italy.	To develop a notion of efficiency in the execution of public works, based on the adherence to the financial and time obligations set out in the public work contract. It is exploratory attempt to model and estimate the technical efficiency of public work execution using DEA.	Data Envelopment Analysis (DEA)-nonparametric estimation method.	Cost overruns are the additional costs incurred by contracting authorities above those agreed on in the contract.	The results show that the efficiency of execution of public works for roads and highways was relatively high in Italy, in the period 2000-2005. Moreover, these results show that the performance is relatively independent of the value of the reserve price and of the type of work (maintenance or new works).
18	Guccio et al. (2012b)	Italy	9,888 public works awarded in the period 2000 to 2004 and completed by 2005, whose costs range from 150 000 euros to 5 million euros, procured by Italian Observatory for Public Contracts.	To test empirically the determinants of adaptation costs in the Italian public works market focused on the main results reached in the literature.	Tobit model and its estimate through maximum likelihood methods.	The cost of adapting post-award changes, namely the difference between actual or final costs and the contract costs as a ratio of the contract costs, where the contract costs are those representing the value of the winning bid.	The main drivers of adaptation costs, as recognized in the literature, also seem to be relevant to explain this phenomenon in the Italian public works market: • complexity of the project; • opportunistic behavior of bidders; • optimism bias.
19	Iimi (2013)	Nepal	155 rural road contracts whose works started after 2005 and completed before June 2010, collected from 19 districts of Nepal.	To analyse the endogeneity issue between the low-balling bid strategy and ex post adjustments.	The three-stage least squares (3SLS) estimation model and the Hausman exogeneity test.	Cost overruns are the amount of actual payment divided by the original contract amount.	The empirical results confirm that endogeneity exists. Bidders are likely to anticipate ex post contract adjustments and take advantage of the low-balling strategy, causing actual cost overruns and project delays.
20	Jung (2016)	Vermont-USA	Road construction projects procured by the Vermont Agency of Transportation (VTrans) from May 2004 through December 2009.	To investigate the impact of incomplete contracts on procurement costs in road construction auctions.	Descriptive statistics and nonparametric estimation methods.	Adaptation cost as the difference between final costs paid by VTrans and the bid for an auction as a ratio of the bid for an auction, using only the contracts with extra work adjustment.	There is a significant cost difference between projects that are renegotiated for extra work and projects that are not renegotiated. Furthermore, the results show that renegotiations for unforeseen factors have no effects on bidder's profit margin with markups not statistically different. The explanation of adaptation costs is rely on legal disputes over ex post extra work and on workflow disruptions.

21	Mahamid and Bruland (2012)	Palestine	169 road construction projects awarded in the West Bank in Palestine over the years 2004-2008	To reveal the magnitude and direction of cost deviation. To address the relation between the cost deviation and the project size (i.e. road length and road width)	Descriptive statistics; simple linear regression analysis	Divergence between estimated and actual costs	76% of projects have cost under-estimates and 24% have cost over-estimates. The deviation between estimated and actual cost has an average of 14.6%, ranging from -39.3% to 98%. A very weak relationship is found between cost deviation and project size (i.e. road length and road width)
22	Makovšek (2014)	Slovenia	36 major road projects completed between 1995 and 2007	To focus on the dynamics of cost performance and its relation with the cost estimation mechanism	Descriptive statistics; simple linear regression analysis	As in Flyvbjerg et al. (2002), divergence between estimated (defined as budgeted, or forecasted, construction costs at the time of decision to build) and actual costs	Cost estimation accuracy is dependent on past unit price movements and on the strategic behavior of bidders. This will cause systematic cost overruns even in the absence of deliberate underestimation
23	Odeck(2014)	Norway	1,045 transport projects over the period 1993-2007	To investigate the impact on cost overruns of reforming the agencies in charge of controlling the project's execution	Descriptive statistics; non-parametric tests; Linear regression analysis	Divergence between detailed plan estimates (i.e. the final cost estimates presented to the decision-makers at the time of the decision) and actual costs	The 1996 first reform that separated planning and construction into two different departments did not improve costs overruns. On the contrary, the pro-competitive 2003 second reform that encompassed the separation and privatization of construction work led to a consistent improvement in the cost estimates and construction time, decreasing both cost and schedule overruns
24	Odeck (2004)	Norway	620 road construction projects completed in the period 1992–1995	To investigate the relationship between cost overrun and other factors such as completion time, size of estimated cost and regions where projects are situated	Linear regression analysis	Divergence between estimated and actual costs	Overruns are more predominant among smaller projects. Other factors found to influence the size of cost overruns include completion time of the projects and the regions where projects are situated. Surprisingly, neither project type nor work force type seems to influence the level of cost overrun.
25	Shrestha et al. (2013)	Nevada (United States)	363 Clark County Department of Public Works (CCDPW) projects constructed from 1991 to 2008	To determine whether construction cost and schedule overruns significantly vary based on types and sizes of the projects.	One-factor ANOVA	Divergence between award and actual construction costs	Cost and schedule overruns increased as the project size and construction duration increased. Possible explanations for these findings rely on major complexity and greater chance of disruption in the project, respectively.
26	Verweij et al. (2015)	The Netherlands.	45 transportation infrastructure projects with a total construction contract value of over € 8.5 billion procured by the Rijkswaterstaat.	To investigate: 1) whether there is a relation between lower bids by contractors and the size of contract changes; 2) what are	Descriptive statistics and non-parametric tests	Contract change costs	Scope changes and technical necessities as the most significant reason for contract changes. Smaller projects tend to have higher relative contract change costs (especially those due to omissions in the contract)

				the sizes of and reasons for contract changes in transportation infrastructure projects			

Source: our elaboration on the SCOPUS database

Appendix B

Table B.1

The cost overruns determinants according to the economic and engineering/managerial literature reviewed in the paper

Categories of determinants	Determinants	Operationalization	Economic literature	Construction engineering/managerial literature
Bidding Process	Strategical/Opportunistic bidder behaviour	Auction format, value of winning bid, rebate of winning bid, second winning, backlogs, legal disputes, number of contract with renegotiation and without renegotiation, number of contract awarded to firm, number of contract awarded to a firm by the same contracting authority, number of contract change, numbers of the days to prepare the bid, value of the contract changes after the closure of the construction contract, number of the contract changes due to scope changes, value of the contract changes due to scope changes, renegotiation cost, final contract cost	1, 1, 1, 1, 1, 9, 9, 11, 11, 11, 11,18, 18, 18, 18, 18, 19, 19, 19, 3, 3, 17, 20, 20, 26, 26, 26, 26, 26	2, 7, 16, 16, 22, 21
	Level of competition	Number of firms, number of bidders, number of wins, number of bids submitted, firm size, distance of competitor	1, 1, 1, 1, 1, 1, 1, 18, 3, 11, 20, 19	2, 7, 16, 16
Elements of Contract	Complexity of work	Reserve price, contract award, engineer's estimate, type of contract, contract duration, signing date (year), presence of subcontractors, type of contracting authorities, final project design, number of days required to award a contract after bid opening, number of omission in the contract, value of the contract changes due to omission in the contract	1, 3, 3, 3, 9, 9, 9, 11, 11, 11, 11, 17(-), 18, 18, 18, 18, 18, 18, 19, 19, 19, 19, 20, 20, 26, 26	2, 7, 7, 16, 16, 16, 16, 25, 24
Work	Disruption the originally planned work	Number of contract extra work, number of contract with work cancelled, number of extra work, extra work amount, number of the contract changes due to technically necessary changes, value of the contract changes due to technically necessary changes	1, 19, 19, 20, 26, 26	7
	Characteristic of work	Value of project, type of work (new or maintenance), distance to job site, work force, elevation of work site	1, 9, 11, 17, 20, 20	5, 2, 16, 24
	Security	Number of security incidents before each auction and during the project implementation	19, 19	
Regulations	Local reform and law	Reform on market (monopolistic, semi-monopolistic or full competition), the number of the contract changes due to changes in laws and regulations, the value of the contract changes due to changes in laws and regulations	26, 26	23, 23, 23
	Index costs	indexed project programmed cost, price escalation		8, 21, 22,
Characteristics of project	Type of project	Rail, urban rail, high-speed rail, ordinary rail, bridge, tunnel, highways, road projects, traffic, asphalt	1, 20, 20, 18, 18, 26, 26, 26	2, 4, 4, 4, 4, 5, 5, 5, 5, 8, 14, 14, 14, 14, 12, 12, 12, 12, 12, 13, 13, 13, 13, 21, 16, 16, 16, 24(-),24, 24, 23, 23, 23

	Size of project	Value of project, estimated cost, contract value, length of road (km), width of road, length of bridge¸ length of tunnel, quantity of bitumen and cement, class of estimated cost	19, 19, 19, 26, 17, 11	5, 7, 8(-), 13, 15, 21, 21, 22(-), 23, 25, 24, 24, 24
	Project duration	Days, months, years	19	2, 15(-), 24, 23, 25
	Length of project phases	Months, years		5, 13
	Change orders – Scope change	Extra work, extra quantities of materials, % of projects represented, cost of services relocation	1, 20, 19, 26	4, 7, 8, 15
	Design project, technical studies	Technical documentation, cost of design, property acquisitions, management costs, % of projects represented, deficient documentation, insufficient investigations and latent conditions, constructability, external design	26, 9	7, 8, 8, 8, 25
	Risks	Contractor risk		8
	Project ownership	Private, state-owned enterprise and other public ownership		13 (-), 13 (-), 13 (-)
Environmental factors	Geographical positions	Country, region	11	4, 8, 14, 13, 24, 23
	Weather conditions	% Adverse weather days, wet weather effects, amount of cumulative precipitation (mm), proportion of cold days, rainy days, snow days, days with snow on the ground and of inclement days, work during rainy seasons	19	2, 8, 16, 16, 16, 16, 16
	Environmental corruption	Index of corruption, number of crimes against public administration	11, 11, 18	
Political-economic factors	Strategic misrepresentation	Forecasted costs at the decision to build, actual cost-final construction cost		4, 4, 5, 5, 14, 22, 22
Technical reasons	Underestimation of costs	Forecasted costs at the decision to build, actual cost-final construction cost, funding authorization, budget		4, 4, 5 (-), 5 (-), 7, 12, 12, 14, 14, 15(-),15, 22, 22, 21, 24, 24, 23, 23
Psychological factors	Optimism bias	Forecasted costs at the decision to build, actual cost-final construction cost	18	4, 4, 5 (-), 5(-), 14, 14, 22, 22
Behavioural factors	Selection bias	Estimated and actual costs		10, 10
	Lock-in	Sunk costs, escalating commitment, need for justification, inflexibility, and closure of alternatives		6, 6, 6, 6, 6

Notes: The references to the coded studies are provided in Table A.1 in the Appendix A. Multiple references represent multiple operationalizations of the same determinant in a study.
Source: our elaboration

Chapter 2

On the magnitude of cost overruns throughout the project life-cycle: An assessment for the Italian public works contracts

Abstract

By considering project performance along the various phases of the project life-cycle, this paper aims to fill a gap in the literature on cost overruns and project management in Italy. Employing a large dataset of Italian transport infrastructure projects for roads, started and completed during the period 2000-2013, it applies the same methodology used by the construction management research regarding project types and phases. More specifically, the research goal is to assess the generating process of the magnitude of cost overruns in the sample, trying to evaluate the role of cost evolution by project phase distinguish between the costs of physical execution and the other costs. The findings show that contracting authorities seem to overestimate the extent of the final costs systematically. This behaviour was more important in term of financial coverage. The results can be relevant to explain the cost overruns in the execution stage suggesting the adoption of more stringent rules in budgeting and financial coverage of the projects.

Keywords: Cost overruns; project life-cycle; transport infrastructure; Italy

JEL Classification: H4, R4; D8

1. Introduction

Several studies have investigated cost overrun for infrastructure projects in several countries (e.g., among the others: Flyvbjerg et al., 2002; Bordat et al., 2004; Odeck, 2004; Cantarelli et al., 2012a,b,c; Odeck et al., 2015; Verweij et al., 2015; Chong and Hopkins, 2016).

Though facing the issue from different perspectives and with different scopes and methodologies, most of the empirical literature share a common aspect: it mainly focuses on cost overrun in the execution phase of the project, thus neglecting what happens throughout the entire life-cycle of it. The rationale behind this choice can be traced back to the larger availability of data but also to the greater attention paid by the economic studies to the performance of the contract rather than to the efficient implementation of the whole project. From this point of view, a relevant difference exists between the economic and the managerial literature as the latter generally has a more 'holistic' vision of the problem of cost overrun.

Few authors have studied the evolution (escalation) of cost overruns empirically across the various phases of the project life-cycle, from the beginning of the project to its completion. Existing recent contributions have analysed the issue with regard to different countries, mostly in Northern Europe, the U.S. and Australia (Cantarelli et al., 2012b, Chong and Hopkins 2016, Terrill, 2016).

Following the approach of the managerial literature, the main object of this work is to understand how cost overruns of Italian public works evolve across the various phases of the project lifecycle. For doing this, the magnitude of cost overruns is estimated in the different stages of the process of realisation of the public works, to determine the impact of each step to the overall final performance - regarding cost overruns - of the project. More specifically, the main research question guiding this study is: "how are the project phases related to overall project performance?". However, to answer it, the following question has to be considered: "How much extra cost is each phase expected to produce?". Addressing these issues is extremely important for improving the understanding of cost overruns and its causes.

The contribution of this study to the current literature is manifold. First of all, the paper adds on the scant empirical literature by investigating the problem of cost

overruns in infrastructure projects with a more comprehensive approach, considering the issue from the points of view of both the society and the policymaker. In this respect, while the former mainly looks at the overall performance of the project in terms of final cost overrun, the latter is usually more interested in understanding the generating process of cost overruns so as to be able to intervene effectively with the necessary policy measures to contain the risk of extra-costs at each stage of the project process. In this respect, this research is likely to yield important policy implications. Furthermore, the present analysis concerns the Italian context that has not been yet investigated by such kind of analyses, as previously mentioned. Consequently, interesting findings could emerge from the comparison of this paper's results with those available in the other countries.

The paper proceeds as follows. The next section introduces the theoretical background, focusing on the agency theory to explain the relationships existing between the different actors involved in the process of realisation of public work. Section 3 briefly reviews the main literature on cost overruns throughout the project life-cycle. Then, the dataset and the methodological approach are described. In section 5 the results of the empirical analysis are reported and discussed. Finally, some policy implications are drawn.

2. Conceptual framework

Public works procurement involves a process in which the inputs made available by different actors are coordinated to produce a physical asset in accordance with *a-priori* specified requirements. Many different stakeholders are involved in the management of a construction project: the project owner, the project manager, designers, contractors, sub-contractors, consultants, users and so on. All have different roles and responsibilities and are likely to be involved at different time and stages of the project life-cycle. Several authors have discussed project organisation, concluding that it is not always easy to disentangle the roles and responsibilities of the various actors (Berggren et al., 2001).

Nevertheless, the performance of project management is recognised to be largely affected by the nature of the relationship existing between the different actors as well as by the way relevant information is shared between them. Theoretically, the

achievement of the project's goals, among which is that of restraining costs to the original planned, requires all the actors to cooperate and to exchange information. However, in real-life scenarios, this is not the case. The involvement of a plurality of actors, each of which has his/her own interests (and want to maximise his/her own utilities), give rise to conflicts. Furthermore, the presence of information asymmetry, as well as uncertainty, leaves space to strategic and opportunistic behaviours in the management of the project.

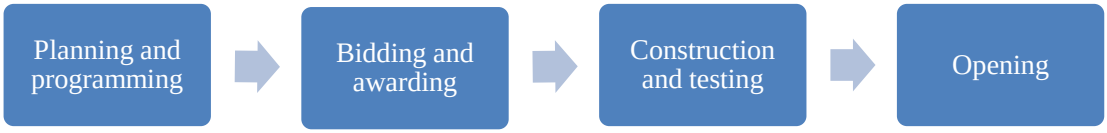
Indeed, the relationship between the different parts involved in the realisation of a work is one of the principal-agent framework analyzed in the classical theory of the firm (Baumol 1959, Williamson 1964, Alchian and Demsetz 1972). In this setting, the principal (i.e. the project owner or the contractor) delegates tasks to the better-informed agent (i.e. the contractor/project manager or the subcontractor, respectively), which agrees to act on behalf of the former. However, it can be the case that the agent will try to maximise his/her own benefit even when that may involve damaging of the principal. In the presence of incomplete or asymmetric information, the agent's opportunistic behaviour cannot be straightforwardly identified by the principal and, hence, appropriately sanctioned. As a result, mistrusts and conflicts arise, in particular between the project's owner and manager, which have been proven to undermine the best project performance (Turner and Muller, 2004; Krane et al. 2012).

According to the principal-agent theory (Milgrom and Roberts, 1992), opportunism in the relationship between the principal and the agent can assume three forms: adverse selection, moral hazard, and hold-up. With regard to construction project management, adverse selection occurs before the contract between the parties is signed. In these circumstances, the principal (e.g., the project's owner) does not hold all the necessary information (a problem of 'hidden information') to select and hire the agent properly (e.g., the contractor). Therefore, the contract is incomplete, and there exists the risk of adversely attracting too many 'lemons' (Akerlof, 1970). Moral hazard takes place after the contract between the involved parts is signed. The agent makes an action that was not agreed *ex-ante* in the contract but, due to the presence of asymmetric and incomplete information, cannot be directly verifiable or observable by the principal (a problem of 'hidden action'). Finally, a hold-up

problem takes place in the post-contract stage, when the agent (e.g., contractor) hides his/her 'real' intentions to the principal, behaving strategically (i.e., asking for contract renegotiation). In such a situation, it is too late for the principal to withdraw the irreversible investments and, hence, too costly to resolute the contract. Thus, the agent is able to appropriate the economic rent of the project.

To better understand how different actors interact in the management of a project and how opportunism is likely to affect their relationship, the project life cycle should be considered. A typical infrastructure project has to undergo several stages, which depend on the nature and characteristics of the particular project and the specific procedures employed by the management of the work. To identify the main stages of an infrastructure project, I start focusing on the conceptualisation provided by Bennett (2003). Looking at a private construction industry the author analyses in depth the typical life-cycle of a project works from its preliminary conception to its closeout and termination. In the most general flow-chart, Bennett (2003) describes six phases of the construction project life cycle: a) pre-project phase; b) planning and design phase; c) contractor selection phase; d) project mobilisation phase; e) project operations phase; f) project closeout and termination phase. With respect of the above-mentioned conceptualisation, Chong and Hopkins (2016) for international development donor projects use a more simplified sequence of phases based on four stages of the project life-cycle: a) planning and programming; b) bidding and awarding; c) construction (including testing); and, d) opening (see Figure 1).

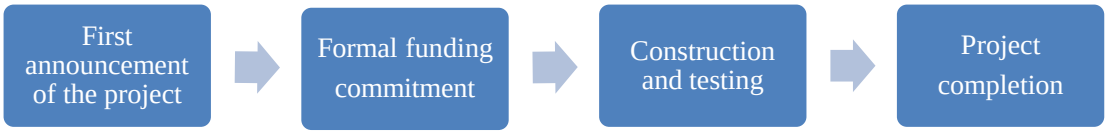
Figure 1
Project stages in international development donor projects



Source: our elaboration on Chong and Hopkins (2016)

Similarly, Terrill (2016), looking at the Australian public transport, analyses the cost overruns during the project life-cycle focusing on four stages: the first announcement of the project; the formal funding commitment; the start of construction; and, the end of construction (see Figure 2). The authors claim that, for the sample of the analysed Australian public transport infrastructure projects, the early announcements are the main causes of the cost overruns.

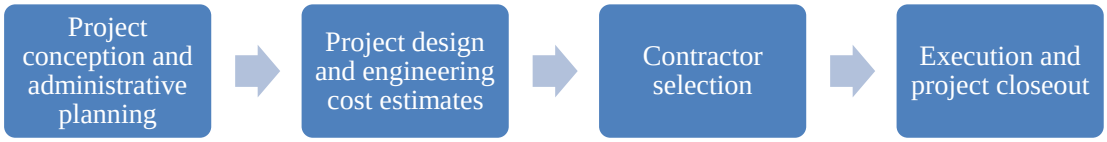
Figure 2
Project stages including the first announcement of the project



Source: our elaboration on Terrill (2016)

Following the abovementioned literature, I propose a sequence based on four stages for assessing cost overruns in the Italian public work: (i) project conception and administrative planning, (ii) project design and engineering cost estimates, (iii) contractor selection and (iv) execution and project closeout. Figure 3 illustrates the flow-chart of the proposed conceptualisation whereas Table 1 shows the actors involved in each single phase, their relationships, and goals as well as the information flows (and asymmetries) between them.

Figure 3
Project stages in Italian public work sector



Source: our elaboration

Table 1
Actors, goals, information asymmetries and opportunistic behaviours in the different stages of a public project life-cycle

Stage	Actors		Goals		Information Asymmetries	Opportunistic behaviours
	Principal	Agent	Principal	Agent		
Project conception and administrative planning	Users/Taxpayers	Government	Realization of the work in the agreed time and at the minimum of cost.	To balance project social costs and benefits and to maintain own political position through the support of community.	Knowledge of political mechanisms.	Realization of useless works to community or incompletes.
	Contracting authority	Consultant, planner	To realize the work with the minimum of time and cost.	To rise their income by extending the contract and increasing the number of assignments	Knowledge of the actual project costs as well as of the limited budgeting resources of the contracting authority.	Biases (i.e. strategic underestimation) in forecasting costs → increased cost overruns.
Project design and engineering cost estimates	Contracting authority	Engineer, Architect as internal personnel	To obtain a high-quality design that meets the existing technical-regulatory standards, at the minimum cost.	To obtain extra payments for his7her technical activity as designer.	Specialised competencies and knowledge of technical regulation.	A low-quality design which can imply cost overruns and time delays.
Contractor selection	Contracting authority	Bidder	To choose the better contractor that bids the minimum price in the tender and meets the contractual terms.	To win the tender.	The contracting authority does not know the true intentions of the contractor. In an auction, he/she can hidden these and acts opportunistically. He/she does represent the better choice in the market ⟶ adverse selection.	Increase in the agreed costs and time.
Execution and project closeout	Contracting authority	Contractor	To meet the contractual terms.	Increasing the profit.	After the contract is signed, the contractor reveals his/her 'real ' intentions and can ask for a renegotiation of the contract so as to increase his/her profit ⟶ moral hazard.	Legal disputes and renegotiations of the contract with the risk of cost overrun and delays. (increased transaction costs)

Source: our elaboration

In the first phase, the conception and administrative planning one, the idea for a project is examined to determine whether or not it satisfies the community needs. The government recognises and verifies the societal needs, plans the realization of the work and includes it in the agenda of public works programmes. At this stage, the citizens represent the principal (i.e. project owner), and the government is the agent (i.e. project manager) who is delegated to satisfy their priorities. The citizens aim to obtain the work in the agreed time and at the minimum cost. On the contrary, the government is asked to strike a balance between cost savings and value for money, looking at the social welfare. Though the government should only act on the society's behalf, it depends directly on the citizens' votes. Therefore, he is interested in maintaining his political position through the support of the community. This can incentivise works that increase the personal prestige of politicians, whose name is linked to a particular project, without paying attention to the actual feasibility and the overall utility of the work, but with the only goal of being re-elected (Flyvbjerg et al., 2009). The above considerations can support the hypothesis of a relationship between the political/electoral cycle and the outcomes of public procurement. The issue has been recently investigated by Coviello and Gagliarducci (2017) who find that an increase in politicians' tenure in office is associated with worse procurement outcomes. Another paper by Chong et al. (2014) finds that in France public work contracts are more likely to end in the years preceding the legislative election in municipalities where the mayor ran in the election.

Whenever the project is managed at a local level, the local government acts as an agent of both the citizens and the central government, to whom is responsible for the allocation of the funding resources. Local governments are, however, more likely of being captive of local lobbies in public procurement increasing the risk of corruptive and collusive phenomena (e.g. Hyytinen et al., 2007; Decarolis and Giorgiantonio, 2014). Once established the need to carry on the work, in this stage the government, as the project manager, conducts a feasibility study to estimate project costs. Here, the government, through the contracting authority, plays the role of the principal while consultants and planners are the agents. While government's interest is to realise the work with the minimum time and cost, the consultants/planners look at their personal interests. These include extending the contract and increasing the number of assignments, thanks to a set of information which they get and are not

willing to reveal to their principal. Indeed, by enjoying their informative advantage over the actual costs of the work and the limited resources available for funding, they can underestimate strategically forecasting costs (a sort of 'optimism bias') to favour the project approval and its financing by the government. This behaviour is also likely to give rise to further consultancies, thus increasing their income.

The second step is that of project design and engineering, where all the procedures required for the implementation of the design phase are defined, and costs are estimated. In details, this stage is focused on the choice of the design works to be delivered, the type of contract to be awarded and the delivery system to be used. With regard to the latter, two options are generally available: 1) the Design and Build (D&B) (*appalto integrato*) where the design and the execution of the work are awarding together to the same contractor; 2) the Design-Bid-Build (DBB or "design–tender") (*sola esecuzione*) where the two phases are awarded in different moments to different contractors. Relying on a single point of responsibility contract, the D&B approach is used to minimise risks for the project owner and to reduce the delivery schedule by overlapping the design phase and construction phase of a project.

In a standard DBB delivery system, the actors are the government and the designer. In the framework of the Italian regulation, the decision has to be taken on whether to assign the design task to the technical personnel of the contracting authority or to award it to external designers (i.e. design in-house vs outsourcing). The complexity of the project and the related need to select specialised designers, together with the lack of internal technical personnel are two of the main reasons that can lead the contracting authority to opt for the outsourcing solution.

Regardless of the choice, the relationship between the contracting authority and the designer is always one of principal-agent. The contracting authority is the principal, whose goal is to obtain a high-quality design (i.e. compliant with technical-regulatory standards) at the minimum cost. The designer is the agent. However, the agent's goals and interests are likely to be different according to in-house/outsourcing choice.

In the case of design in-house, the engineer/architect is an employee of the contracting authority, who acts as its agent with the goal of obtaining an extra

payment for his/her technical activity as a designer[17]. The designer shows his/her opportunistic behaviour by trying to get a separate consultancy for the further design contingencies, being thus induced to deliver a low-quality design plan. As a consequence, time delays in the execution of the work due to possible project variants and extra-costs for project occurrences (i.e. inappropriate technical procedures, inadequate technologies, materials and equipment not optimal for the work realisation) are likely to arise.

On the contrary, whenever the contracting authority outsources the design, the external designer, exploiting his/her expertise in the technical aspects of the project, is able to 'blackmail' the contracting authority, asking for higher payment to provide a high-quality design.

In the bidding phase, the actors of the selection mechanism are the contracting authority and the contractor, as the principal and the agent, respectively. The aim of the contracting authority is to select the better contractor, that is the one bidding the minimum cost in the tender. An adverse selection problem can arise because of the information asymmetry between the actors. This is likely to be dependent on the type of selection procedure (i.e. negotiation or auction). Indeed, in a negotiation procedure, more information is shared, reducing the asymmetry between agents. This leaves less space to the contractor's opportunistic behaviours, thus preventing possible renegotiation of the contract that is likely to produce extra costs.

When the selection mechanism is an auction, the information asymmetry between the agents is higher. In such a case, the selected contractor can hide his/her real intentions and acts opportunistically. In absolute terms, this does not represent the better contractor on the market (i.e. the more efficient). Nonetheless, he/she is able to bid the lowest price (and, thus, to win the tender), under the expectation of exploiting the incompleteness of the contract and calling for a further renegotiation of it. Hence, time delays in the execution of the work and extra costs are likely to arise (Bajari et al., 2009; Guccio et al., 2009).

In the framework of the principal-agent theory, the contractor is generally considered as risk-adverse. In this regard, different type of contracts (i.e. fixed price or cost plus) are used to share differently between the parts the risk inherent in the

[17] This point is recognized by the Italian Code of public work until the first months of 2016.

construction. A cost-plus contract places the construction risk upon the government/funder. This kind of contract does not contain implicit incentives for the contractor to restrain costs and to operate efficiently as it provides extra-payments in case of extra costs. Contrarily, when a contract is fixed price or lump sum, the contractor bears all the construction risks. In this case, changes to the contract are admitted but extra costs are usually borne by the contractor. Under such a contract, an incentive exists for the contractor to meet the project objectives in terms of agreed time and costs, avoiding moral-hazard phenomena. In the presence of particularly complex works, however, fixed price contract can lead to higher extra costs because of the possible changes in orders due to project changes (Bajari and Tadelis, 2001).

In the execution phase, whenever the contract is D&B, the winning bidder must execute both design and construction together and employs the qualified staff to carry out the two tasks. Theoretically, the contractor (as an agent) has the know-how and the capacity to meet the agreed time but could exploit his/her information advantage to cheat about the costs. However, in this type of contract, the construction risks are all borne by the contractor. Thus, the contractor is interested in meeting the contractual terms, with a lower likelihood of moral-hazard problems, cost overruns and potential legal disputes.

3. The literature on cost overruns throughout the project life-cycle

The issue of cost overruns in the realisation of a project has been widely studied in literature. From an empirical point of view, many papers have tried to evaluate the magnitude of cost overruns and to identify potential determinants. Despite the academic interest on the topic, only recently few papers have focused on the different phases of the project life-cycle, trying to determine the critic steps of a construction project during which extra costs are more likely to occur.

In the following, evidence from these studies is reported. For each of them, the Table 2 reports the main findings – regarding magnitude, frequency, and determinants of cost overruns – are outlined as well as the methodological approach used to investigate the different stages.

Table 2
Literature on cost overruns throughout the project life-cycle (in chronological order)

Author/s	Country	Sample	Stages of the project life-cycle	Frequency of cost overruns (% of projects)	Magnitude of cost overruns (%)	Determinants
JLARC (2001)	Virginia (USA)	297 road projects of which: 86 projects that have completed the design phase and 211 that have completed construction	- Planning stage; - Design stage: 1. scoping stage; 2. preliminary field review estimate; 3. field inspection estimate; 4. approval of rights of way plans; 5. 100 percent design estimate; - Bidding phase; - Construction phase;	-	Average % cost estimate change from scoping phase to 100 percent design: from 74.3% to 151.9% compared to the construction phase and the preliminary engineering, respectively. No cost escalation in the bidding phase. Average percentage change in project costs from contract award to completion is 11.1%	In the scoping stage: unforeseen events, scope change, forecasting technical errors. In the construction phase: unforeseen events, design errors, underestimated costs linked to technical and administrative factors.
Cantarelli et al. (2012b)	Netherlands	78 large-scale transport infrastructure projects	Pre-construction phase (the period between the formal decision to build and the start of construction) Construction phase (the period between the start of construction and the start of operation (opening)	In the pre-construction phase: • 70% of projects with cost overruns; • 30% of projects, estimated costs stayed the same or decreased. In the construction phase: • 38% of projects with cost overruns; • 62% of projects with cost underruns	In the pre- construction phase: the average cost overrun is 19.7% In the construction phase: the average cost overrun is -4.5%	Underestimation of costs due to optimism bias.
Chong and Hopkins (2016)	13 developing countries: Burkina Faso, Cape Verde, El Salvador, Georgia, Ghana, Honduras, Mali, Mongolia, Mozambique, Nicaragua, Senegal, Tanzania, and Vanuatu.	48 completed MCC's road construction projects.	Three stages: - Design phase; - Bidding phase; - Construction phase. Four cost estimates: 1. FA-funding authorization; 2. EE-engineer's estimate; 3. CA-contract award; 4. FC-final cost.	-	General view (FC to FA) → Cost escalation on average 135%; Design phase (FA to EE) → Cost escalation on average 100%; Bidding phase (EE to CA) → No cost escalation; Construction phase (CA to FC) → Cost escalation on average 21%	Scope change of the project.
Terrill (2016)	Australia	836 transport infrastructure projects	- First public cost announcement; - Formal funding commitment; - Commencement of construction (construction phase);	34% of projects with cost overruns;	First cost estimate to final cost estimate 24% Cost estimate from announcement prior to budget commitment 9% Budget commitment to start of construction (design phase) 6% In the construction phase: 9%	Premature public announcement.

Source: our elaboration

A first report by the Joint Legislative Audit and Review Commission (JLARC) (2001) compares cost estimate and final cost data for a sample of 297 road projects in Virginia that have either completed the design phase (86 projects) or the execution phase (211 projects). The work is based on separate cost estimates that are developed throughout the project life-cycle to respond to the different actors' purposes. In the first stage, the planning one, a feasibility study is made for an initial funding decision. The design phase comprises: (a) the scoping stage, where a purely indicative estimate is made after a site visit to the project; (b) the preliminary field review stage, when the design project is 20-30% complete but a metric estimate is made on the quantities of materials needed for constructing; (c) the field inspection stage, when the design is around 50-60% complete and the previous cost estimate is refined based on more reliable quantity estimates; (d) the approval of rights of way plans stage, when the design plans are 75% complete, no major design change is expected and a more refined cost estimate is defined to be presented for approval to the Right of Way and Utilities Commission; (e) the 100 percent design stage, when the design plans are complete and a final cost estimate can be developed based on precise quantities and prices lists. After the design phase, two further cost estimates for the project are made during the bidding phase and the construction phase.

With regard to the capacity of forecasting costs during the design phase, the report by JLARC shows a substantial underestimation of costs. As expected, such underestimation of costs is likely to be a more serious problem during the first stages of the design phase (i.e. scoping stage and preliminary field review stage) because of the lower uncertainty about the quantities and prices of inputs used in the construction process (e.g. labour, equipment and materials). Thus, the percentage of increase in construction estimates during the different design phases varies on average between 74.3% and 18.7%, depending on the degree of completeness of the design plans. Determinants of underestimates are found to be: project changes due to unforeseen events, project scope expansion, and technical forecasting and design errors or omissions. The report also compares the cost estimate made in the design phase when the project is complete with that made in the bidding phase. The results show that the two estimates are quite similar. Conversely, differences in cost estimates exist between the bidding phase and the final construction phase: on average, final construction costs add 11.1% to the contract award amount, mainly

due to unforeseen contract cost, design errors and underestimation of technical/administrative costs of construction.

A study by Cantarelli et al. (2012b) identifies, in a less detailed way, different project phases and analyses cost overruns during the project development in the Netherlands. The sample comprises 78 Dutch large-scale transportation infrastructure projects, and only two project phases are considered: the pre-construction phase, the period between the formal decision to build and the beginning of the work construction; and, the construction phase, the period between the execution of the work and its opening. The authors find an overall average cost overrun of 16.5%. Considering the magnitude of cost overruns during the project development, an average value of 19.7% is found in the pre-construction phase and -4.5% in the construction phase. The probability of projects incurring in cost overruns is also higher in the pre-construction phase compared to the construction one: 70% (with an average cost overrun of 30.8%) against 38% (with an average cost overrun of 9.5%). Therefore, the authors conclude by defining the phase before the work construction as the most critical and the more vulnerable to cost overruns. They also disregard technical explanations as for the main reason for forecasting errors, thus preferring psychological (such as "appraisal optimism". See, Flyvbjerg et al., 2002) and political-economic explanations (i.e. a deliberate and strategic underestimation of the project costs to increase the likelihood of its approval).

Recently, two contributions have explored the same issue. To the best of our knowledge, the study by Chong and Hopkins (2016) is the only existing cross-country investigation of cost variability for road construction projects. It considers data on 48 road projects funded and managed by an international donor organisation (the Millennium Challenge Corporation) in 13 developing countries. To track costs along the project life-cycle, the authors identify four phases: the planning phase when an estimate is made for funding authorization; the design phase when an independent engineer estimates costs based on a detailed design; the bidding phase where the estimate is the value of the awarded contract; and, the execution phase when the total cost of construction can be computed. Considering the entire project life-cycle, the increase in cost estimate is on average of 135%. The most significant uncertainty in cost estimates is found during the design and the execution phases,

when the average cost increase in regard to the previous phase is of 100% and 21%, respectively. All in all, cost performance from this study is either comparable or slightly better than that of similar analyses. By analysing the major drivers of cost variability, the authors identify three areas of improvements: refining funding authorisation estimates, using performance-based incentives to reduce contractor reliance on contingencies, and packaging projects into larger contracts to better exploit the cost benefits arising from economies of scale.

The second recent contribution on the topic is that by Terrill (2016), who analyses the project life-cycle focusing on four stages: the first announcement of the project; the formal funding commitment; the start of construction; and, the end of construction. By considering a sample of 836 infrastructure projects, planned or built in a period between 2001 and 2015, they find an average magnitude of cost overruns of 24%, distributed equally among the different phases: the 9% in the first phase before the budget commitment, 6% in the period between budget commitment and the start of construction and 9% in the phase of execution of work. The authors find that scope changes actually explain only a small share of overruns and identify the premature project announcement as the main determinant of cost overruns. In facts, projects that are announced prematurely are found to have larger and more frequent cost overruns than those announced at a more mature stage of development. This is true not just in the run-up to a formal cost assessment but throughout the project lifecycle. This result finds its theoretical basis in the concept of deception expressed by Flyvbjer et al. (2009; 2011), namely the strategic behaviour of a politician to misrepresent costs and benefits of a project for being closer to the community thinking and, hence, favouring his/her re-election.

4. Data and method

4.1 Data

The present analysis is obtained by merging data provided by the Italian Ministry of Economics and Finance (*Ministero dell'Economia e Finanze*, MEF) and by Italian Authority of Public Contracts (*Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture*; hereafter, AVCP). The sample comprises 1,083 public

infrastructure projects for roads, started and completed during the period 2000-2013. The data provided by MEF allow tracking the realisation process of a given public work, from the cost estimate made by the contracting authority during the feasibility study, which is required for funding authorisation, up to the final costs incurred for constructing and making it operative.

To analyse the cost variability during the project development, information on estimated and effective costs for each phase of the project life-cycle are required. To this purpose, the data from MEF have been merged with data provided by the Italian Authority of Public Contracts (*Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture*; hereafter, AVCP) and concerning the contractor's selection, the award of the contract and the realisation of the work.

Indeed, a substantial difference exists between the two datasets. The data from MEF provide a quite general view of public works by means of the public work monitoring system (*Monitoraggio delle Opere Pubbliche*, MOP) and the database of public administrations (*Banca Dati delle Amministrazioni Pubbliche*, BDAP), which report all contracting authorities' estimated (forecasted/budgeted) and actual (accounted) expenditures. Specifically, expenditure flows concern the entire project life-cycle, from the financing and start of the work up to the completion of the work and its testing. Furthermore, the expenditures include not only the costs for the material execution of the public work but also those bureaucratic and administrative costs linked to the realisation of the work (e.g. expropriation, adjudication commissions, consultancy, unexpected contingencies, etc.). However, due to missing information, it is not possible to extrapolate the costs incurred by the contracting authority for the pure execution of the work (i.e. the stage of the awarded of the contract and the execution). For this purpose, the data on the expenditure flows are linked with those of AVCP that report information on engineering cost estimates (i.e. the contracting authorities reserve price), the winning bid and the final cost for physical execution of the public work. Thus, sample results by merging the two datasets, for which actual costs for the construction stages can be identified. Furthermore, more detailed and complete information concerning the process of contract selection and awarding are obtained. Table 3 reports some descriptive statistics of road projects in the sample by geographical area. The Table reports both

the cost for physical execution and total final cost. Two elements emerge from the Table 3. First, in our sample, the execution phase account for about two-thirds of the final cost. Second, the large share of the public works are in located in the North and the Centre of the country.

Table 3 – Distribution of infrastructure project by geographical area

Geographical area	Observations	Final cost for physical execution of the public work		Total final cost	
		Average	Total	Average	Total
North-Est	260	333,002.38	86,580,619.08	575,980.36	851,409.20
North-West	339	361,768.59	122,639,550.70	654,167.23	2,291,443.47
Centre	224	327,675.37	73,399,283.72	574,593.96	474,709.11
South	73	351,326.77	25,646,854.32	506,042.27	363,844.10
Islands	187	529,864.80	99,084,718.15	860,335.66	710,988.03
All sample	**1.083**	**376,132.07**	**407,351,025.90**	**644,552.62**	**1,402,649.81**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

In Table 4 the same statistics for the type of contracting authorities are reported. As expected the largest of contracting authority are the municipalities, followed by provinces that in Italy have special competences on secondary roads (i.e. provincial roads). The residual category (Other) refer to different subjects (e.g. Private concessionaires, Public ownership companies, Public agencies with special budget autonomy, etc.). From the Table 4 is possible to look that public works in our sample managed by different contracting authorities vary both for the average cost and for the incidence of the cost of physical execution.

Table 4 – Distribution of infrastructure project by contracting authorities

Contracting authorities	Observations	Final cost for physical execution of the public work		Total final cost	
		Average	Total	Average	Total
Municipalities	767	299,255.02	229,528,603.98	501,658.60	609,911.17
Provinces	240	533,395.58	128,014,940.23	1,089,186.56	2,680,711.15
Others	76	655,361.60	49,807,481.72	682,546.93	917,143.74
All sample	**1.083**	**376,132.07**	**407,351,025.90**	**644,552.62**	**1,402,649.81**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

As previous mentioned, unfortunately, the available data do not allow an accurate cost evaluation in each phase in the life cycle of the project as described in Section 2. To make more clear the reconstruction of accounting flows, in Figure 4, the accounting sources are reported in connection with the different stage of the project. Thus, I assume as a starting point the estimated budget provided by MEF and disentangle the different cost components. In particular, I distinguish between physical costs and other costs[18]. Then, these data with the other source of information are linked. In particular, the one between budget and actual cost for physical execution provided by MEF and AVCP. Table 5 shows the descriptive statistics of different cost estimates and variables related to financial planning.

Table 5 – Descriptive statistics of different cost components

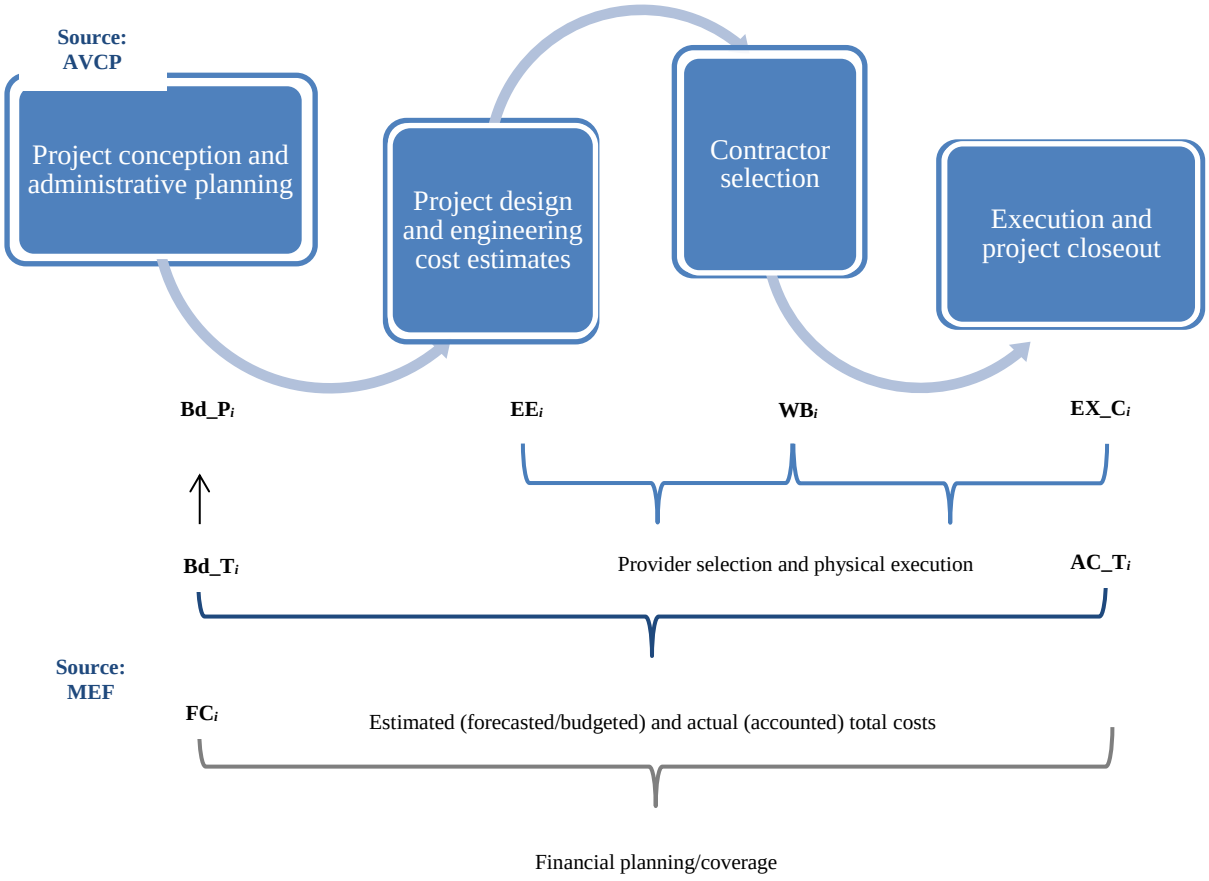
Variables	Meaning	Obs.	Mean	St. Dev.
Bd_T	Total estimated budget	1,083	662,616.43	1,419,817.07
Bd_P	Estimated budget for physical execution	1,083	522,124.50	691,296.91
EE	Engineering estimates/reserve price	1,083	474,716.92	666,372.41
WB	Winning bid	1,083	367,517.75	504,106.58
EX_C	Total cost for physical execution	1,083	376,132.06	510,278.96
AC_T	Total actual cost	1,083	644,552.62	1,402,649.81
FC	Financial planning/coverage	1,083	730,224.20	1,117,541.86

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

At the first look on Table 5 it can be noticed that the contracting authorities in our sample, on average, overestimate both the budget and the financial needs of the projects. To provide a better understanding of the contracting authorities' behaviour, in the next Section, I explore more in-depth the data obtained to assess the costs in each phase in the life cycle in the sample of the public works.

[18] Although we have paid a close attention to disentangle the different cost components looking at the data one by one we have recognized that in some cases the distinction may be arbitrary due to not uniform rules in accounting in the MEF dataset. Nevertheless, we are reasonably confident that our cost estimate is not far from real cost.

Figure 4
Project stages and accounting flow



Source: our elaboration

4.2 Method

From the economic and engineering literature on cost overruns, no clear and unambiguous indications concerning the methodology for determining the magnitude of cost overruns stems from. Specifically, different moments are used as the basis for the estimated and actual costs.

Flyvbjerg et al., (2002, 2003), Cantarelli et al. (2012b) adopt as time reference that of the formal decision to build. However, when the time of the decision to proceed is unknown, or costs are not available at it, the nearest available estimated costs, which are generally later and, hence, more accurate, are used as a proxy, leading to lower cost overruns. In the case of this paper, estimated costs for either the initial phases of project planning or budgeting are employed. However, the choice of adopting the decision to build, as the base for the estimated costs, is in contrast with that of many other studies. These, prefer to assess the contractual performance and use the execution stage as base to calculate the cost overruns (e.g. Decarolis and Palumbo, 2015; Guccio et al., 2009, 2012).

In this paper, the issue of the development of cost overruns throughout the project life-cycle is addressed step by step. First, in the following Section, we describe how data are used to investigate the characteristics of cost generating process in execution in each project stages in terms of magnitude and whether cost estimates have been improved (become more accurate) over time. Then, as a further step, in the subsequent Section, we investigate the contracting authorities' behaviour in terms of total budget and actual cost and financial coverage.

4.2.1 Cost index for physical execution

During the planning and programming phase, the contracting authority prepares a feasibility study of the work, makes a first estimate of the project costs, identifies and receives the funding necessary for the realisation of the work. At this stage, the funded amount corresponds to the overall budget the contracting authority has available to complete the project both from a technical as well as a bureaucratic-administrative point of view. As previously mentioned, the dataset used in this paper comprises both the physical estimated costs in the planning stage (Bd_P) and the overall budget (Bd_T). Furthermore, we collected data on the engineering estimates EE use in the provider selection phase. Therefore, as a first inspection of the generating process of cost overrun in the planning stage ($\Delta C_{planning}$) is measured as engineering estimates (EE) minus estimated budget costs (Bd_P) expressed as a percentage of the estimated physical costs in the planning stage:

$$\Delta C_{Planning} = \left(\frac{EE}{Bd\_P} - 1\right)*100\% \quad (1)$$

Eq. (1) provides a measure of the quality of the cost estimate of public work physical execution made by the contracting authority (Bd_P) as compared to the engineering estimate (EE) based on the metric analysis of the quantities of inputs needed for physical constructing.

During the bidding phase, the projects are generally tendered[19]. Here, the focus is on the technical performance in the realisation of the work, which initially depends on the contract award process and on the optimal selection of the contractor. In addition, EE also represents the maximum amount the contracting authority is willing to spend for the realisation of the work (i.e. the reserve price). Cost overrun in this phase ($\Delta C_{bidding}$) is, thus, the gain that contracting authorities achieve in the phase of provider selection. Therefore $\Delta C_{bidding}$ is computed as reserve price (EE) minus the estimated costs in the bidding stage (WB) expressed as a percentage of the EE:

$$\Delta C_{gain} = \left(\frac{WB}{EE} - 1\right)*100\% \quad (2)$$

Index in Eq. (2) is thus negative by construction.

The following phase, the construction one, comprises the execution of the contract. Cost overrun in the construction phase is measured as final cost computed at the completion of the work and after testing it (EX_C) minus the value of contract award (WB) expressed as a percentage of WB:

$$\Delta C_{execution} = \left(\frac{EX\_C}{WB} - 1\right)*100\% \quad (3)$$

At this time, problems of moral hazard are likely to occur as the contractor is able to exploit the incompleteness of the contract. This opportunistic behaviour may give rise to increases in costs due to potential contract renegotiations.

[19] Due to the lack of data, the characteristics of the planning phase (in-house or outsource) are not studied. However, the value of the contract is used as a proxy for the work complexity.

Finally, it is possible to evaluate the final cost for physical execution EX_C in comparison with the estimated budget (Bd_P). The overall extra-costs (ΔC_{tot}) are, then, calculated as the difference between the final costs (EX_C) and, the available budget (Bd_P) expressed as a percentage of Bd_P:

$$\Delta C_{tot} = \left(\frac{EX\_C}{Bd\_P} - 1\right)*100\%. \quad (4)$$

4.2.2 Cost index for the whole provision of public work

As a further step, it is possible to evaluate the overall cost incurred in the provision of public work comparing the total budget (Bd_T) with the actual cost (AC_T). This, index provides information on the capability of the contracting authority in forecasting all the contingencies achieved during the public work provision. As before, we can express this index as a percentage of actual budget minus estimated costs expressed as a percentage of the estimated costs in the planning stage:

$$\Delta C_{whole} = \left(\frac{AC\_T}{Bd\_T} - 1\right)*100\%. \quad (5)$$

Finally, we can evaluate the capabilities of contracting authorities to forecast the financial coverage for the public work execution expressed as a percentage of financial coverage FC minus actual costs AC_T expressed as a percentage of the actual costs:

$$\Delta F = \left(\frac{FC}{AC\_T} - 1\right)*100\%. \quad (6)$$

5. Results

5.1 Cost generating process in public work execution

The cost generating process, linked to the execution of the project, is analysed through four stages (i.e. planning, bidding, execution and conclusion of work). The

former and the latter are compared to the estimated budget for the execution of the works, and give us a measure of the accuracy on which the contracting authority forecast cost in two different stages. The first stage before the project is realized (and after the decision to build) and the second stage at the end when the project is completed. The others measures give us two different information to the bidding phase and the execution phase, namely before and after the awarding process.

To assess if institutional characteristics of contracting authorities play a role, we report the distribution of abovementioned index both for the different geographical area and for different types of contracting authorities, in particular looking at Municipality and Provinces as the more representative categories (see Table 4).

From Table 6 it can be seen that in the planning phase, the accuracy of cost forecast assumes, on average for all sample, although small, a negative value (-1.34%). However, looking at the geographical distribution, the figures reported in Table 6 show that there is a considerable variation both along the North-South axis and between types of contracting authorities.

Table 6 – Cost forecast accuracy in the planning stage by geographical area and type of contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	-10.88	31.73
North-West	339	-0.14	35.22
Centre	224	-0.24	22.53
South	73	19.03	55.48
Islands	187	0.49	16.45
Contracting authorities			
Municipalities	767	-1.50	34.88
Provinces	240	-1.72	27.22
Others	76	1.53	11.88
All sample	**1,083**	**-1.34**	**32.18**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

As for bidding stage, no marked differences exist both for geographical areas and type of contracting authority. As said in the previous Section, this cost according to the construction method of the index, assumes negative values and on average is

around of -20%. This means that the contracting authority has, on average, a cost saved of 20% respect the reserve price (see Table 7).

Table 7 – Cost gains in provider selection stage by geographical area and type of contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	-15.50	10.64
North-West	339	-18.55	12.91
Centre	224	-26.83	19.55
South	73	-29.54	10.62
Islands	187	-18.78	7.98
Contracting authorities			
Municipalities	767	-20.97	15.25
Provinces	240	-16.86	10.00
Others	76	-24.57	10.02
All sample	**1,083**	**-20.31**	**14.07**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

In the execution phase, as reported in table 8, cost overrun is on average around of 11% for the all sample, with a higher value in the North-Est area and for the category Others as regards the type of contracting authority.

Table 8 – Cost overruns in the execution stage by geographical area and contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	20.07	95.43
North-West	339	8.08	14.88
Centre	224	11.72	17.96
South	73	8.72	13.80
Islands	187	3.21	15.79
Contracting authorities			
Municipalities	767	11.72	21.49
Provinces	240	4.29	13.34
Others	76	23.69	170.56
All sample	**1,083**	**10.92**	**49.03**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

Table 9 – Total cost overruns in execution by geographical area and contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	-14.59	34.81
North-West	339	-13.66	28.83
Centre	224	-26.09	22.32
South	73	-8.62	50.69
Islands	187	-23.16	26.90
Contracting authorities			
Municipalities	767	-16.63	32.10
Provinces	240	-21.33	29.95
Others	76	-17.81	26.57
All sample	**1,083**	**-17.76**	**31.31**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

In the last step, we evaluate total cost overruns at the completion of the works. The results reported in the Table 9, show that there is no marked differences between the geographical areas and types of contracting authorities. All values are negative and, on average, total cost overruns assumes the value of -17.76%. This result seems to tell us that the forecast budget can be overestimated by contracting authorities.

5.2 Whole cost overruns and financial coverage.

Regarding the whole provision of public work, the magnitude of the differences between estimated and actual total cost assumes, on average, a value around zero (see Table 10). This result is not surprising due to the index computation. The more simple interpretation is that we are able to correctly identify the elementary costs in two datasets and this result in an overlapping measure of the two measures.

Looking at the Index of financial coverage we find an interesting result that seems to indicate an over-coverage behaviour by contracting authorities. In fact, as we can see from Table 11, in all the geographical areas and for all the type of contracting authorities, the financial coverage results higher than total actual cost. In a similar

way to the magnitude of total cost overruns for the execution of work, the financial coverage results overestimated by contracting authority, on average, with a value of 26.35%. Finally, Table 11 reports the pairwise correlation between estimates index in our sample.

Table 10 – Differences between estimated and actual total cost by geographical area and contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	-0.31	4.63
North-West	339	1.69	33.01
Centre	224	1.66	64.36
South	73	-7.61	13.77
Islands	187	-2.69	7.32
Contracting authorities			
Municipalities	767	1.94	39.48
Provinces	240	-0.71	19.05
Others	76	-19.88	14.14
All sample	**1,083**	**-0.18**	**35.04**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

Table 11 – Financial coverage on total cost by geographical area and contracting authorities

	Obs.	Mean	St. Dev.
Geographical area			
North-Est	260	5.00	15.90
North-West	339	51.70	248.70
Centre	224	20.63	63.53
South	73	36.69	79.78
Islands	187	12.90	23.16
Contracting authorities			
Municipalities	767	29.70	170.85
Provinces	240	9.82	33.88
Others	76	44.79	32.55
All sample	**1,083**	**26.35**	**145.21**

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

Table 12 – Pairwise correlation matrix between index

	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta C_{Planning}$	1.0000					
ΔC_{gain}	-0.2088	1.0000				
$\Delta C_{execution}$	-0.0295	-0.1276*	1.0000			
ΔC_{tot}	0.6858*	0.2205*	0.2262*	1.0000		
ΔC_{whole}	0.1885*	-0.1047*	-0.0019	0.1802*	1.0000	
ΔF	0.0684*	-0.1475*	0.0345	0.0404	-0.0563	1.0000

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

*Note: * denote significance at the 1% level.*

5.3 Assessing the determinants of cost overruns in the life-cycle of the project

To assess the determinants of cost overruns in this Section, we analyse the relationship of cost overruns indexes in the life-cycle of the project using econometric approach. More, in particular, we conduct some analysis using OLS regression.

We limit our analysis here only a few indexes that we believe have more relevance for our investigation. Namely, we first assess the role of institutional characteristics of contracting authorities in term of different gain obtained in the selection stage and the cost overruns in the execution stage. Then, we investigate on the role of institutional characteristics on the whole life-cycle of the project in term of cost overruns and financial coverage.

In fact, the analysis conducted in the previous Section showed that contracting authorities presenting a better performance in provider selection incurred in higher cost overruns in the execution stage. A possible explanation for this findings is the presence of opportunistic behaviour in the selection stage that has effects in term of cost overruns. Thus, with the first analysis, we aim to better understand the performance in the execution stage in connection with those in the selection stage. For this purpose, we first study the relationship between indexes $\Delta C_{execution}$ and ΔC_{gain} to explore if higher cost overruns in the execution stage was related with larger cost gain in the selection stage controlling for type of contracting authorities and for the geographical area. In doing so we employ a parsimonious

approach using each covariate one at time. Furthermore, to control for heteroscedasticity we use robust standard error. In Table 13 we report the estimated results. It show that the cost overruns in the execution stage $\Delta C_{execution}$ is negatively and significant correlated with cost gain in the selection stage. This result is robust to different specification and employed controls. Furthermore, the estimates in Table 13 confirm that, compared with reference group of "provinces", municipalities show a lower level of the performance. Summing up, the above estimates provide new results suggesting that cost gain in the selection stage exerts a negative effect on the performance of public contracts on the execution stage.

Table 13 – Relationship between cost gain in the selection stage and cost overruns

VARIABLES	**(1)**	**(2)**	**(3)**
	$\Delta C_{execution}$	$\Delta C_{execution}$	$\Delta C_{execution}$
ΔC_{gain}	-0.4448***	-0.4066***	-0.5634***
	(0.1316)	(0.1072)	(0.1829)
d_municipalities		5.7656***	5.5173***
		(1.2685)	(1.2157)
d_other		16.2667	11.1705
		(18.7185)	(17.8173)
d_north-west			7.0229*
			(3.7266)
d_centre			21.1509**
			(10.1794)
d_south			3.5788
			(2.3232)
d_islands			-1.4478
			(4.0642)
Constant	1.8821	13.6996	8.0420
	(1.6637)	(17.1674)	(16.4656)
Observations	1,083	1,083	1,011
R-squared	0.0163	0.0223	0.0463

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

*Note: robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The second line of analysis conducted in this Section refer to the previous findings on the actual total cost and financial coverage. More in particular, we first try to understand better the role of selection and execution stages on the actual cost studying between the index ΔC_{whole} and the indexes $\Delta C_{execution}$ and ΔC_{gain}

controlling for type of contracting authorities and for geographical area. In Table 14 we report the estimated results. Table 14 show that once again the efficiency gain in the selection stage have a negative effect on the cost overruns. Furthermore, the estimates in Table 14 confirm that compared with reference group of "provinces" both municipalities and other contracting authorities show a lower level of the performance in the actual cost.

Table 14 – Determinants of public work actual costs

VARIABLES	**(1)**	**(2)**	**(3)**
	ΔC_{whole}	ΔC_{whole}	ΔC_{whole}
ΔC_{gain}	-1.5019***	-1.4389***	-1.5951***
	(0.4104)	(0.4064)	(0.4996)
$\Delta C_{execution}$	0.0472	0.0376	0.0530
	(0.0787)	(0.0772)	(0.0853)
d_municipalities		13.6908***	11.3808*
		(5.0923)	(6.1957)
d_other		23.1507***	23.6477***
		(5.2533)	(6.2619)
d_north-west			33.5130***
			(11.4858)
d_centre			-10.1089**
			(4.3037)
d_south			-13.9636
			(9.8445)
d_islands			-2.0714
			(12.3154)
Constant	-4.6654	-14.6017**	-20.9217**
	(5.0034)	(7.2664)	(10.1471)
Observations	1,083	1,083	1,083
R-squared	0.0220	0.0240	0.0407

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

*Note: robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

Finally, we try to assess the role of financial coverage both on cost overruns and for actual cost. For this purpose, we re-ran the regression reported in Tables 13 and 14 using as a covariate the variable ΔF. The results of this additional exercise is reported in Table 15.

Table 15 – The role of financial coverage

VARIABLES	(1)	(2)	(3)	(1)	(2)	(3)
	$\Delta C_{execution}$	$\Delta C_{execution}$	$\Delta C_{execution}$	ΔC_{whole}	ΔC_{whole}	ΔC_{whole}
ΔF	0.0116***	0.0097**	0.0133***	-0.0136***	-0.0128***	-0.0134***
	(0.0038)	(0.0046)	(0.0037)	(0.0051)	(0.0048)	(0.0049)
d_municipalities		7.2440***	4.2072***		2.9005***	2.9546***
		(1.1617)	(1.0118)		(0.9092)	(0.8897)
d_other		19.0644	21.4288		18.7215***	18.7414***
		(19.5956)	(22.3171)		(2.0152)	(2.4972)
d_north-west			5.3027			1.8239
			(3.4008)			(2.4188)
d_centre			18.2965**			-1.3641
			(9.2939)			(1.6630)
d_south			7.5431**			2.9219
			(2.9339)			(4.5617)
d_islands			3.1063			-4.4264**
			(3.1354)			(1.7687)
Constant	10.6088***	4.1929***	-1.7147	0.1774	-0.5846	-1.0161
	(1.5347)	(0.8632)	(2.3247)	(1.0931)	(1.2140)	(0.7186)
Observations	1,083	1,083	1,083	1,083	1,083	1,083
R-squared	0.0012	0.0098	0.0256	0.0032	0.0276	0.0300

Source: our elaboration on data provided by Italian Ministry of Economics and Finance (Ministero dell'Economia e Finanze, MEF) and by Italian Authority of Public Contracts (Autorità per la Vigilanza sui Contratti Pubblici di Lavori, Servizi e Forniture; AVCP).

*Note: robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1*

The results reported in Table 15 show that financial coverage has a different effect on cost overruns and actual cost. More in particular, high level of financial coverage seems to extend an adverse effect in the execution stage because increasing the cost overruns incurred in public work execution. On the contrary, the actual cost was negatively correlated with the level of financial coverage. This puzzling picture requires a more in-depth investigation, but our findingis, althouth preliminary seems suggest that an over coverage of the financial needs for project could incetivize opportunistic behaviour of providers in the execution stage.

6. Concluding remarks

This research aimed to provide empirical evidence on cost evolution across the different phases of project life-cycle. Following the managerial approach, I individuate four stages of project from the beginning to its completion. To address this purpose, the magnitude of cost overruns is estimated in each phase, to determine the impact of each step to the overall final performance. Thus, by distinguishing between costs of physical execution and other costs due to bureaucratic and administrative costs linked to the realisation of the work, we estimate cost overruns taking into account different index. The main results show that although a traditional estimation of cost overruns in the execution phase is relevant and around of 11%, most interesting evidence regards the behaviour of contracting authority in the planning phase. This phase seems to be the critical stage in which both the budget linked to the execution of the work and the financial coverage is overestimated systematically respect the actual cost of the project.

However, at the present stage of the research, we are not able to assess the reasons of this phenomena. However, these results shed light on a new aspect until now not extensively investigated, namely the role of contracting authority in the planning phase of the project. We believe that more effort is needed in this direction.

Finally, we believe that our empirical evidence although preliminary suggests that more stringent rules in budgeting and financial coverage could be useful to limit cost overruns in the infrastructure projects.

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Chapter 3

Assessing the role of design phase on cost overruns and time delay: evidence from public works in Italy

Abstract

This paper aims at analyzing the impact of the design phase on the performance in the realization of public works. In the literature, the design phase is largely recognized as one of the possible determinants of inefficiency in public works execution. Notwithstanding, empirical evidence on the topic remains scarce. Using a large dataset of public works awarded in Italy in the period 2008-2014, we investigate empirically the relationship between different choices made in the design phase and the performance in public works execution. Our empirical findings show that the presence of an external designer is associated with higher cost and time renegotiations. The issue is especially relevant for small municipalities that more heavily rely on external designers, possibly because of the limited expertise of their technical offices. From a public policy perspective, our findings offer some support to the recent reform of the Italian public procurement regulation that has introduced new accreditation requirements for the contracting authorities.

Keywords: Italy, public works, design phase, cost overruns, time delay, external designer.

JEL: L51, H57

1. Introduction

Public procurement represents a relevant economic field, accounting, on average, for the 12% of GDP in developed countries (OECD, 2017). Indeed, during the last years the deterioration of the public finances and the increasing global competition have forced governments and public institutions to obtain the best value for money through the purchase of goods, works and services in the form of procurement contracts (D'Alpaos *et al.*, 2009).

Common features of public procurement contracts for infrastructure provision are the presence of information asymmetries between the parts involved and the resulting contractual incompleteness, which are often related to the complexity of the project (Guccio *et al.*, 2012b). Furthermore, the lack of complete information and the uncertainty surrounding its execution prevents any future contingencies from being anticipated in the contract, thus requiring post-award adjustments. This can result in extra costs and time delays that ultimately affect the overall performance of infrastructure provision (Ganuza, 2007) .

With regard to the Italian context, ex-post contract renegotiation is a major issue in the public procurement sector, with serious economic consequences. Data from the Italian Authority for Public Contracts (hereafter, AVCP[20]) show that renegotiations of the original contracts occurred in almost two-thirds of the works awarded in the period 2000-2007 (AVCP, 2008). Such renegotiations were economically relevant, amounting to an average of about +6% for costs and +70% for time with respect to the original planned values. Moreover, for about a quarter of all works extra costs were higher than 10% of the original cost, and for about two-thirds of all works time delays were higher than 20% of the completion time agreed in the contract (Guccio et al., 2008).

The efficiency in execution of public works can be defined in terms of time of completion and final costs (Guccio et al., 2012a,b). Therefore, a public work can be regarded as efficiently executed if the time of its completion is equivalent to that agreed in the contract and if no additional project costs arise over time compared to the value of the winning bid. Both cost overruns and time delays in project execution

[20] Since 2014 AVCP has been transformed in the Anticorruption Authority (ANAC).

may have an adverse impact on the economic growth and development of local economies and, more generally, on social welfare (Flyvbjerg et al., 2002; Ganuza, 2007; Lewis and Bajari, 2011; Guccio et al., 2012a and 2014a). As point out by Lewis and Bajari (2011), the extra costs due to time delays represent a social price for the community, affecting negatively the social welfare. Indeed, the realization of public works is often necessary for the realization of other public and private investments that are likely to foster the accumulation of the economic and social capital of local communities.

The reasons for the low performance in the execution of the Italian public works reflect, among other factors, the inefficiencies of the Italian regulatory framework, the characteristics of the procurement system (i.e., the contractor selection mechanisms, the contractual forms, etc.), and the problems linked to the project design and to its management and delivery.

In the existing literature, the design phase is recognized as one of the possible determinants of the inefficiency in public work execution (Decarolis and Palumbo, 2015; Chong and Hopkins, 2016). Notwithstanding, empirical evidence on the topic still remains scarce. Using a large dataset of public works awarded in Italy in the period 2008-2014, in this paper we analyze the relationship between different choices in the design phase and the performance in public work execution. More in particular, we try to assess empirically the implications for cost overruns and time delays of the different choices made by the contracting authorities in the design phase.

Due to the large decentralization process of the public procurement system and the presence of a complex and often contradictory regulatory framework, the Italian public procurement sector is an ideal case-study to analyze the relationship between the different choices in the design phase and the presence of cost overruns and time delays. In fact, several considerations can be formulate based on the Italian public procurement regulation that encompasses a detailed and complex set of rules established by the national Parliament. In this respect, the regulatory framework for public procurement appears to be characterized by hyper-regulation at the regional and, sometimes, at the municipal level. On the one hand, precise rules about procedures and award criteria exist that must be followed by all public institutions

throughout the country. As a consequence, differences in performance cannot be straightforward related to differences existing in the procurement laws and rules, though the previous remains true for those aspects of the procurement process to which local regulations apply. Rather, it is more likely that such differences are due to the way the laws and rules are actually applied to the procurement process and to the behavior of the actors (e.g., procurers, contractors, etc.) involved in the execution of the public work. On the other hand, the Italian regulation has been strengheten over the the years, in response to the EU legislation that aimed at improving the design of the awarding procedures and at enforcing the principles of publicity, transparency and equal treatment. However, this increasing regulatory effort in the public procurment sector has had unintended consequences, leading to a significant instability of the regulatory framework and to a higher uncertainty for public and private operators. In fact, the extreme fragmentation existing in the public procurement regulatory framework determines a trade-off between the ability of the regulatory system to fully respond to the specific needs of the country and its capacity to produce benefits, at the aggregate level, in terms of reductions in public expenditures and an efficient allocation of resources (Decarolis and Palumbo, 2011).

In such a regulatory framework, the design stage is also subject to specific rules that have changed over time. The design process analysed in this study (as regulated by the Code of public contracts for works, services, and supplies – Decree n.163/2006) is made up of three distinct phases: preliminary (*progetto preliminare*), detailed (*progetto definitivo*) and final (*progetto esecutivo*). A poor initial public work design, being unable to fully specify all the characteristics of the project, can represent one of the main causes of ex-post contract renegotiation. Indeed, it is almost impossible to develop an optimal design at the beginning of the procurement process, as new and relevant information comes up only when the public work is awarded. Thus, ex-post renegotiation of the contractual terms is likely to occur.

This paper aims to contribute to the existing literature by providing further empirical evidence on the relationship between the choices made in the design phase and the extent of cost and time renegotiations of public contracts in Italy. Specifically, we investigate the impact of the choice between an internal and external designer on the performance in public works execution as measured by cost overruns and time

delays. We also critically discuss the results arising from the empirical analysis and their policy implications in the light of the new Italian Code of public works.

The remainder of the paper is organized as follows: Section 2 provides the background for the analysis by reviewing briefly the relevant literature; Section 3 examines how the public procurement regulatory framework concerning the design phase has changed in Italy over time; Section 4 presents the dataset and the empirical strategy for the analysis; Section 5 shows and discusses the results; finally, Section 6 draws some concluding remarks and policy implications.

2. Background

As previously mentioned, this paper provides a contribution to the relatively scant empirical literature on contract renegotiations in public works. Particularly, the attention has been devoted to the effects of the design phase on the extent of cost overruns and time delays, building on the previous empirical and theoretical research works.

An interesting theoretical contribution in the field of auction and contract theory, is provided by Bajari and Tadelis (2001). Looking at the whole project process, the authors discuss the strategic role of the procurer in the procurement process. In particular, they analyze the relationship existing between providing the right incentives to the procurer and the deriving effects in terms of ex-post renegotiation costs. The authors highlight the importance of the investment in the completeness of the project design made by the auctioneers at the initial phase of contracting, which lowers the likelihood that parties will need to renegotiate changes *ex post*. They show that the procurer faces a trade-off between providing the right incentives (a costly action) and reducing ex post transaction costs due to costly renegotiation. Bajari and Tadelis (2001) also examine how the optimal incentives to reduce ex post renegotiation depend on the size/complexity of the project and, ultimately, on the type of ex ante contract that the parties sign (i.e. renegotiation costs are endogenous). Indeed, in case of public works with relatively simple characteristics, detailed project designs are possible. Therefore, their model predicts that this type of works are better

procured using fixed-price contracts where a predetermined price for completing the project is defined and the risk of *ex-post* renegoziation is drastically reduced. Furthermore, fixed-price contracts provide contractors with the right incentives to contain the execution costs and, used together with ex ante competition mechanisms, are able to transfer these cost savings directly to the procurer. However, as the back of the medal, fixed-price contracts usually require higher contract design costs. Moreover, if the contract will afterwards turn out to be incomplete, the ex-post adjustment costs would be significant.

Differently, in the case of public works with more complex characteristics, it is very difficult (and costly) to achieve a detailed project design. As not all aspects and contingencies of the project realization can be included in the design, it does not make sense for the procurer to invest much in the completeness of the contract. The theoretical model developed by Bajari and Tadelis (2001) predicts that for compex works cost plus contracts, where the contractor is reimbursed for all costs incurred plus a stipulated fee, may be preferred. Furthermore, under this typology of contracts, ex-post adjustments are less costly because renegotiation frictions are eliminated (Iimi, 2009). However, a higher financial risk for the procurer occurs.

More generally, in the initial stage of procurement process, a learning period is usually required to understand the characteristics of the project and to reach a detailed design. This can give rise to sub-optimal results in the short term (due to the limited available information) that are likely to be corrected over time. Nevertheless, gathering information on the project characteristics (i.e., the previous learning process) is more costly before than during the realization of the project, as the ex-ante learning process requires forecasting contingencies that will arise during the building of the work. Moreover, the more accurate (and, thus, costly) is the initial learning process, the higher the probability that the winning firm in a competitive bidding will be the most efficient one according to the ex-post optimal design. Hence, the contracting authority faces a trade-off between the costs for the ex-ante specification of the design project and the probability of selecting the most efficient firm in the procurement process (Ganuza, 2000). In the real world, the unavoidable incompleteness of the information at the initial stages of the project requires to

renegotiate and to adjust the contractual arrangements, to correct the deficiencies of the original imperfect contract.

Another factor that should be taken into account when examining the public procurement process is the time required to construct a detailed and complete contract. Indeed, the contracting officers must decide how to allocate their limited work time among different tasks. As the number of tasks (i.e. procured works) increases, less time will be necessarily devoted to optimally specify each contract, thus leaving some contingencies unaddressed and, hence, the contract incomplete.

Based on an extension of the economic model developed by Bajari and Tadelis (2001), Warren (2014) investigates empirically how the contractual completeness and terms change in presence of a varying workload. The main result is that decreasing workload leads to less renegotiation (due to more complete contracts) and lower prices (due to a greater reliance on full and open competition mechanisms as well as to fixed-price contracts). By assumption, writing an entirely complete contract is prohibitively costly, and the marginal cost of the contractual completeness is increasing in workload. An incomplete contract may lead to costly renegotiations, but contractual completeness is set optimally, so an increase in its marginal cost will tend to decrease the equilibrium level of completeness. The effects of workload on all the other contractual choices arise due to the adjustment in completeness (Warren, 2014).

However, as the work of public bureaucratic structures is generally influenced by political decisions, the choice to leave the contract incomplete cannot only be regarded as a consequence of a high workload but it is often likely to depend on external (exogenous) factors. In such a situation, being influenced by the political power, public administrations are not the most suitable subjects to carry on planning and design activities as well as to effectively monitor the project execution phase. Otherwise, the risk would be the need to revise the project during the execution phase with the expected consequences that works are interrupted and delays are generated (Guccio *et al.*, 2009).

A further concern regards the opportunistic behavior by the contractor when the contract is incomplete. Indeed, the incentives for the contractor to carry out the changes to the original project may not depend only on the incompleteness of the

contract and on the nature or the size of the awarded work. Rather, the extent of the opportunistic behaviour and the attempt to achieve a "generous" renegotiation may be related to the characteristics of the winning bid. More precisely, they can depend on the fact that a relatively low bid, originated, for instance, by the effort to win the auction, may find a "compensation" in the event of a renegotiation (Guccio *et al.*, 2008).

As pointed out by Decarolis and Palumbo (2015), the design phase plays a relevant role in the performance of public works execution. Using data on public works awarded between the years 2000 and 2007, they test the effect of Design and Build (D&B) contracts on renegotiation. Theoretically, different typologies of design could have a different impact on the performance of public works, leading to opposite results. On the one hand, the lack of an executive project allows the firm to carry out the project using those technical solutions that are consistent with the firm's productive capacities and know-how. This might reduce the pressure for renegotiation and changes in the original project, thus decreasing the likelihood of cost overruns and time delays in the execution. On the other hand, whenever the design and the execution activities are separated, more constraints and controls arise, thus reducing the room for opportunistic behaviors by the contractor. This situation may have positive effects on the time and the costs of project completion. In their analysis, Decarolis and Palumbo (2015) find that the use of D&B contracts causes higher cost renegotiations but, unexpectedly, cost overruns decrease when the design is outsourced to a third party.

In a different paper, Decarolis and Giorgiantonio (2015) study how the Italian local public procurement regulation has changed over time and has influenced the performance in the execution of public works. Indeed, the Italian regulatory framework at the national level is supplemented by the laws and the regulations laid down by the Regional, Provincial and Municipal Authorities, thus creating a hyper-regulated system. This fragmentation in the regulatory framework generates a trade-off between the ability of the public procurement system to address and respond effectively to the different and specific needs of the territory and its capacity to produce benefits, at the aggregate level, in terms of reductions in public expenditure, and effective allocation of resources (Decarolis and Giorgiantonio, 2015). Their

analysis focuses on three core aspects of the procurement process that are economically relevant and for which they have statistical data: (i) the winning discount; (ii) the number of offers received; (iii) the probability that the winning firm is from the same region of the Public Administration. They find evidence that, in some cases, local reforms had positive effects that served the specific needs of the territory; in others, an anti-competitive orientation prevailed, with extra costs for the contracting authorities and less efficient allocation of resources (Decarolis and Giorgiantonio, 2015)

3. The design phase in the evolution of Italian regulatory framework

The Italian public procurement system is based on a complex set of rules that has been reformed many times over the years. Such excessive bureaucratization of the regulatory context is considered one of the main reasons for the inefficient use of public resources in the Italian public procurement sector (Di Giovanni, 2017), also resulting in a widespread corruption (Golden, 2003).

Over the time, the inadequacy of the existing rules, the risk of collusion, and the need to align the national regulation with the European directives have led the legislator to introduce new and significant changes to the existing regulatory framework, the last of which was in 2017 (Legislative Decree n.56/2017).

Indeed, since the 1980s the Italian public sector has been characterized by an increasing presence of corruption (Chang et al., 2010). Following the start of the so-called 'Clean Hands' inquiry in the early 1990s, which uncovered a huge web of corruption (Acconcia and Cantabene, 2008), greater public attention has been paid to the issue of corruption.

The close relationship between politics and business is also likely to affect negatively the efficiency of public works execution. The acknowledgement of this has led the Italian legislator to reorganize the entire public procurement regulatory system with the aim to ensure a more transparent and efficient management of public works. As a

consequence, a stringent regulatory approach has been adopted, which has reduced the administrative discretion over the procurement of public works.

Therefore, to improve the performance in the execution of public works as well as to align the Italian public procurement system with the European Directives, the so-called "Merloni law" (n.109/1994) was amended. Consequently, each procedural element of the procurement process was minutely regulated. The law reorganized the entire Italian public procurement regulatory system, introducing the concept of quality of the process[21] and emphasizing the strategic role of the project phase[22] as a tool to protect and to empower the interests of the contracting authority.

The first Merloni law also defined the separation between the design phase and the execution phase, assigning the former to the contracting authority[23] and the latter to an external operator. Furthermore, as previously mentioned, it disaggregated the structure of the design phase in three different levels: preliminary, detailed and final[24], each of which with specific objectives. In doing this, the law recognized the importance of the design phase for the procurement process and the fact that a low quality of the design phase may lead to a bad performance in the execution phase, thus implying the need for renegotiation.

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[21] To increase the competition and to reduce the information asymmetry on the characteristics of contractors, the Merloni law introduced a certification of qualification for the execution of public works (SOA). Specifically, it established a set of technical, organizational and financial requirements for firms wishing to participate in public tenders. Such certification ensured the firm's capacity to carry out a specific category of work for a specific level of value.

[22] The law introduced a temporal (three-years) planning for the projects and limited the use of variants during the execution of work to a percentage not exceeding 5% of the value.

[23] According to the law, the contracting authority represented the main project stakeholders whose and interests were pursued by introducing the technical figure of the RUP (*Responsabile Unico del Procedimento* - procedure manager). The RUP task was to control the realization process of the public work and to manage the different phases of the project.

[24] The preliminary design consists of an analytical and graphical report that explains the reasons for technical, environmental and economic choices given the amount that the contracting authority was willing to pay. The detailed design is developed taking into account the indications, the limits and the needs pointed out by the preliminary design. It consists of descriptive reports, graphic works, preliminary studies for structural calculus and economic analysis (*computo metrico estimativo*). The last level is the final design that contains in details the technical operations required for the execution of the work and their related costs. It consists of reports, calculus and technical designs.

Accordingly, the Merloni law denied the possibility of awarding D&B contracts where the same firm is responsible for both the design of the project and its execution. The reliance on D&B contracts in the public procurement sector presents some advantages and disadvantages. On the one hand, awarding both the design and execution phases to the same subject allows identifying responsibilities in a more straightforward way. On the other hand, using the same contract to assign the roles of the designer and the builder leaves grater room for opportunistic behaviors by both the contracting authority and the awarded firm.

To conclude, the Merloni law tried to fight the presence of corruption as well as of political influences in the Italian public works sector, providing a strict public procurement legislation aiming to reduce the inefficiency in the execution of public works and, consequently, time delays and cost overruns.

The subsequent amendment (the Merloni quarter, law n. 166/2002[25]) provided two exceptions to the general principle of separation between the design phase and the execution phase. First, it allowed the use of D&B contracts under particular circumstances. Second, it allowed the use of concessions for the realization public work. Specifically, the possibility of employing a D&B contract was limited to: (1) works with a value of up to 200,000 euros; (2) works with technological components that amount to at least 60% of the value of the work; (3) maintenance works, restoration works and archaeological excavations; (4) works with a value equal or higher than 10 million euros.

In 2006, the Legislative Decree n. 163, the so-called "Code of public contracts for works, services and supplies" transposed the European Directive n. 2004/18/EC, adding some innovative elements. Indeed, from a policy perspective, the too strict regulatory framework of the first Merloni law had resulted in a slowing down of the Italian public works sector. Thus, the new Code overcomed the previous principle of

[25] Before the Merloni *quater*, other laws in the public procurement sector were: the Law no. 216/1995 (so-called Merloni *bis*) and the Law no. 415/1998 (so-called Merloni *ter*). The legal framework also included other enforcement measures: the DPR 554/1999 - Regulation for the implementation of Merloni law; the DPR 34/2000 - Discipline of the qualification system of the subjects executing public works; the DM 143/2000 - Details and schemes for the preparation of the three-year plan and the list of works; the DM 145/2000 - General terms of contract of public works.

separation between the design and the execution phases, enlarging the possibility of using D&B contracts. In detail, three different types of contracts were considered to award public works:

1. Build contracts, to be executed on the basis of a final design;
2. Design and Build (D&B) contracts, in which the object of the bid was the final design, while the work had to be executed on the basis of the detailed design provided by the contracting authority[26];
3. Design and Build (D&B) contracts, in which the preliminary design was provided by the contracting authority, while the bidders in the competitive tender process had to provide the detailed design[27].

According to the new code, the contracting authority could use its own discretion power to choose the type of contract more suitable to its technical, economic and managerial needs. Moreover, the limits set by the previous Merloni *quater* to the use of the D&B contracts disappeared. However, for both the types of D&B contracts (i.e. points 2) and 3) of the above list), the new code imposed that the contractor had to own some technical requirements through a specific certification (*certificazione SOA*). A firm without this certification had to hire a designer with the necessary technical requirements.

Nonetheless, under the new Code, the contracting authority continued to play a crucial role in the design phase. In line with the first Merloni law, the design activity continued to be reserved to the contracting authority through its internal technical office or the technical offices of the other public authorities. Only in those cases established by the law, and after following a specific awarding procedure, the contracting authority could designate an external designer in place of an internal one. Among these cases were the lack of personnel, the difficulties met in carrying out the task and the complex works projects. Nevertheless, the use of internal personnel as designers is commonly considered a more efficient choice as it is generally less expensive than hiring an external designer. Moreover, according to the new Code, except for specific reasons, the detailed and final design phases had to be carried out

[26] It corresponds to the Design & Build stated by the Article 19, paragraph 1, letter b) of the first Merloni law.

[27] Code of Public contracts, art.53.

by the same subject. Thus, to avoid the fragmentation of the design activity, it was no more allowed to an external designer to carry out just one design, that is either the detailed or the final one.

Furthermore, the Code established a threshold of 100,000 euros as the maximum contract value for selecting an external designer without an awarding procedure. Therefore, below this threshold, the contracting authority was free to choose the designer following the principle of equal treatment, transparency, non-discrimination, and proportionality. According to the Article 57, below the above threshold, the contracting authority could also select the designer through a simplified negotiated procedure with a minimum of five tenderers. When the reserve price of the contract was equal or above € 100.000, only open competitive procedures were allowed, or the use of restricted and negotiated procedures in accordance to the rules for EU contracts.

On the opposite, when the contracting authority opted for an in-house designer, the Code recognized that an extra payment less than 2% of the value of the work was due. Thus, the law emphasized the strategic role of the contracting authority in the design phase, incentivizing the choice of internal designers. At the same time, by doing this, the new Code also limited the discretionary power of the contracting authority in the procurement process, to prevent corruption and opportunistic behaviors.

More recently, a new set of reforms has been undertaken in the Italian public procurement regulatory framework through the decree n. 50/2016 that contains the new Italian Public Procurement Code (PPC), the decree n. 56/2017 and three new European Directives (Directives 2014/23/UE, 2014/24/UE and 2014/25/UE). The new PPC has introduced many innovations in the concept of quality of the procurement process, paying further attention to the design phase and to the alignment of the national regulations with the European Directives[28].

[28] The European policy regarding public procurement aims to: (i) ensure competition in the market, (ii) reduce the public spending, (iii) fight corruption, collusion and fraud through the transparency and traceability of operations. In line with the goals of the strategy "Europe 2020", the new EU Directives are also addressed to increase the discretionary power of the contracting authorities, changing their role and assigning them higher responsibilities.

The PPC has intended to simplify the complex set of rules and laws developed in the public procurement sector over time. The concept of simplification appears in the structure of the code (e.g. a lower number of articles and attachments - soft law) and has been applied to the reform of the role of the contracting authorities (i.e. only qualified contracting authorities are allowed to award public works) as well as to the dispute settlement.

Moreover, under the new PPC, the regulation of the D&B contracts has changed again. Similarly to the first Merloni law, the PPC has reintroduced the separation between the design and the execution phases, stating the centrality of the design phase. The use of D&B contracts has not been anymore allowed, except for very few cases[29]. In addition, the rules for the public procurement process have been redifined. For example, in the planning stage, the budget for the project design has been separated by that for the execution of the work. The two budgets are now required to follow two different procedural paths. On the opposite, the preliminary design and the feasibility design[30] have been unified in a single stage. In such a way, the execution of technical and archaeological investigations must precede the design activity as a means of avoiding subsequent problems. Moreover, the new first level of design (i.e. the technical and economic feasibility project) has assumed a more prominent role than in the past, because it now includes technical analysis of the different project solutions along with a cost-benefit analysis. In addition, it represents the necessary precondition for having access to the public funds, being the project to be included in the three-year plans.

[29] The D&B contracts can be used whenever the innovative or technological part is prevalent in the value of the work and in case of a general contractor agreement, project financing, concession and public-private partnership. In such cases, the object of the contract regards exclusively the final design and the execution of the project (art.59 of D.lgs. 56/2017).

[30] The Art. 23 indicates the levels of design: (i) the technical and economic feasibility project, which replaces the preliminary design (which contains surveys, studies, graphical elaborates and economic estimates to realize the work); (ii) the detailed design; (iii) the final design. The same article provides a simplest design for those ordinary maintenance works with a value up to 2,500,000 euros. Moreover, it also specifies that the detailed and the final designs should be preferably awarded to the same subject for reasons of homogeneity and coherence. Finally, the projects with relevant archaeological, historical, artistic, environmental and technological importance has to be designed by internal designers. However, in the case in which no adequate skills are held by the technical offices, it is possible to make use of design contests or competition inviting ideas.

As far as the design phase is concerned, the PPC has paid attention to all the actors involved in the procurement process: the contracting authorities, the firms/contractors, and the technical professionals. The law has provided a qualification system for the contracting authority, a rating system for the firms and specific technical requirements for professionals. Furthermore, under the new Code, the contracting authority has lost the priority in design phase and the use of either an internal or an external designer has been virtually treated equally. In fact, the previous limits for outsourcing the project design (art. 90 D.Lgs. 163/2006) were repealed. Finally, the economic incentives recognized to the internal designers were moved from the design phase to the planning and control phases. In such a way, the new Code has underlined the importance of the planning phase, by changing the role of the contracting authority that should now be more addressed toward this direction. In this respect, the appointment of the external designers has been favoured.

Tables 1 and 2 summarize the main elements of the first Merloni Law, the Code of public contracts and the new Italian PPC with regard to the design activity and the use of D&B contracts.

Table 1 - Evolution of the regulatory framework for the design phase

Design activity	**Merloni Law (n.109/1994)**	**Code of public contracts for works, services, supplies – De Lise Law (n.163/2006)**	**New Public Procurement Code (n.50/2016) - integrated and amended by decree n. 56/2017**
Who can design	As a matter of priority, the design is assigned to the contracting authority. However, the following exceptions exist: - lack of personnel; - difficulties met in carrying out the task; - complex works; - complex projects.	As a matter of e priority, the design is assigned to the contracting authority. However, the following exceptions exist: - lack of personnel; - difficulties met in carrying out the task; - complex works; - complex projects.	No priority. Projects of relevant archaeological, historical, artistic, environmental and technological importance have to be made by an internal designer. If the required expertise is not present inside the contracting authority, it is possible to rely on design contests or competition inviting ideas.
Design levels	Three design levels: - Preliminary design; - Detailed design; - Final design.	Three design levels: - Preliminary design; - Detailed design; - Final design.	Three design levels: - Technical and economic feasibility design (which gather together the preliminary design and the feasibility design of previous Code); - Detailed design; - Final design. The Code provides a simpler design for those works of ordinary maintenance with a value of up to 2,500,000 €.
What can do the external design	The external designer is allowed to carry out just a part of a design level.	The external designer is obligated to carry out one or more complete design levels.	No specified.
Incentives for internal design	The law recognized to the public employees, an incentive (in the form of an extra payment) , but up to 1% of the value of the work to carry out . According to the Law n. 216/1995 (the so-called Merloni *bis*), this incentive is recognized for all design levels.	The extra payment recognized to the public employees acting as internal designers has not to be higher than 2% of the value of the work.	No incentive for thedesign activity.

Source: our elaboration

Table 2 - Evolution of the regulatory framework for Design and Build contracts.

Design&Build contracts	**Merloni Law (n.109/1994)**	**Code of public contracts for works, services, supplies – De Lise Law (n.163/2006)**	**New Public Procurement Code (n.50/2016) - integrated and amended by decree n. 56/2017**
Underlying philosophy	Separation between the design and the execution of the work.	Liberalization of the use of the Design and Build contracts.	Separation between design and execution of work.
Typology	No Design and build contracts. The *Merloni-quater* law (n.166/2002) introduced the Design and Build contract, in which the object of the bid was the final design, while the execution of the work was based on a detailed design provided by the contracting authority.	Two types of Design and Build contracts: - In the first type, the object of the bid is the final design, while the execution of the work is based on a detailed design provided by the contracting authority. - In the second type, the object is the final design, while the execution of the work is based on a preliminary design provided by the contracting authority. In this case, however, the task of the bidder is to provide the detailed design to submit during the tender. The bid should include the costs for the detailed design, the final design and the execution.	No Design and build contracts; each work is awarded on the basis of the final design. The decree (n. 56/2017) introduces the Design and Build contract only for works where the innovative or technological part is prevalent in the overall value of the work and in case of a general contractor, a project financing, a concession and a public-private partnership. In all such cases, the object of the contract regards exclusively the final design as well as the realization of the project.

Source: our elaboration

4. Data and empirical strategy.

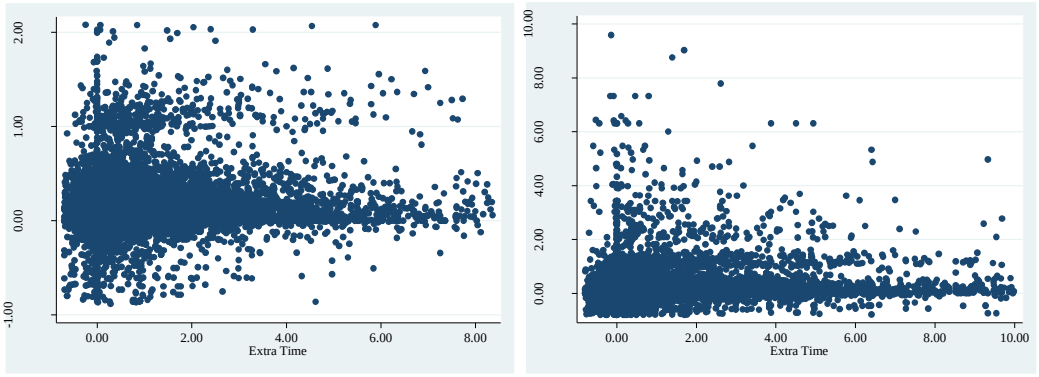
The dataset used in our analysis is provided by AVCP and comprises information on 40,898 public works contracts awarded in Italy in the period between 2008 and 2014.

Following Decarolis and Palumbo (2015), as measures of cost overruns and time delays in the execution of public works we consider the percentage variation of the final cost with respect to the awarded cost (*Extra Cost*) and the percentage variation of the time (i.e. number of days) needed to complete the work with respect to the time agreed in the contract (*Extra Time*), respectively. Therefore, positive values of these measures highlight an inefficient execution of the public contract in terms of cost overruns and/or time delays. As information on cost overruns and time delays is not available for all public works included in the dataset, after cleaning for missing data and outliers[31], the final sample is reduced to 20,757 observations (50.75% of the full sample).

Figure 1 plots data concerning cost overruns and time delays for the observations included in the study (left-hand side) and the full (right-hand side) sample. In both cases, the two variables seem to be uncorrelated. In line with Decarolis and Palumbo (2015), albeit many observations present a zero value (in the study sample: 6.4% and 12.6% for cost overruns and time delays, respectively), an upward deviation from zero seems systematic for both variables, and especially large for time delays. To further verify the previous results, we compute the Pearson correlation coefficient for the study sample. This is equal to 0.0008 and not statistically significant, thus confirming that cost overruns and time delays can be considered two independent outcomes and treated as two different dependent variables.

[31] More specifically, we drop, as outliers, observations in the first and last centile of the distribution of cost overruns and time delays values as well as those public works with a reserve price less than 150,000 euros.

Figure 1 - Scatterplot of the extra costs and the extra time. Data from the stady sample (left) and the full dataset (right)



Source: our elaboration on data provided by AVCP.

To estimate the impact of the design phase on both cost overruns and time delays, the following two Ordinary Least Squares (OLS) regressions are performed:

$$Extra\ Cost_{ijt} = \alpha + \beta X_{ijt}^{Design} + \delta X_{ijt}^{Work} + \eta X_{ijt}^{Procedure} + \theta X_{ijt}^{CA} + \gamma_t + \varepsilon_{ijt} \quad (1)$$

$$Extra\ Time_{ijt} = \alpha + \beta X_{ijt}^{Design} + \delta X_{ijt}^{Work} + \eta X_{ijt}^{Procedure} + \theta X_{ijt}^{CA} + \gamma_t + \varepsilon_{ijt} \quad (2)$$

where the dependent variables are either cost overruns or time delays in the execution of the public work *i* awarded by the procurer *j* in the year *t*. In both equations, X_{ijt}^{Design} is the vector of our interest variables. These include a dummy variable equal to 1 whether the contract is a Design and Build and zero otherwise (*Design & Build*). Furthermore, two different dummies are also considered in the estimations that assume a value of 1 (zero otherwise) when an internal designer is chosen (*Internal designer*) and/or the project design is delivered by an external designer (*External designer*). The use of two dummies for the appointment of the designer allows controlling for the case in which both an internal and external designer coexist, though this occurrence regards a very limited number of our observations (about 2% of the study sample).

Building on the previous literature (see among others Decarolis and Palumbo, 2015; Guccio et al., 2012b and 2014b), X_{ijt}^{Work} , $X_{ijt}^{Procedure}$ and X_{ijt}^{CA} represents three vectors of control variables, related to the type of work, the characteristics of the

awarding procedure and the typology of contracting authority. In particular, the vector X_{ijt}^{Work} includes the log of the reserve price (*Log_Reserve price*) as a proxy of the complexity of the work. Here, the underlying idea is that more complex is the work the higher the uncertainty in the planning stage that could lead to more inaccurate cost forecasts. However, as higher reserve prices could imply higher penalties for time delays, the variable is expected to be negatively associated with extra time. As a further control for the type of awarded work, we insert a dummy (*New construction*) taking the value of 1 if the work is a new construction and zero otherwise. Thus, we expect that the likelihood of time delays is greater for the execution of new works due to the higher uncertainty surrounding the construction of a new building. On the opposite, the ex-ante expectations on the impact of this dummy on cost overruns is more controversial, as the maintenance of an existing structure might even lead to higher cost renegotiations than the realization of a new construction. Finally, a dummy for each type of work, following the Italian classification of public works (general works - OG, specialized works - OS and their subcategories) is also added to control for the variability of cost overruns and time delays across different work categories.

As far as the type of awarding procedure is concerned, we use a set of dummies to distinguish between: direct award (*Procedure: direct award*), negotiation (*Procedure: negotiation*), first price auction or economically most advantageous tender (*Procedure: auction FP and EMAT*), and average price auction (*Procedure: auction average price*). For these variables, we expect that more competitive procedures can affect the extent of renegotiation, since they provide firms with an incentive to underestimate the costs in order to increase the probability to win the deal.

With regard to the type of the contracting authority, X_{ijt}^{CA} includes a set of dummies (i.e., *PA type: small municipality* = municipality with less than 5,000 inhabitants*; medium municipality* = municipality with a number of inhabitants between 5,000 and 15,000*; big municipality* = municipality with more than 15,000 inhabitants;, *province; region; public company; autonomous entity and Central Government*) to account for the different governance models. Our hypothesis is that smaller-sized and generalist public contracting authorities, such as small municipalities, are expected to

be more inefficient than bigger-sized and specialist ones. This happens because in most small Italian municipalities the offices in charge of monitoring the execution of public works can fail to achieve the optimal size required to execute the work efficiently and are also more likely that they are lacking of all the proper professional human competences needed to carry out this task. Last but not least, all estimates control for year and regional fixed effects. To test the robustness of our findings, we include also contracting authority fixed effects.

Descriptive statistics for all the variables included in the analysis are provided in Table 3 for both the study sample and the full dataset. The summary statistics for the two samples are quite similar, except for the mean of dependent variables *Extra Cost* and *Extra Time* that, in the full sample, is affected by the presence of many outlier values. Nevertheless, the median value is almost the same between the samples. This provides evidence that the study sample, though comprising a reduced number of observations, is as representative of the universe as the full sample.

Looking at specific issue of this research, namely the role of the design phase on cost overruns and time delays, Table 4 shows the share of public works in the study sample for which an internal or an external designer was selected according to the geographic macro-area where the work was procured and the type of the contracting authority. As expected, small municipalities make a larger use of external designers due to the lack of adequate internal technicians (skills) in their purchasing offices. On the opposite, as the contracting authorities serve a larger population or became more specialized (such as for autonomous entities or for public companies), the use of internal designers prevails. The only exception is regional contracting authorities in the North-West area of the country where the reliance on external designers is much greater than that on internal designers. However, such anomaly is mostly due to the influence of the small autonomous region of Valle d'Aosta, in which almost all public works make use of an external designer (about 96%). Except for this, difference in the use of internal/external designers by type of the contracting authority are similar among macro-areas. For such reason, in order to give more robustness to our analysis, we also estimate Eqs. (1) and (2) for a restricted sample including just public works awarded by municipalities (11,306 observations).

Table 3 - Descriptive statistics for the selected variables

Variable	Source	Study sample				Full dataset			
		Mean	SD	P50	N	Mean	SD	P50	N
Extra Cost	AVCP	0.11	0.26	0.05	20,757	0.27	6.10	0.05	40,423
Extra Time	AVCP	0.77	1.19	0.38	20,757	0.97	3.06	0.36	30,337
Internal designer	AVCP	0.45	0.50	0	20,757	0.44	0.50	0	34,008
External designer	AVCP	0.37	0.48	0	20,757	0.39	0.49	0	34,008
Design & build	AVCP	0.08	0.28	0	20,757	0.08	0.26	0	40,695
Log (reserve price)	AVCP	12.76	0.71	12.59	20,757	12.62	0.81	12.49	40,857
New construction	AVCP	0.33	0.47	0	20,757	0.33	0.47	0	40,898
PA type: small municipality(<5000)	AVCP	0.15	0.35	0	20,757	0.15	0.36	0	40,898
PA type: medium municipality (5000/15000)	AVCP	0.13	0.34	0	20,757	0.12	0.32	0	40,898
PA type: big municipality (>15000)	AVCP	0.27	0.44	0	20,757	0.26	0.44	0	40,898
PA type: province	AVCP	0.14	0.34	0	20,757	0.15	0.36	0	40,898
PA type: region	AVCP	0.05	0.22	0	20,757	0.06	0.23	0	40,898
PA type: public company	AVCP	0.15	0.35	0	20,757	0.14	0.35	0	40,898
PA type: autonomous entity	AVCP	0.04	0.19	0	20,757	0.04	0.20	0	40,898
PA type: central government	AVCP	0.08	0.27	0	20,757	0.08	0.27	0	40,898
Procedure: direct award	AVCP	0.08	0.28	0	20,757	0.14	0.35	0	40,898
Procedure: negotiations	AVCP	0.41	0.49	0	20,757	0.44	0.50	0	40,898
Procedure: auction average price	AVCP	0.33	0.47	0	20,757	0.27	0.44	0	40,898
Procedure: auction FP and EMAT	AVCP	0.17	0.38	0	20,757	0.16	0.37	0	40,898

Source: our elaboration on data provided by AVCP.

Table 4 - Distribution of works with an internal and external designer by macro-area and type of contracting authority (study sample)

Type of contracting authority	Macro area											
	North-East		North-West		Central		South		Islands		Italy	
	Internal designer	External designer	Internal designer	External designer	Internal designer	External designer	Internal designer	External designer	Internal designer	External designer	Internal designer	External designer
Small municipality	15.8%	59.7%	11.1%	87.3%	13.5%	66.1%	19.6%	60.8%	13.2%	78.2%	14.3%	72.0%
Medium municipality	24.7%	51.9%	27.7%	72.6%	32.4%	47.3%	19.6%	65.9%	29.3%	66.1%	26.0%	61.1%
Big municipality	47.5%	27.6%	51.3%	49.6%	49.4%	25.2%	50.4%	33.1%	49.9%	43.0%	46.5%	38.3%
Province	47.0%	18.2%	68.1%	34.3%	66.1%	10.8%	60.2%	24.6%	72.5%	21.8%	61.2%	22.4%
Region	79.5%	5.2%	29.3%	71.1%	40.6%	19.4%	79.9%	10.7%	64.2%	25.0%	58.5%	29.2%
Public company	47.0%	20.5%	50.0%	45.1%	40.7%	17.2%	58.1%	8.9%	73.6%	6.8%	51.6%	24.9%
Autonomous entity	42.7%	37.1%	63.4%	32.9%	31.2%	17.8%	82.3%	23.2%	71.2%	27.3%	51.0%	25.1%
Central Government	31.0%	22.8%	54.7%	26.0%	77.8%	6.0%	58.4%	20.1%	56.7%	19.2%	58.3%	16.6%

Source: our elaboration on data provided by AVCP.

Table 5 sheds light on the awarding of Design & Build (D&B) contracts. In line with the nature of the D&B contract, the table shows that in almost all geographical areas the use of this type of contract rises as the reserve price (and, hence, the complexity of the work) increases. For each of the three reserve price classes, it exhibits values slightly higher in the Central Italy, especially in the region Lazio where is located the capital city (i.e., Rome) and the seat of central government.

Table 5 - Distribution of Design and Build contracts by macro-area and reserve price (study sample)

Reserve price	**Macro area**					
	North-East	North-West	Central	South	Islands	Italy
< 1,500,000	5.6%	6.7%	8.6%	6.8%	11.0%	7.0%
1,500,000 / 5,000,000	13.4%	18.1%	16.3%	26.0%	17.0%	16.7%
>5,000,000	24.3%	34.6%	50.0%	27.6%	33.3%	32.6%

Source: our elaboration on data provided by AVCP.

5. Results

Table 6 presents the estimation results for the Eqs. (1) and (2), without (columns 2 and 3) and with contracting authority fixed effects.

Overall, the findings confirm the strategic role of the project designer in the performance of public works execution. The empirical evidence reported in Table 6 shows that, *ceteris paribus*, the choice of relying on an external designer is associated with higher cost overruns and time delays compared to all the other design options: in all estimates, the coefficients of the *External designer* variable are positive and highly statistically significant. One possible explanation for these results is that an external designer does not put much effort in performing his/her task, thus resulting in wrong predictions concerning the expected costs and time for the work execution. This is because his/her assignment ends with the realization of the project design and he/she will not be considered responsible for the consequences of carrying out a bad job.

Table 6 - Estimation results. Dependent variables: Extra cost and Extra time. Study sample.

VARIABLES	(1) Extra cost	(2) Extra time	(3) Extra cost	(4) Extra time
Internal designer	0.0005	-0.0592***	-0.0020	0.0129
	(0.0046)	(0.0213)	(0.0057)	(0.0276)
External designer	0.0257***	0.1288***	0.0164***	0.1675***
	(0.0051)	(0.0243)	(0.0060)	(0.0322)
Design & Build	-0.0144**	0.0143	-0.0365***	0.0713*
	(0.0066)	(0.0280)	(0.0082)	(0.0374)
Log (reserve price)	0.0007	-0.0439***	0.0077**	-0.0242
	(0.0029)	(0.0122)	(0.0035)	(0.0152)
New construction	-0.0081**	0.1376***	-0.0081*	0.0944***
	(0.0039)	(0.0195)	(0.0047)	(0.0238)
PA type: small municipality	0.0113**	0.2394***		
	(0.0056)	(0.0300)		
PA type: medium municipality	-0.0090*	0.2132***		
	(0.0050)	(0.0308)		
PA type: province	-0.0258***	-0.0358		
	(0.0057)	(0.0272)		
PA type: region	-0.0082	-0.1445***		
	(0.0079)	(0.0371)		
PA type: public company	-0.0178***	-0.1582***		
	(0.0058)	(0.0264)		
PA type: autonomous entity	-0.0070	-0.1948***		
	(0.0091)	(0.0365)		
PA type: central government	0.0167*	-0.1462***		
	(0.0095)	(0.0340)		
Procedure: negotiations	0.0231***	0.1625***		
	(0.0068)	(0.0316)		
Procedure: auction average price	0.0302***	0.1518***		
	(0.0070)	(0.0335)		
Procedure: auction FP and EMAT	0.0270***	0.2396***		
	(0.0079)	(0.0384)		
Constant	0.1100**	1.1237***	0.0651	1.2975
	(0.0474)	(0.1773)	(0.0724)	(0.9557)
Work type category fixed effects	YES	YES	YES	YES
Regional fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Contracting authority fixed effects	NO	NO	YES	YES
Observations	20,751	20,751	18,582	18,582
R-squared	0.1686	0.0799	0.4038	0.3081

Source: our elaboration on data provided by AVCP.
Notes: ***, **, * denote significance at the 1%, 5% and 10% level. Robust standard errors in parenthesis.

Table 7 - Estimation results. Dependent variables: Extra cost and Extra time (restricted sample).

VARIABLES	(1) Extra cost	(2) Extra time	(3) Extra cost	(4) Extra time
Internal designer	-0.0004	-0.0437	0.0072	0.0753*
	(0.0061)	(0.0350)	(0.0078)	(0.0451)
External designer	0.0167***	0.0659*	0.0241***	0.1632***
	(0.0064)	(0.0346)	(0.0077)	(0.0475)
Design & Build	-0.0058	-0.0365	-0.0262**	0.0325
	(0.0093)	(0.0458)	(0.0133)	(0.0632)
Log (reserve price)	0.0133***	-0.0542***	0.0114**	-0.0499**
	(0.0038)	(0.0188)	(0.0048)	(0.0245)
New construction	-0.0194***	0.1075***	-0.0141***	0.1055***
	(0.0044)	(0.0259)	(0.0054)	(0.0326)
PA type: small municipality	0.0099*	0.2501***		
	(0.0056)	(0.0322)		
PA type: medium municipality	-0.0054	0.2449***		
	(0.0050)	(0.0319)		
Procedure: negotiations	0.0516***	0.1338**		
	(0.0104)	(0.0605)		
Procedure: auction average price	0.0632***	0.1365**		
	(0.0105)	(0.0628)		
Procedure: auction FP and EMAT	0.0484***	0.2119***		
	(0.0112)	(0.0673)		
Constant	-0.1003	1.2150***		
	(0.0666)	(0.2688)		
Work type category fixed effects	YES	YES	YES	YES
Regional fixed effects	YES	YES	YES	YES
Year fixed effects	YES	YES	YES	YES
Contracting authority fixed effects	NO	NO	YES	YES
Observations	11,306	11,306	9,658	9,658
R-squared	0.2255	0.0665	0.4853	0.3355

Source: our elaboration on data provided by AVCP.
Notes: ***, **, * denote significance at the 1%, 5% and 10% level. Robust standard errors in parenthesis.

Theoretically, the above explanation leaves room for wrong predictions by the external designers in terms of both costs and time delays that should be randomly distributed between overestimation and underestimation. Notwithstanding, our results seem to show that the final impact of appointing an external designers is that of increased costs and time, meaning that in the design phase the costs and days required for the realization of the project are systematically underestimated. In this respect, an alternative explanation for this systematic underestimation relies on the possibility that during the execution phase, when the design is appointed to an external designer the audit performed by the internal technical offices is less effective than when the design is performed internally.

As for the *Internal designer* variable, Table 7 does not show statistically significant associations with our dependent variables of public work performance in the execution phase. On the opposite, *Design & Build* shows a negative and statistically significant (at the 5% level) association with *Extra cost* only when contracting authority fixed effects are inserted. This means that within those works awarded by the same contracting authority, contracts that assign the execution and the design phaseto the same subject (i.e., D&B contracts) appear to reduce cost renegotiations.

With regard to the other control variables, consistently with our previous expectations, the coefficients for the variable indicating the complexity of the work (as measured by the log of the reserve price), though not always significant, are positively associated with *extra cost* and negatively associated with *extra time.* Moreover, the coefficients for *New construction* are always statistically significant, indicating a positive association with time delays and a negative relationship with extra costs. Except for the specifications in columns (3) and (4), the dummy for small municipalities is always significant and positively related to both time and cost renegotiations (reference category: big municipalities), while public companies exhibit a better performance with regard to both extra costs and time, thus confirming our previous hypotheses. Finally, the dummies for competitive procedures (reference category: direct award) show positive and statistically significant signs with both cost overruns and time delays, in almost all specifications.

When the analysis is restricted to the sample of municipalities, Table 7 shows that previous conclusions concerning the role of the internal/external designer, D&B contracts and small-sized municipalities on extra costs and extra time continue to hold, though most associations are statistically less significant.

6. Concluding remarks

In this paper, we explore the role of the design phase on the cost and time performance in the execution of public works. Particularly, we analyse empirically how variables such as the choice of an internal and/or an external designer, the use of D&B contracts and the type of the contracting authority are related to the cost overruns and time delays of Italian public works.

Our findings show that entrusting the design phase to an external designer is statistically associated with higher cost overruns and time delays. This is a particular relevant issue as the probability to rely on an external designer is likely not to be uniform across contracting authorities but to depend on their characteristics. Specifically, in Italy small-sized municipalities, acting as contracting authorities, are often unable to manage the design phase in-house, due the lack of adequate and specialized personnel in their technical offices. Therefore, they often outsource the design phase, thus undermining the overall efficient performance in the execution of the work. Moreover, as the capability and the experience of the bureaucratic structures are generally influenced by the size and the availability of economic resources, local governments are likely to be less efficient in the execution of public works, other things being equal. In this respect, our empirical analysis seems to confirm this conclusion.

A further result arising from the paper concerns the use of D&B contracts where the design phase and the construction phase are appointed to the same subject. In contrast with Decarolis and Palumbo (2015), we find that D&B contracts are negatively associated with extra costs. Indeed, our result seems to be more consistent with the prediction that by overlapping the two phases of the project opportunistic behaviours are reduced.

In terms of policy implications, our findings seem to support the recent regulator's decision to improve the quality and the performance of public work by introducing a system of qualification of the contracting authorities that takes into account the type of procurer as well as the endowment and the expertise of the personnel in its technical offices. On the contrary, our evidence does not support the provisions included in the new Public Procurement Code that go in the direction of weakening the priority role of the contracting authority in the design phase, putting on the same plane the appointment of either an internal or an external designer.

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