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Framework Agreements in the Public Sector: the impact of a Hybrid Form of Procurement on the Government Objective of Cost Control

Evidence from the Military Supplies, with a focus on the Italian Ministry of Defense

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Abstract

In the current dialogue on the effectiveness of Government procurement practice, hybrid structural approaches are considered valid instruments to foster an efficient resource allocation.
However, they pose unique challenges in terms of controlling the level of variability and uncertainty in the supply chain, and ultimately, can threaten the advantage obtainable from the centralization of the procurement process.
Since the first introduction of the contractual form of Framework Agreement, academics and practitioners are constantly in search of new ways to solve the trade-off between the need for standardization of the procurement process and the variability triggered by a decentralized order management at the level of individual procuring authorities. Such decentralized execution, indeed, introduces conditions of heterogeneity in the administration of requests that must be considered with caution if one aims to ensure efficiency in public procurement, as it may have a direct impact on procurement prices.
Starting from these premises, the research aimed to quantitatively estimate the impact of the heterogeneity generated during the order allocation phase on the prices obtained through the use of Framework Agreements. In this sense, an attempt has been made to estimate whether the price advantage obtained over purely decentralized procurement systems will be subject to fluctuations due to these sources of heterogeneity, named heterogeneity in lot quantities, heterogeneity in times of order, heterogeneity in delivery terms, and the number of procuring authorities.
The empirical analysis was conducted in collaboration with the Italian Ministry of Defense, and built upon the data retrieved from the Framework Agreements awarded to Motorola Solutions Inc. and Leonardo S.p.A.
The empirical findings from the multiple regression revealed that the centralization of the procurement function, even if only partly conducted in the use of Framework Agreements, resulted in an advantage in terms of cost control. However, evidence of correlation with systematically lower price savings was found in the specific dimensions of heterogeneity in lot quantities, times of orders, and the number of procuring authorities, and not for the heterogeneity in delivery terms, which was not found to be statistically significant. Therefore, the weaknesses of a hybrid model were highlighted in these results.
The scope for academics and executives is aimed at raising awareness of these dimensions and directing action and investigation towards more compliant technical processes to sustain an effective government procurement management.

The study roots its originality in its attempt to uncover specific boundary conditions within which the cost control objective of the public operator is challenged. Most of the earlier literature has focused on either purely centralized or decentralized procurement systems, poorly considering hybrid configurations.

The specified *hybrid* form of Framework Agreements is indeed a promising context for increasing the existing knowledge regarding centralized purchasing systems and testing their preferential considerations also considering the dynamics that occur in its decentralized operativity.

The objective of raising awareness of the implied criticalities is not only aimed to ensure better management of the public budget but, in a broader framework, poses its rationale in directing a more effective allocation of resources for the benefit of the entire community.

Preface

The master's thesis "Framework Agreements in the Public Sector: the impact of a Hybrid Form of procurement on the Government objective of Cost Control" is in your hands.
This thesis project was the culmination of the Double Degree program conducted between LUISS “Guido Carli” and Tilburg University.
During this program, I had the opportunity to conduct two degree courses - in parallel - at two leading universities, among the best in Europe.
I will never be adequately thankful for the opportunity given to me, which has been fundamental for my professional and, above all, personal growth.
Indeed, this path has been a crucial challenge, allowing me to prove myself in an international field and at a university of renowned academic worth.
Therefore, I would like to thank my family for making this possible, you gave me a life I could never have even imagined.
I would also like to thank professors Eirini Spiliotopoulou and Fabian Homberg.
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Furthermore, I would like to express my gratitude to Colonel Marco Iannone, who was vital in guiding me to conduct my study within the Ministry of Defense.
I will treasure this chance and all the valuable advice.
Finally, I would like to express my greatest affection to all my fellow travelers, you are such beautiful and talented people who always pushed me to do my best. Thank you.

Maria Vittoria de Robertis

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Chapter one – Introduction

1.1 Research background

The evaluation of the effectiveness of public procurement practices is of high priority in the current debate. It involves a significant amount of taxpayers' money, and governments have always been expected to manage these processes effectively and in accordance with high expectations of conduct to preserve the quality of services delivered and to promote the citizen's interest (OECD, 2022)[1]. Public procurement policies, procedures, and systems have a direct impact on the government's objective of cost control, and more broadly contribute to citizens' quality of life and well-being. For this reason, it is a key priority that the procurement policies are conducted according to sound technical processes, which need to be in line with the characteristics of the supply.

In particular, standard contractual agreements have shown to be inadequate in those procurement processes where public administrations cannot predetermine, precisely and circumstantially, the quantities of goods to be purchased or in situations characterized by rapid technical obsolescence and/or strong market value fluctuations. There are numerous examples of abuse and failure to achieve value for money in such procurement, which can often be attributed to largely opaque, non-competitive, and unstructured methods of procurement (The World Bank, 2021). To meet this need, Article 33 of Directive 2014/24/EU of 26 February 2014 has introduced the contract instrument of the Framework Agreement to overcome the problems encountered in the standard contractual forms used by Member State Governments.

According to the definition, a FA is "an agreement between one or more contracting authorities and one or more economic operators, the purpose of which is to establish the terms governing contracts to be awarded during a given period, in particular with regard to price and, where appropriate, the quantities envisaged" (Official Journal of the European Union, 2014).

Many arguments supported its use in government procurement (Albano, Ballarin, & Sparro, 2010; Tennant & Fernie, 2010; Loader, 2010; Caldwell, Walker, Harland, Knight, Zheng, & Wakeley, 2005), including the possibility for authorities to establish strategic alliances with their

[1] According to data reported for OECD countries, government budget allocation for procurement as a share of GDP increased slightly from 11.8% in 2008 to 12.6% in 2019. However, it's significant to note that the impact of the COVID-19 pandemic resulted in a noticeable growth in 2020. Specifically, according to the data for the 22 countries that are part of both the OECD and the EU, 14.9% of GDP was devoted to public procurement in 2020, up from 13.7% in 2019. These data show that, in comparison to the year before the pandemic, a larger percentage of GDP was allocated to public procurement, and an ever-increasing trend is suggested by the current geopolitical instabilities (retrieved from https://www.oecd-ilibrary.org/sites/18dc0c2d-en/index.html?itemId=/content/component/18dc0c2d-en).

supply chain partners, fostering coherence of approach, and better value for money (achieving procurement savings through the generation of economies of scale), and providing the opportunity for continuous improvement. A practical advantage is that the authority can save time and money by duplicate tendering avoidance, without the need to re-advertise and re-apply selection and award criteria.

Framework Agreements are currently an established award method and generally accepted practice across Europe (OECD, 2011).

1.2 Problem Indication

Over time, the academic debate has focused on defining categories of benefits and conditions of operativeness (The World Bank, 2021), as well as proposing models to quantitatively estimate FA cost effect (Karjalainen, 2009), contributing to the creation of a consensus on the real effectiveness of the contract in terms of savings in the specific legal case.
Much has been debated on the efficacy of centralized forms of purchasing versus decentralized forms (Mccue & Gianakis, 2001; Thai, 2001; Hunja, 2003; Karjalainen, 2009), and considerations specifically regarding the contractual form of the FA intersect in this debate considering its inherently centralized nature but, at the same time, clarifying its decentralized approach in order management as the most used architecture observed among practitioners. This said, FAs have been more generally considered as *hybrid* forms of procurement.

However, it is precisely in their partial decentralization that critical issues may be hidden. It was pointed out that the benefits of FAs may be enhanced in the case of a *high degree of standardization on the demand side*, i.e. from the point of view of the procuring authorities (The World Bank, 2021). The possibility of standardizing needs and limiting demand-side variations should increase the possibilities of achieving economies of scale and realizing volume pooling benefits. Specularly, this would affect firms' bidding strategies, as it would lead to more favorable pricing conditions as they can rely on economies of scale for bulk orders and reduced uncertainty in the planning process and demand forecast. The central idea is that a more (or less) homogeneous demand would lead to greater (or lesser) cost savings in a centralized purchasing system than in a decentralized one. In the specific case of a hybrid structure, issues may arise precisely from the reduced homogeneity in the requests, which may lead to reduced efficiency of the procurement process.

1.3 Problem Statement and Research Gap

Considering these premises, it would seem reasonable to investigate what the direction of impact of heterogeneous demand is on the potential cost savings associated with a centralized purchasing system, in the specific case of a FA. The specified *hybrid* form of Framework Agreements is a promising context for increasing the existing knowledge regarding centralized purchasing systems and testing their preferential considerations also considering the dynamics that occur in its decentralized operativity. When properly designed, demand aggregation or centralized public procurement, may significantly lower purchasing costs and in so increase the possibility of obtaining efficiency gains for the Government procurement practice.
According to the distinction made in the literature (Baldus & Hatton, 2020), a centralized structural approach to procurement (as the use of the FA contractual instrument) increases the potential for efficiency gains, which can be defined as the potential of conducting procurement initiatives within an optimized cost structure. The potential to achieve a better value for money can, in the words of Baldus and Hatton (2020), be achieved from two different sources: more advantageous price conditions, given the possibility of aggregating demand from several contracting authorities; by duplicate tendering avoidance, making the process leaner.

However, as outlined before, most of the earlier literature has focused on either purely centralized or decentralized systems, poorly considering *in-between* areas. This leaves a significant gap, which offers the possibility for new research in the field. Furthermore, a limited number of earlier research studies have been highlighted as addressing the issue of centralization of public procurement from a specialized SCM perspective and for specific contractual forms. When found, prior contributions have mainly focused on investigating the advantages and disadvantages of different organizational arrangements without considering the impacts in monetary terms and from a cost control perspective in sufficient detail.

Particularly, prior works, such as the article published by Karjalainen in 2009, took the first steps in estimating the extent of the cost reduction achievable with the use of a Framework Agreement, and in so considering in monetary terms the contribution of the two sources of efficiency as evidenced by Baldus and Hatton (2020).

The present research intersects this dialogue with a focus specifically directed at estimating which conditions can erode the price savings achievable by centralized forms of procurement. The introduction of the concept of demand heterogeneity was presented precisely for this purpose, as it is exactly the specific aspects that characterize a heterogenous demand from the procuring

authorities that will be subject to analysis in order to estimate whether a relationship with lower price savings can be verified for these dimensions.

For the specific objective, the present research defines sources of demand heterogeneity for a specific FA along four dimensions: heterogeneity in lot quantities, heterogeneity in times of order, heterogeneity in delivery terms, and the number of procuring authorities. Justification for the specific variables is rooted in the actual academic contributions, which are captured in Chapter 2. Specifically, according to the "Guidebook for Setting-up and Operating Framework Agreements" published by the World Bank (2021), degrees of heterogeneity in these dimensions can cause a decline in the required performance standardization, thus reducing the possibility of justifying lower prices from economic operators, as they induce variability and uncertainty in order management. The result is a decrease in the potential cost savings, due to the increased complexity that is taken into account in the settlement of firms' bidding strategies.

For this reason, the research direction will delve into quantitatively estimating the cost savings of specific FA and test the impact of demand-side variations, answering the query of whether, in what form, and with what intensity they are correlated with lower savings, negatively affecting the attainment of more favorable contract price conditions.
In this light, it is possible to assess the criticalities of a procurement structure that is not purely centralized, but decentralized in its execution, with more accuracy, and with an estimation of the price effect of *hybrid* forms of procurement.

The estimation of price savings achievable with the use of Framework Agreements will be done through a methodology used for similar studies conducted in the field, where the cost reduction was calculated by comparing historical price records of decentralized tenders (adjusted considering the effect of inflation) against the baseline prices offered in several Framework Agreements utilized as a sample. The different variables presented as dimensions of demand heterogeneity will be then regressed to assess the presence, direction, and intensity of correlation with lower values of the indicated price saving. The present research will therefore be directed at answering the following question:

Is the use of Framework Agreements related to a more efficient Government Procurement and are conditions of demand heterogeneity from the point of view of the procuring authorities correlated to the attainment of less favorable price conditions?

1.4 Research questions

To address the problem as cleared, this study is grounded in several research questions, which will each attempt to realize a specific research objective.

1.4.1 Theoretical Questions

RQ1: What are the actual rules for setting up and correctly operating Framework Agreements, and which arguments support its use for promoting efficiency in Government procurement?

RQ2: Are hybrid forms of Framework Agreement potential sources of variability in the procurement process? In particular, how do they relate to forms of demand heterogeneity from the procuring entities, and how can we explain their effect on the contract's price?

1.4.2 Empirical Question

RQ3: How and in which form do sources of demand heterogeneity relate to less favorable price conditions? In so, which additional contingent factors need to be furtherly considered in the mentioned relationship?

1.5 Theoretical contribution and Managerial Implications

A greater understanding of the phenomenon is of theoretical relevance because it is expected to offer empirical and quantifiable support of specific boundary conditions under which the benefits of moving the procurement process on a more centralized configuration can be scaled down, conditions that need to be taken into account when performing a cost-benefit analysis in the choice of alternative design.
Quantifying the intensity of the impact of specific variables connected to dimensions of demand heterogeneity on the attained price, can also inform public authorities by improving their decision models toward more price-effective procurement management. In so, it has practical relevance, as to inform the decision-making of procuring authorities in implementing sound technical processes to satisfy public needs efficiently.

Indeed, in the choice of hybrid procurement configurations, they must take into account the side effects of a model that is not purely centralized, i.e. centralized in the award phase and decentralized in the post-award phase, as a Framework Agreement can be defined.

In addition to this, a new avenue can be opened for contributing to increasing social welfare, which is the fundamental goal of the Public Mission. Yet, cost control is only a limited view of the objective(s) pursued by centralized procurement processes conducted by governmental authorities, despite being still quite popular. Benefits can be added that accrue to the entire society, as opposed to just the final consumers of the purchased good, service, or work.

Chapter two - Theoretical background

The following chapter presents the theoretical foundation of the master thesis. The aim is to separately analyze what a Framework Agreement is, and which arguments favored its adoption by a growing number of States.
Therefore, the rationale behind hybrid forms of FA will be introduced and explained to the reader, and in so, an answer to RQ1 will be disclosed. The relationship with the concept of demand heterogeneity and its impact on procurement price will be also clarified, and this has been done to provide theoretical support to the hypotheses to be tested and answer RQ2.
For this purpose, the theoretical part is structured as follows: The FA is first defined in 2.1 and how it can drive efficiency in public procurement is explained; afterwards, the rationale and description of hybrid forms of FA and how they relate to forms of demand heterogeneity is discussed in section 2.2; section 2.3 will be delved to clarify how and in which form conditions of demand heterogeneity can have an impact of price savings; finally, section 2.4 will follows, with the presentation of the conceptual model and some concluding remarks.

2.1 Framework Agreements as a driver for efficiency in the public procurement process

2.1.1 Central purchasing bodies and Framework Agreements: a brief introduction

Framework Agreements are pre-established agreements for the provision of specific supplies over an extended period of time.
Three general definitions of FAs can be found in international standards and legislation (Racca, Cavallo Perin, & Albano, 2010):

- In the context of the European Union, Article 33 of Directive 2014/24/EU of 26 February 2014 defines Framework Agreements as “an agreement between one or more contracting authorities and one or more economic operators, the purpose of which is to establish the terms governing contracts to be awarded during a given period, in particular with regard to price and, where appropriate, the quantities envisaged” (Official Journal of the European Union, 2014);
- The definitions given by The United States of America entail the notations of Government-Wide Acquisition Contracts (GWAC), Indefinite Delivery/Indefinite Quantity (IDIQ)

contracts, and Multiple Award Schedules (MAS), which refer to the provision of several ongoing agreements followed by a phase of competition for tasks or orders to be delivered;

- The United Nations Commission on International Trade Law (UNCITRAL) provides another definition of a Framework Agreement as a "periodic/recurrent purchase arrangement" or a "periodic supply vehicle", which secures the delivery of specific supplies over a predefined time horizon.

From the common traits evidenced in the definitions above, is precisely the ability to aggregate demand for goods and services, which will be delivered or provided at various times, that distinguishes Framework contracts from other contractual instruments. For this reason, the use of Framework Agreements is best suited for contracts that meet consolidated needs over time, the number of which, as well as the precise time of their occurrence, is unknown in advance. Moreover, since the price is defined at the award stage, and remains constant during the post-award horizon, this makes it particularly useful when the good or service subject to the agreement is subject to strong price fluctuations.

A Framework Agreement is also defined in practice as a form of centralized purchasing system. The OECD (2011) definition of a centralized purchasing system is "the establishment by the government of a centralized agency with the task of procuring goods and services for the benefit of other government agencies and bodies in order to reduce the cost of public procurement" (OECD, 2011, as cited in Aboelazm & Afandy, 2019, p. 263).
This means that the creation and administration of the suggested contract will therefore be handled by a centralized organization. Indeed, the Public Sector Directive[2] defines a Central Purchasing Body (CPB) as a contracting authority that:

- purchases products or services for single or multiple contracting authorities;
- grants public contracts to one or more contracting authorities for works, products, or services; or
- awards Framework Agreements for specific supplies on behalf of the requirements identified by multiple contracting authorities.

Thus said, the research will primarily focus on a centralized purchasing system (CPS) in which the CPB awards and manages Framework Agreements. The FA's customers will be defined in

[2] SIGMA (2011). Central Purchasing Bodies. Public Procurement Brief 20. Retrieved from https://www.sigmaweb.org/publications/Purchasing_Public_Procurement_2011.pdf

the remainder of the discussion as “procuring authorities”, in such a way that the ambiguity in its multiple definitions is neutralized.

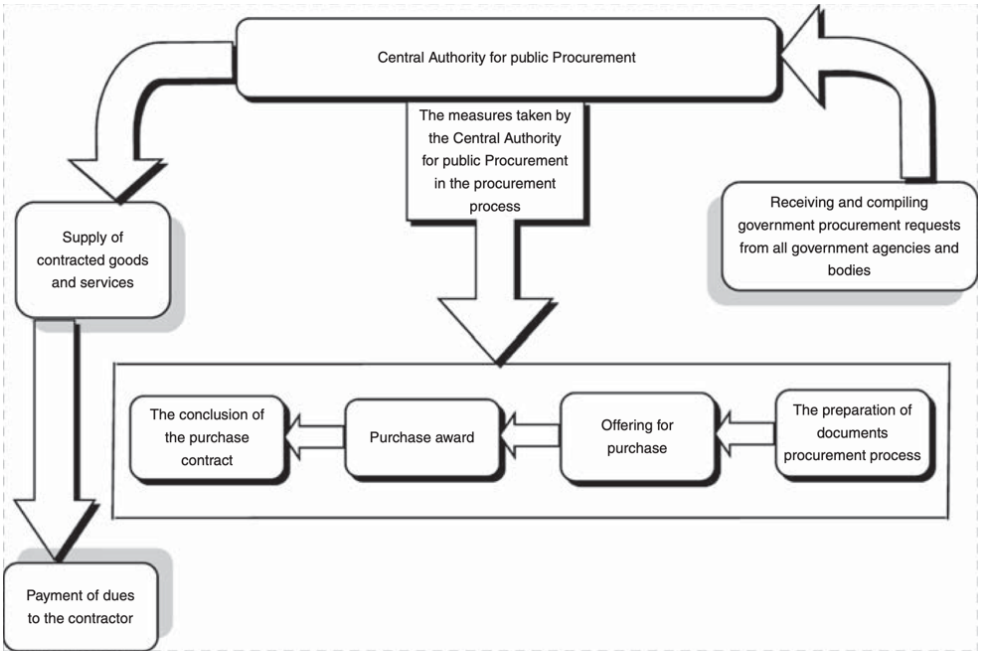
2.1.2 The rationale for centralized forms of procurement and the objective of Controlling the government spending

It is becoming more widely recognized that purchasing contributes significantly to organizational competitiveness and that it should be treated as a strategic function rather than merely an operational one (e.g. Carr & Smeltzer, 1997; Paulraj et al., 2006). As more companies recognize the value of this function in their supply chain management strategies, there has been a trend toward a stronger, more centralized purchasing processes (Stanley, 1993; Cousins, & Spekman, 2003; Dubois, 2003). Centralized public procurement is defined in a variety of ways. Many refer to it as “the process by which all public procurement procedures can be controlled in one centralized location” (Islam, 2014, as cited in Aboelazm & Afandy, 2019, p. 263). According to the Chartered Institute of Procurement and Supply (2006), it is “the process in which a single government institution shall be responsible for providing the needs of all government departments and carrying out all functions of public procurement” (Chartered Institute of Procurement and Supply, 2006, as cited in Aboelazm & Afandy, 2019, p. 263). Another definition of public procurement is “centralization of public procurement means that all public procurement procedures are concentrated in a centralized procurement unit to procurement all goods and services requested from various government entities” (Karolis et al., 2011, as cited in Aboelazm & Afandy, 2019, p. 263). The OECD (2011) also defines the centralization of public procurement as “the establishment by the government of a centralized agency with the task of procuring goods and services for the benefit of other government agencies and bodies with a view to reducing the cost of public procurement” (OECD, 2011, as cited in Aboelazm & Afandy, 2019, p. 263).

Given these definitions, it is possible to emphasize two important features that are common characteristics of centralized procurement systems. A first attribute refers to the consideration that, in a procurement system that can be considered centralized, the procurement task is carried out by a single central authority and on behalf of all individual procuring administrations. In this, the role of the Central Purchasing Body introduced in the previous chapter is recalled. A second characteristic concerns what is the ultimate objective of the choice for a centralized structural design, namely the possibility of cost control. It is precisely in the delegation to a single Central Agency, specifically established to carry out this function, that the possibility of a more effective and efficient allocation of the public budget is realized. More broadly, greater control over the procurement function is achieved (Aboelazm & Afandy, 2019).

From Figure 1, is possible to understand the typical phases characterizing a typical procurement process conducted using a centralized method.

Figure 1. Centralized public procurement process description



Source: Aboelazm and Afandy (2019)

The role of the CPB is here evidenced: it collects specific procurement requests from all government agencies which, once received, are translated into a single specification to be awarded to the best offer. After the contract phase, the Centralized Agency, acting in the government's best interest, completes the procurement process.

To explain why the centralization of public procurement has been always considered as an efficient procurement practice, is possible to analyze several benefits of centralized procurement strategies that can have a significant impact on the total cost of the procurement:

1. **It helps to exploit purchasing synergies**

Currently, both in the private and public landscape, many organizations make use of Framework Agreements to benefit from what Karjalainen et al. (2009) define as *purchasing synergies*. With FAs, contracts are made with a small number of preferred suppliers on behalf of the entire organization as opposed to each procuring authority selecting their own requirements. For their operational purchases, all organizational units are required to make use of these FAs instead of

independently choosing their vendors, contractual agreements, and managing the associated processes multiple times. The centralization of purchasing processes and the pooling of volumes have several synergy benefits, but one of the most significant underlined by the extant purchasing literature is the ability to save money through volume discounts and the elimination of duplicative tasks. By lowering procurement prices and transaction costs (related to the procurement process), the centralized procurement strategy can significantly lower the overall cost of public procurement, which in turn influences public spending (Karjalainen, 2009).

According to the distinction made in the literature (Baldus & Hatton, 2020), a conceptualization of the mentioned cost reduction provided by a centralized structural approach to procurement (FA), is done according to a twofold perspective: savings on contract prices and efficiency in the procurement process execution (duplicate tendering avoidance). By reducing the overall cost of procurement, the potential for increased synergy makes centralized systems more suitable for achieving efficiency goals.

2. It increases the possibility of bulk purchases

The potential for economies of scale is the primary justification for centralizing procurement. Adopting one high-volume process would lead to an abundance of resources and a decrease in the cost of purchasing materials (OECD, 2015). Furthermore, it would give the CPB more negotiating power, which naturally lowers the cost of public spending on public procurement (OECD, 2015). According to OECD (2000), due to the ability to process many orders at once, a FA allows the supplier to access a larger market with less fluctuation in his costs. Staff and production lines can be organized more effectively. For the producer, who effectively subcontracts the sales side to the procurement, managing sales is made simpler.

Following the rationale of the author, theoretically, an entrepreneur should be able to boost his profits, make investments, and/or reduce his prices after winning a sizable contract with a centralized procurement agency. As a result, lower prices are provided, which benefits the centralized procurement agency.

The article by OECD (2000) continues by saying that the impact of higher demand and lower prices is not just a function of buying in bulk. A contract for a significant amount of goods and/or services can lower the risk to the supplier and the marginal costs of production, but there are additional financial advantages. The agency's increased purchasing power enables it to streamline its supply chain and lower overhead expenses. Additionally, it enables the proactive buyer to request adjustments to the supplier's structure and manufacturing processes, further bringing down costs.

3. It gives opportunities for standardization and benefits from *risk pooling*

Following the previous theme, it was pointed out that the benefits of FAs may be enhanced in the case of a *high degree of standardization on the demand side*, i.e. from the point of view of the procuring authorities (The World Bank, 2021). The possibility of standardizing needs and limiting demand-side variations should increase the possibilities of achieving economies of scale and realizing volume pooling benefits. Specularly, this would affect firms' bidding strategies, as it would lead to more favorable pricing conditions as they can rely on economies of scale for bulk orders and a reduced uncertainty in the planning process and demand forecast. This is particularly true when the process is integrally centralized, thus saying that the customed need of the single procuring authorities is over sought and translated into single standardized procurement specifications by the central purchasing body.

These advantages are connected with the concept of *risk pooling*. When it comes to operations management, this is accomplished by combining a product with a random demand in a single location, which is known to be advantageous (Eppen, 1979; Cherikh, 2000). According to Oeser (2015), by combining individual demand and/or lead time variability (measured with the standard deviation), the risk pooling can lower overall demand and/or lead time variability, as well as uncertainty and risk (the possibility of not meeting business objectives). By combining demands (demand pooling) and/or lead times (lead-time pooling), these individual variabilities are consolidated. This decrease in uncertainty enables dealing with product variety by reducing inventory without reducing customer service levels (product availability), raising service levels without raising inventory, or doing both at once.

With an aggregation of demand, for instance, across locations, products, or time periods, demand variability is reduced. The amount of safety stock needed to protect against fluctuations decreases as demand variability decreases.

According to Bernhardt (1977), demand fluctuations are expensive, as is the uncertainty they cause because of shaky forecasting. Sellers are forced to hold inventory, use expensive production methods, or adjust prices or other terms of the sale to counteract the effects of short-run fluctuations. For this reason, the possibility to aggregate demands from different procuring authorities will increase the possibility to exploit the benefit provided by risk pooling (by pooling and standardized heterogeneous demands) and this should have a direct effect on prices.

The work of Sharma and Aispuro (2020) demonstrated that by incorporating risk pooling into the current network, major product classes' supply chains could reduce their costs by 15% without sacrificing their service levels.

4. It helps to decrease the Bullwhip Effect

According to the traditional definition of the bullwhip effect (BWE), order variability increases as one moves upstream in the supply chain. Since Lee et al.'s (1997) formal introduction and analysis of the BWE, the topic has received considerable attention from both academia and industry. Overall, demand variability plays a significant role in the bullwhip effect. The bullwhip effect is the supply chain's amplified variation in demand, which may result in production and demand imbalances, and cause efficiency loss in the supply chain (Bray & Mendelson, 2012). This kind of benefit is strictly related to the previous one. Reducing demand variability through improved forecasting with the exploitation of the risk pooling benefit given by a centralized form of purchasing can reduce the BWE, with a stronger positive impact along the supply chain. This means that the supply chain can be managed more efficiently and effectively, whit a direct impact on the total cost of procurement.

The bullwhip effect was initially described as an instance of "information distortion" by Lee et al. (1997). This definition captures the upstream information flow distortion because the downstream stage's order serves as the demand input for the upstream stage. Because the decision regarding upstream inventory and capacity is influenced by the downstream order information, the information-based definition has a direct relationship to supply chain costs. The information-based bullwhip effect is a cost factor as a result (Chen & Lee, 2012). The benefit of demand aggregation is therefore to allow aggregated and reliable demand to fluctuate upward along the supply chain actors, which in turn can benefit from that information to make more accurate planning and production decisions.

2.2 The quest for more hybrid forms of procurement and its relationship with sources of demand heterogeneity

Strong centralization, however, is typically only feasible at a cost. This entails essentially the risk of remiss tailoring of public contracts to the needs of purchasing units.
According to Albano, Ballarin, & Sparro (2004), Framework Agreements can be seen as an interesting contractual alternative that benefits public agencies - at the central or local level – with the possibility to pool demand, streamline procurement procedures, and maintain some degree of contract flexibility in their procurement activities.
Indeed, according to the authors, FAs can be designed to make a centralized procurement system opened to different levels of flexibility.

2.2.1 The concept of “hybrid forms” of procurement and what motivates their adoption by central purchasing agencies

A complete centralization of the government procurement process may lead to an inefficient resource allocation – and ultimately cause the spending objectives to fail - if it ignores some of the following circumstances or retains to proactively modify its current practices in the face of some of the following threats.
In particular, the possibility of a misunderstanding between various procuring authorities and the Central Purchasing Body can significantly threaten the government's objective of cost control (OECD, 2000). In the process of standardization of heterogeneous requirements, there is the risk that the applications submitted, and their details, can be misinterpreted or overlooked. This may result in the procurement of non-required goods and services with an inefficient allocation of resources. Also, the centralized public procurement body may take longer than expected to meet the needs and demands of all the involved procuring authorities, which could be extremely harmful to some organizations that may be in dire need of earlier-ordered goods and services. (Islam, 2013). Other criticalities refer also to the incurrent rigidity and the lack of innovativeness.

To overcome the limits of purely centralized systems, the practice and the Academia provided a series of alternatives. These alternatives can be summarized into purely decentralized systems or, in the middle of the two, *hybrid* arrangements.

To begin with a first definition of a decentralized procurement system, it can be the one by Leenders and Johnson (2000): “The process by which each government agency or department [sic.] controls the procurement of goods and services” (Leenders & Johnson, 2000, as cited in Aboelazm & Afandy, 2019, p. 267). Otherwhise, it could also be defined as “the process by which the public procurement unit of each government entity is responsible for the procurement process, which is also often responsible for a variety of products procured in fewer quantities than what is procured by centralized public procurement agencies” (Islam, 2013, as cited in Aboelazm & Afandy, 2019, p. 267).

These definitions demonstrate that the previous literature finds agreement in defining a "decentralized procurement process" as an obligation for the various procurement authorities to conduct this activity independently and in the interest of its own constituents. Given this, the term "public procurement decentralization" can be used to describe the process whereby the single procuring administrations satisfy the requirements of their own governments for a given provision of supplies, in accordance with a procurement strategy that has been established by each procuring authority (Aboelazm & Afandy, 2019).

This definition states that this method of public procurement is wholly incompatible with the

mentioned centralized procurement arrangement. Indeed, the CPB is responsible for addressing the collective needs of numerous government ministries through a single procurement process. However, it can be considered a reliable method for avoiding the drawbacks of centralized purchasing systems, namely: rigidity, lack of responsiveness and innovativeness, and distance from the real necessities of the procuring entities in search of the right degree of standardization.

The literature evidenced some advantages of a decentralized procurement structural design. Firstly, it helps in lowering the costs and dangers associated with storage and delivery (Islam, 2013). Secondly, it made response time for urgent operational needs and requirements quick (Islam, 2013). Furthermore, the decentralization of public procurement has shown to be the only alternative in the case of procurement of certain uncommon goods and services, which threats the possibility of standardizing in common specifications the mentioned requirements. They would therefore suggest reducing government spending in this area through centralized procurement, as the risk is of an over-budget allocation (Islam, 2013).

Deutsch (2013) underlined that it helps in establishing connections between programs related to the decentralized procurement units. Decentralized procurement makes sure that procurement is in line with government goals and objectives, which strengthens the connection between government agency purchases and their programs (Deutsch, 2013). This strategy uses procurement as a tool to carry out government initiatives and reach specific goals. The needs of various government agencies are met by centralized procurement organizations, which may not fully comprehend the nature of those needs or how they relate to the plans and goals of the requesting entity (Deutsch, 2013).

As a result, while decentralized procurement has many advantages, it may have some disadvantages for those who use it, just like a centralized purchasing system.

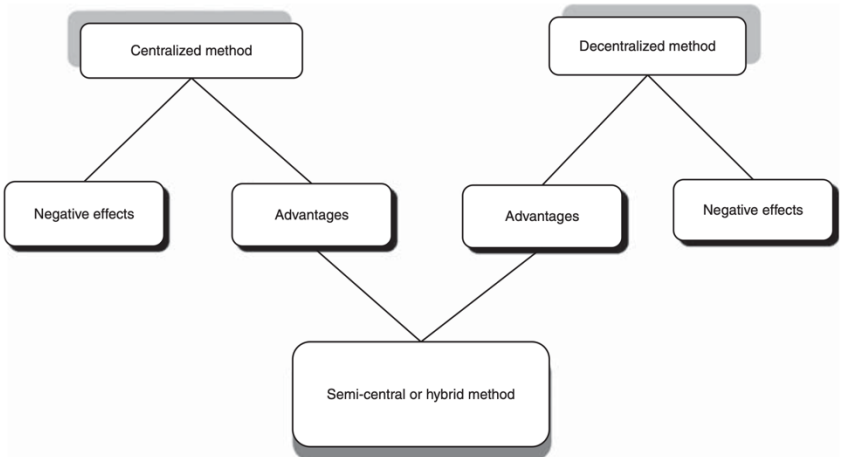
Leenders and Johnson (2000) backed the hypothesis that decentralized forms of procurement may result in higher prices for goods than those obtained through centralized means. There won't be complete coordination among the decentralized public procurement units (Leenders & Johnson, 2000). When more than one decentralized procurement unit purchases a single good, the cost of the good will be higher than if the purchase were made using a centralized method (Wanyama, 2010), which also considers inefficiencies in duplicate tenders.

Furthermore, the previously mentioned benefits related to demand pooling, namely increased benefits of risk pooling and reduction of the bullwhip effect results are inapplicable in this context, and surely of reduced positive cost impact.

These considerations led to a new method known as a "*semi-centralized*" or "*mixed method*", most commonly - and as it will be used in this research - "*hybrid method*". It is considered

a from of centralized procurement, which is supposed to take the befits of both centralized and decentralized procurement arrangements, while reducing their main drawbacks. Figure 2 shows how to do this as a result.

Figure 2. Hybrid model conceptual rationale



Source: Leenders and Johanson (2000, p.19), retrieved from Aboelazm and Afandy (2019)

Arnold (1999) asserts that, in a *hybrid method*, while not all procurement functions are necessarily centralized, at the very least, supplier management and contract handling are. Governments, such as private organizations, frequently opt for hybrid systems, with varying practices, for instance, differentiating by product category. Munson and Hu (2010) claim that the majority of businesses appear to combine centralized and decentralized purchasing. In these contexts, is possible to observe a division of tasks between the head and local offices. For instance, the head office handles the negotiation of some long-term contracts, and subsidiaries place orders in accordance with these agreements (Trautmann et al., 2009).

In this study, "purchasing centralization" refers to the use of Framework Agreements, where the activities that are considered to be centralized, are the ones up to and including the conclusion of the main contract/Framework Agreement for use by the entire organization, as well as the administration of that contract. On the contrary, order management is conducted independently and in a decentralized fashion by the single procuring authorities. Munson and Hu (2010) referred to this kind of purchasing strategy as "centralized pricing with decentralized purchasing", which combines the best elements of both centralized and decentralized systems.

2.2.2 Hybrid forms of Framework Agreements and the concept of "demand heterogeneity"

FAs designed as hybrid structures, in the definition of Munson and Hu (2010), constitute of an award phase which is completely in the hands of the CPB, and a post-award phase, which is carried out independently by the individual approving authorities.
This means that the individual units are responsible for carrying out the entire purchasing process (in some cases with the help of the CPB) according to their own needs.
This consideration notably increases the possibility of experimenting higher level of demand heterogeneity, coming from the necessary solution of the trade-off between demand aggregation and operational efficiency, and the need to ensure the right level of customization, adaptability, and allocative effectiveness.
Because it forced businesses to abandon standardization tactics and consequently made decision-making more difficult, demand heterogeneity has historically been seen as a challenge (Athaide, 2021). This implies the impossibility to specify precise patterns and see a propagation of requests from the side of the procuring authorities, in response to the specific needs.
As a result, there is an increased uncertainty in demand, which should induce supply chain managers' psychological stress. This is because of its potential to give rise to upstream supply chain disruptions, result in catastrophic forecasting errors, and add unanticipated costs to the organization (Abolghasemi et al., 2020).

2.3 Demand heterogeneity: sources and impact on the objective of cost control

A recall of what was stated in the previous section here is needed, i.e. that the benefits of FAs may be enhanced in the case of a *high degree of standardization on the demand side*, i.e. from the point of view of the procuring authorities (The World Bank, 2021).
FAs typically provide better economies of scale when procuring entities that are similar in their needs, so that can be standardized because of a high level of homogeneity, or when demand varies only slightly. Products and services are more homogeneous, less complex, and easier to specify, which promotes standardization and lowers transaction costs.

As mentioned in the introduction, the objective is to consider how, in the context of FA operationalized in a hybrid manner, heterogeneity in demand in the post-award phase can have an impact on the price savings obtainable in such a centralized public procurement.
For this specific purpose, the present research defines degrees of demand heterogeneity for a specific FA along four dimensions, concerning the specifications declared by the individual

procuring authorities: heterogeneity in lot quantities, heterogeneity in times of order, heterogeneity in delivery terms, and the number of procuring authorities.
As stated, according to the “Guidebook for Setting-up and Operating Framework Agreements” published by the World Bank (2021), degrees of heterogeneity in these dimensions can cause a decline in the required performance standardization, increasing the complexity that is taken into account in the settlement of firms' bidding strategies.

To explain how the mentioned demand heterogeneity dimensions can threaten the attainment of more favorable price conditions, some fundamental concepts will be reported.
As a starting point, to allocate a procurement contract effectively, the CPB must choose the contractor who will provide the requested services at the lowest total cost.
According to Albano, Buccirossi, Spagnolo, & Zanza (2006)’s earlier statement, the bidder must consider at least two different aspects when estimating the cost of carrying out a proposed contract. These two aspects both compete in determining the ability of the bidder to provide the best offer. These includes its effectiveness in carrying out a task (providing a good or service), which is a firm-specific aspect; and other "common components", i.e., not company-specific, but potentially applicable to all bidders.
These include aspects of production costs that are common to all suppliers (such as the cost of raw materials or intermediate products) but also consider the ability of the bidder to accurately estimate the mixture of various components that make up the contract assignment(s). This has the highest impact on business plans. According to Albano, Buccirossi, Spagnolo, & Zanza (2006), this total cost component is based on (i) how much the mix of production inputs will be impacted by different layouts and (ii) the percentage of actual demand that can be anticipated from the various departments of the procuring entity (the ministry), which will directly affect planning capabilities (and thus positively impact efficiency). The Authors argue that the concept of (production) efficiency becomes hazy, if not inapplicable, when production costs must consider the various effects of changes in the procuring entity's requirements on bidders, even considering that bidders may have had inaccurate information about these scosts prior to the contract award. From this, is possible to assume that the higher overall levels of demand heterogeneity of procuring entities negatively impacts the price savings obtainable from centralized procurement systems.
Indeed, it's crucial to comprehend its own demand variability if one wants to manage the supply chain efficiently and be aware of its forecast capacity and accuracy (Rickard, 2020).
As a result, the forecasting ability of the bidder about the task required by the contractor also influences the final cost.

How this heterogeneity can be specified strictly depends on the level of heterogeneity of several specifications that the procuring authorities can make in their purchasing activity. Their nature, and the theoretical assumptions that motives their consideration as sources of variability in the supply chain - with an effect on the prices placed by bidders -, are provided here in the following points:

1. **Heterogeneous specifications in lot quantities**

In supply chain management, order variability is acknowledged as a significant phenomenon. Following the words of Pujawan (2004), the pattern of demand that a supply chain channel receives heavily influences how challenging it is to manage an operation. Variability in lot quantities, i.e. the submission of orders for various batch quantities containing therefore a variable number of items, can negatively impact the possibility of obtaining more advantageous price conditions. According to the World Bank (2021), variability in this dimension results in greater complexity in the forecasting process and optimal production planning.
Following the previous studies of Mula, Poler, García-Sabater, & Lario (2006), Mundi, Alemany, Poler, & Fuertes-Miquel (2019), Zanjani, Nourelfath, & Ait-Kadi (2010), a demand that is unpredictable and heterogeneous, with a multiplicity of customers and different needs - which diversify both quantitatively and temporally - results in higher total cost incurred by the bidding company because of an increased inventory, inefficient processes, and a reduction in the advantages of capacity utilization. These costs, resulting from and dependent on an approach that provides scope for diversification and customization, result in the execution phase in an additive cost that hybrid structures add to the total cost of fully centralized structures.

Order variability, according to Chen et al. (1998), may also lead to overstocking and ineffective resource use. And this is both in terms of use at the scale of the production equipment and in terms of inventory holding costs. An intriguing finding from earlier literature is that order variability is frequently caused by the rational processes carried out by each channel of the supply chain, rather than just the uncertainty of end-customer demand (Lee et al., 1997; Holweg et al., 2001). The resulting bullwhip effect (as in the definition of Lee et al., 1997), which amplifies order variability, can affect supply chain profitability **(**Metters, 1997). These premises guided the development of the following hypothesis:

H1: A higher heterogeneity in lot quantities posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems.

2. Heterogeneous times of orders

Supply chains are significantly impacted by another dimension of order variability, which refers to differences in purchasing behaviors and erratic timing of orders by the procuring authorities. Indeed, to better allocate resources, plan inventories, make manufacturing decisions, and manage supply chains, the idea of inter-purchase timing (IPT) is essential.
According to the World Bank (2021), this kind of heterogeneous specification can negatively impact prices. To describe purchase timing several models have been proposed in the literature[3]. Predicting customer behavior and inter-purchase timing is crucial for resource allocation, inventory planning, manufacturing decisions, and supply chain logistics (Lismont et al., 2018). Since the use of this information is considered critical to enhancing operational performance, heterogeneity, and complexity add inefficiencies that translate themselves into additional total costs.

Studies have shown that order variability and demand variance in the supply chain are influenced by ordering policies (Kelle & Milne, 1999) and scheduling (Lee et al., 1997).
The authors demonstrated that the periods between successive orders are roughly proportional to the variance of orders produced relative to the variance of demand received by a supply chain channel. The connection with the pre-mentioned Bullwhip effect is straightforward.
Guiffrida and Jaber (2008) intersect this dialogue with their analysis of the managerial and economic impacts of reducing delivery variance in the supply chain. A logarithmic investment function and a framework for determining optimal and near-optimal levels of delivery variance were developed. As demonstrated through numerical examples, the results of this model proved to be useful to justify that specific investments are required to reduce delivery variance to a targeted goal as a part of an overall continuous improvement program to improve supply chain delivery performance.

In this sense, is possible to understand that under variable delivery requirements, the suppliers undertake specific investments in order to maintain their promised level of delivery performance, thus increasing the total cost. This led to the development of the second hypothesis:

H2: *A higher heterogeneity in times of orders posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems.*

[3] see Gupta (1991), Jain and Vilcassim (1991), Helsen and Schmittlein (1993), Seetharaman (2004)

3. Heterogeneous delivery terms

Based on the work of Merrills (1989), De Treville (1992), and Suri (1994), Christensen, Germain, & Birou (2007) have demonstrated a link between lead-time variability, or more generally, "time-to-deliver," and a decreased organizational financial performance.
Because it manifests in the requirements for the delivery terms to which firms must adhere and is independently determined by the single procuring authorities under the general rules of the FA, the specified lead-time variance can be thought of as a type of demand heterogeneity.
According to Christensen et al. (2007), supply chain lead-time variance can be defined as the degree of change in a firm's cycle-related processes (i.e. variability in lead-time).
Total quality management (TQM) and just-in-time (JIT) are two literature streams that are well-known for emphasizing variance reduction as a fundamental technique for controlling and enhancing processes. To illustrate the idea that variance is positively and geometrically related to cost, Taguchi and Wu (1980) used Taguchi's quality loss function as an example. Logically, instability and uncertainty are caused by variance, which has negative effects. Customers become dissatisfied, expectations are not met, value and profitability suffer, and costs rise when instability and uncertainty occur (Deming, 1975).

The bullwhip effect, which comes into play when individual variances combine to produce an even larger overall variance, can also occur (Stevenson, 2005). Given the potential for variance to be destructive, the presence of uncontrolled lead-time variance is concerning. It should heighten managers' stress if it is not monitored and controlled. In order to meet the specific contractual obligations, the procuring firm must generally make specific investments.
For this reason, the third hypothesis is derived:

H3: *A higher heterogeneity in orders' delivery terms posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems.*

4. Number of procuring authorities

Another concept to be mentioned here is what the extant literature defines as "Customer-introduced variability". The work of Frei (2006), as the article published by Harvard Business Review in 2006 "Breaking the Trade-Off Between Efficiency and Service" offers a good starting point to explain another important issue that this paper is aimed to test. In particular, the studies pointed out how the managerial implication in terms of specific operational strategies – and related implementation costs

– can be negatively impacted in terms of complexity by the number of customers that the specific firm is intended to serve through its activity. This is because each customer, which in our case can be considered the single procuring authority, given the possibility they have to customize their request, can induce heterogeneity in their specification. The contracting authority must be able to manage the FA, especially if it is for technical, complex, or high-value goods or services or operates across multiple procuring authorities. In such cases, the needs of the relevant purchasers must be met (for example, in terms of complaints) and the monitoring of the FA is dealt to ensure that it is operating in accordance with the terms set out and delivering the desired results. Such FAs may necessitate dedicated contract management, which is thought to be more complex as more procuring authorities are included in the FA.

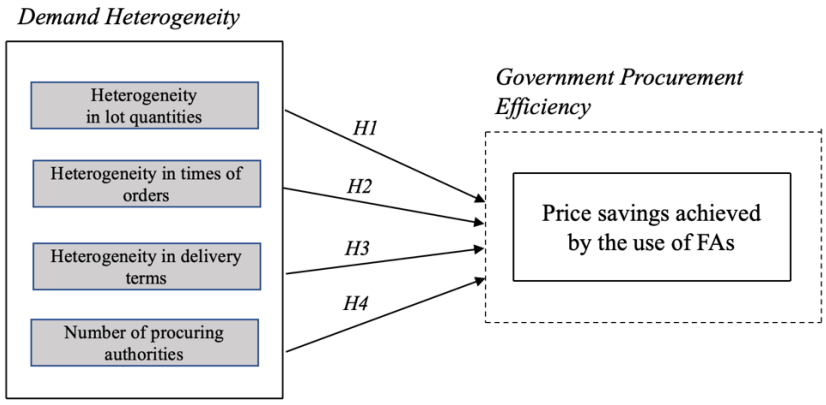
For this reason, it seems reasonable to investigate its impact on price, thus leading to the last hypothesis:

H4: *A higher number of procuring authorities negatively correlates with the price savings obtained from centralized procurement systems.*

2.4 Conceptual model and concluding remarks

From the theoretical considerations collected in this chapter, the following conceptual model can be derived to provide an overview of the major variables and relative relationships:

Figure 3. Conceptual model



The aim of the present research, as mentioned in the introduction, is to answer the present research question:

Is the use of Framework Agreements related to a more efficient Government Procurement and are conditions of demand heterogeneity from the point of view of the procuring authorities correlated to the attainment of less favorable price conditions?

The intention is to conduct a theory testing (deductive) research into the phenomenon, whereby the outcome will be an empirical thesis with multiple regression, as its primary objective is to quantitatively test the truthfulness of the hypotheses and estimate the intensity of the correlation. This will be done in the next chapters, in which the empirical case of the Italian Ministry of Defense will be used to implement the specified analysis, particularly in the case of two sector-specific Framework Agreements.

Chapter three - Research design and methodology

This chapter provides a full description of the research methodology that was employed throughout the study to accomplish its objectives and address its research questions. Specifically, more details about the empirical context of the research, i.e. the Italian Ministry of Defense's procurement activity, will be reported.

3.1 Research Nature and Strategy

A hypothetico-deductive research methodology will be used for this study.
According to this method, the scientific investigation should begin with the formulation of a hypothesis that can be tested against empirical data with an unknown outcome. If the test result differs from what the hypothesis predicted, this is taken as evidence that the hypothesis is incorrect. On the other hand, it offers confirmation if the test result agrees with the hypothesis' predictions. With the proposed strategy, hypotheses are derived using the current theory analyzed in the previous chapter and then tested using secondary archival data observations (Calantone & Vickery, 2009).
To analyze the data a quantitative methodology will be adopted. The use of a multiple linear regression will help me to detect the existence, intensity, and nature of the correlation between forms of demand heterogeneity and price savings of the centralized purchasing system, in this case, the Framework Agreement.

3.2 Data collection

3.2.1 Context of the study

The current study will be carried out in the Italian context, specifically in the procurement department of the Ministry of Defense, which has a centralized and societal procurement management system, the Consip system. Consip employs an "in-house" business strategy. All central government agencies are housed by this publicly traded company, making it qualified to act as these organizations' Central Purchasing Body (CPB) (Consip, 2017). The choice to conduct the research in the Italian context (and specifically considering the Consip's procurement activity) is driven by the fact that this system has been repeatedly mentioned as an example of Good Practice in

the context of FA's contract design (European Union, 2014), especially regarding Consip's "*meet or beat*" rule[4].

Since its foundation in 1997, the goal of Consip has been to increase the efficiency and transparency of the use of public resources by giving public administrations the tools and expertise they need to conduct public purchases, while also encouraging a competitive response from businesses to open calls for bids (Consip, 2017).

According to Consip (2017), there are three main categories that makeup Consip's core activities:

- It is in charge of executing the Program for the Rationalization of Public Spending on Goods and Services using ICT and the most UpToDate procurement tools such as Framework Agreements (open or closed), Framework Contracts, ASP tenders or an e-marketplace (which allows the so-called "*e-procurement"*);
- Assists the individual procuring authorities along the procurement value chain, including as the CPB function, in accordance with specific bilateral agreements; and
- Is in charge of particular statutory or ad hoc administrative tasks (Other Initiatives Area).

The aim is to, on one hand, provide an innovative public finance tool (with an impact on prices), and on the other hand serve as an efficiency and innovation tool, with an impact on the process.

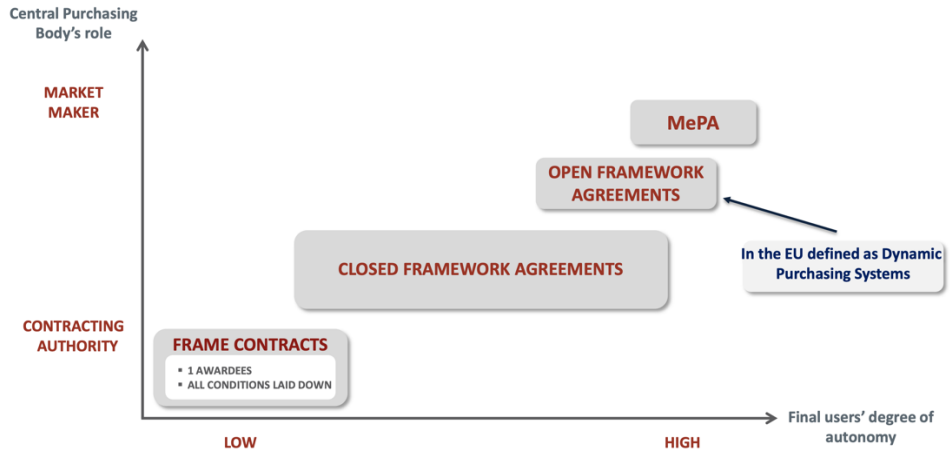
The procurement tools provided by Consip are summarized below (Consip, 2017):

- Framework Agreements for high-value procurement;
- MePA (Public Administration's e-Marketplace) for low-value transactions;
- Specific Tenders awarded on behalf of Public Bodies, mostly used for Tailored projects.

The preferred choice for one instrument rather than another depends on two sets of considerations: the final user's degree of autonomy and the higher or lower role of the CPB.

[4] This rule suggests that procuring authorities have the option to reject Consip's centralized Framework Agreements if they can independently show lower prices. Based on a quality/price benchmark, price comparisons are made.

Figure 4. Overview of the Consip's procurement instruments



Source: Consip (2017)

The choice of the procurement department of the Ministry of Defense appears justified by the strategic importance and criticality of the function performed.

Firstly, the Italian Armed Forces are under the control of the Ministry of Defense, which is also responsible for military and civil defense matters. The procurement process unavoidably reflects some of the peculiarities that make up the defense industry.

Defense is essential to national sovereignty, and military self-sufficiency is frequently seen as a source of national pride and prestige, especially in states with a sizable defense industrial base. For this reason, it primarily only has States as its clients (Black et al., 2021).

Second, since national security, employment, technological advancement, and ultimately a country's political sway are all inextricably linked to defense purchases, they are politically sensitive from both a security and an economic perspective. The currently in-use defense equipment is highly technologically advanced and will require updating in the future (Ministry of Defence, 2005).

For this reason, to modernize and secure access to innovative technologies, the Ministry of Defense makes extensive use of FA contract forms, with the aim of securing access to critical expertise and tools (Ministry of Defence, 2005).

Moreover, given the critical nature of the function performed, and in view of the circumstance that this specific supply chain is characterized by a procurement activity mostly at high-value transactions, this has made the specific field attractive for the choice of the specific data source for the analysis process.

Again, given the high pressure felt in recent years to secure solutions with cutting-edge technologies, the Framework Agreements examined concern product categories with high technological content and closely related to the area of defense.

3.2.2 Data Sources

In this research, secondary data were used in this study. The use of archival data was fundamental for the development of the Dataset and an effective ground on which the inferential analysis was built. The data has been made available by the General Defense Secretariat and National armaments Directorate informatics, telematics and Advanced Technologies (Division 7), within the limit of non-confidential information. By this Directorate, the analysis will be conducted on specific Framework Agreements awarded in the year 2020 e on specific Accession Acts submitted by different adhering procuring authorities in the period 2021-2022.

The first one, awarded on November 11th, 2020, to *MOTOROLA Solutions Inc*. for a total amount of € 33,000,000.00 and a duration of 5 (five) years and directed to the completion of the *land mobile radio (LMR) network mototrbo capacity max*. The second, awarded on December 22nd, 2020, to Leonardo S.p.A. for a total amount of € 12,418,032.79 and a duration of 3 (three) years, with the possibility of an extension of 6 months until the exhaustion of the quantities contained in the agreement, and directed to the supply of *logistic support to the E.I. TLC Park for different families of CIS assets/systems/materials*.

Both agreements were aimed at fulfilling specific needs of modernization of the services and processes of the defense administration and subserving the National Strategic Pole under the direct management of the TELEDIFE section.

The technological load of both supplies was significant and particularly suited to best represent the current trend of defense technological modernization through supply from state-of-the-art providers. In particular, Leonardo S.p.A. currently operates on the national territory in a condition of monopoly in the field of specific National Security and Defence supplies[5]; on the contrary, the Framework Agreement concluded with Motorola Solutions Inc. was the result of a more dynamic competitive tender.

Since the model adopted is a hybrid procurement model, in which specifically the place and terms of delivery within the national territory are agreed upon between the company and the ordering points and indicated in specific Accession Acts, it is from the latter that the Dataset was built. An example of the Accession Act can be found in Appendix 1.

[5] For further information, refer to Leonardo Official Website URL: https://www.leonardo.com/en/home

The information retrieved is contained in 56 Accession Acts for the first agreement and 38 for the second agreement, and a period of approximately two years – 2021-2022 - was covered for the analysis. This made the study longitudinal over the considered period.
In addition, average prices for specific supplies in decentralized purchasing approaches (updated to the year 2020, and originating from the collection of specific invoices) for the construction of specific congruity analyses, were made available from the TELEDIFE archive for the specific purpose of the research.

3.3 Data Analysis and Presentation

A quantitative approach has been used to investigate the research questions.
Multiple variables may simultaneously be linked to an outcome, which is the motivation behind the use of multiple linear regression. Multiple regression can assist us in establishing a correlation between a predictor and an outcome while taking into account (and controlling for) other variables' potential explanatory power. The model follows the step previously used in a similar work by Baldus and Hatton (2020). The use of linear regression will help me to detect the existence, intensity, and nature of the correlation between demand heterogeneity and cost reduction of the centralized purchasing system, in this case, the Framework Agreement.
The Statistical Package for Social Science (SPSS) has been used in the study to assess the presence of a correlation/linear relationship between the variables. The regression equation is here reported (Ho, 2006):

$$Y=\beta 0 +\beta 1\ \chi 1 +\beta 2\ \chi 2 +\beta 3\ \chi 3+\beta 4\ \chi 4+\epsilon$$

Where:

Y = Dependent Variable (Price savings), derived from the percentual saving calculated from the price achieved for the specific product reference in the case of FA and the average price obtained in ordinary decentralized forms of procurement (updated in the year 2020) controlled by the effect of the inflation;

$\chi 1$-n= Independent variables ($\chi 1$ refers to the heterogeneity in lot quantities, $\chi 2$ heterogeneity in times of orders, $\chi 3$ heterogeneity of delivery terms and $\chi 4$, the number of procuring authorities);

$\beta 0$ = the constant;

$\beta 1\text{-}n$= is each change, or "regression coefficient" of χs that was incorporated into Y;

ϵ = the error term.

The variables have been derived across products and by product references. The set of "heterogeneity" variables was calculated considering specific coefficients of variation (per variable) to measure the level of dispersion of the data collected for the specific variable and derived from the specifications included in the Accession Acts[6]. In particular, the decision to use this method of analysis was derived from the fact that it is a non-dimensional index, thus allowing us to obtain a measure of the dispersion of values (*heterogeneity*) around a mean value in a manner that was independent of the unit of measurement. In this way, it was possible to compare across products the different sources of demand heterogeneity in a uniform manner.
A single observation was built upon:

- The product reference;
- The product category;
- The product registered price in the FA;
- The product registered price in the TELEDIFE archive for congruity analysis (as from historical decentralized tender records) adjusted for inflation;
- A coefficient of variation for lot quantities;
- A coefficient of variation based upon the different (inter-purchase) times of orders;
- A coefficient of variation for the delivery terms specification (per order);
- The number of procuring authorities that procured the specific product for the period considered.

The effect of the inflation has been accounted to make a comparison between the average prices for specific supplies in decentralized purchasing approaches (updated in January 2020) and the prices obtained in the FA used for the scope of the research (respectively, November 2020 and December 2020, on a monthly basis).

[6] To calculate, for example, the value of the variable "heterogeneity in lot quantities" for the product *x*, a coefficient of variation was calculated, which puts the standard deviation of the lot quantities recorded for the different orders placed over the study's time span and divided by the average of these quantities. The result is indeed a value which measure the dispersion of demand specifications around an average value, which thus offers a measure of the heterogeneity of demand.

To do so, the ISTAT Database has been used, collecting the specific inflation data per Ateco 2007 codes connected to the different product categories. Here is the list of the Ateco 2007 codes used in the analysis:

- 262: manufacture of computers and peripheral equipment;
- 263: manufacture of telecommunications equipment;
- 264: manufacture of audio and video consumer electronics products;
- and video consumer electronics;
- 271: manufacture of electric motors, generators, and transformers and of electricity distribution and control equipment;
- 272: manufacture of electric batteries and accumulators;
- 273: manufacture of wiring harnesses and wiring equipment;
- 279: manufacture of other electrical equipment;
- 289: manufacture of other special-purpose machinery;
- CL: manufacture of transport equipment.

3.4 Validity and Reliability

Statistical validity is critical in determining the accuracy of research findings, which can be accomplished by using appropriate statistical techniques and tools. Before beginning a regression analysis, it is critical to ensure that the data meets the fundamental econometric assumptions[7]. Several issues may arise when there is evidence of significant violations of these assumptions, such as related to the impossibility of accurately estimating the relationship between variables, their regression coefficients (i.e., skewed standard errors), and accurately estimating confidence intervals and significance tests (Chatterjee & Hadi, 2012; Cohen, Cohen, West, & Aiken, 2003).

To overcome the problem of omitted variable biases, a set of control variables is introduced in order to eliminate the effects of extraneous factors on the results, thus making the analysis more accurate (Spector, & Brannick, 2011).

These are:

- The industry characteristics;
- The presence/absence of competition; and
- The contract value.

[7] Results can be consulted in Appendix 2

The choice of these variables was made considering that their impact on the investigated relationship had been proven in the relevant literature (Kissi, Adjei-Kumi, Badu, & Boateng, 2017; Albano, Ballarin, & Sparro, 2010; Hanák & Muchová, 2015; SIGMA, 2016).
Also, testing for the statistical significance of these factors can help to make the model more resilient to alternative explanations and can enlighten the existence of alternative explanatory factors to be included in the model. In so, answering the third research question of the study.

For the purpose of the analysis, the Industry characteristics have been encapsulated in the value of market beta referred to the specific industry to which the specific product category belongs. The data has been retrieved from Betas by Sector created by Aswath Damodaran at NYU[8], and updated to January 2023.
The betas included in the study have been the ones of:

- Telecom. Equipment;
- Electronics (General);
- Computers/Peripherals;
- Electronics (General);
- Software (system & Application);
- Transportation;
- Aerospace/Defense.

The presence or absence of competition has been introduced in the analysis with the generation of a dummy Variable in SPSS. The value of 1 has been assigned in the case of "Competition" and the value of 0 in the case of "No Competition". The two value has been assigned to clearly represent a categorical variable that can take only two levels (presence/absence) and helps us to test if the presence of any categorical effect might have an impact on the predicted output.

To evaluate and control for the effect of the contract value, the two FA's monetary values have been normalized to obtain them in a form that can be comparable.

Lastly, a great amount of information has been collected in the Ministry to ensure that the data provided had been collected and reported correctly. Since a major part of the information used in the study has been sourced from specific internal Databases (at the disposal of TELEDIFE), a comparison with the original physical Accession Acts has been done for a number of observations. Furthermore, all the data and information used in the study have been subjected to certification by

[8] The complete Dataset is availbabe at the URL
https://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html

the General Defense Secretariat and National armaments Directorate informatics, telematics and Advanced Technologies (Division 7), in so ensuring the integrity and reliability of the data.

Chapter four – The main findings

The following chapter presents the empirical findings of the master thesis.
The results of the Hypotheses test are disclosed in section 4.1 and section 4.2 will provide the results from a further analysis conducted to estimate the relative intensity of impact of the different variables included in the study.

4.1 Model estimation and Hypotheses testing

The study seeks to investigate the effect of demand heterogeneity on Government procurement efficiency.
The concept of demand heterogeneity has been defined along several specific variables: heterogeneity in lot quantities, heterogeneity in times of orders, heterogeneity of delivery terms, and the number of procuring authorities.
What the research intends to estimate is if and with which strength higher values in these dimensions can affect the price savings obtainable from the use of FA, thus impacting the overall efficiency of the government procurement practice.

The dependent variable, codified as **psavings** was regressed on predicting variables of heterogeneity in lot quantities (**cv_lotq**), heterogeneity in times of orders (**cv_ordert**), heterogeneity of delivery terms (**cv_deliveryt**), and the number of procuring authorities (**n_authorities**). The analysis has been also controlled for the industry characteristics (**m_beta**), level of competition (**comp**) and contract value (**contract_v**).

The Multiple regression has been run on a Dataset of 451 observations.

The analysis revealed that a significant regression equation was found ($F(6,451)=29631$; $p<.001$). This indicates that the factors under the study have a significant impact on the dependent variable (price savings).
These values are retrieved from ANOVA. ANOVA tests the null hypotheses, that is for our F test is that R Squared test is equal to 0, so that our model cannot be used to make predictions on the dependent variable because it is not able to explain none of its variation.
The alternative hypothesis is that the R squared is not equal to 0 and so that our model has an explanatory value.
So first we'll look at the probability of F being less than 0.01 and 0.05, corresponding to the 99% and 95% levels of significance.

The p-value of the model for F is <.001, so it can be said that is statistically significant at all this statistical levels and the model has predictor power. At this level we can, in fact, reject at 99% the null hypothesis.

Table 1. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.532[a]	.283	.273	.032635214

a. Predictors: (Constant), contract_v , m_beta , cv_ordert , cv_deliveryt , cv_lotq , n_authorities

Source: IBM Corp. Released 2021. IBM SPSS Statistics for Macintosh, Version 28.0. Armonk, NY: IBM Corp

Table 2. Results from ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.189	6	.032	29.631	<.001[b]
	Residual	.480	451	.001		
	Total	.670	457			

a. Dependent Variable: psavings

b. Predictors: (Constant), contract_v , m_beta , cv_ordert , cv_deliveryt , cv_lotq , n_authorities

Source: IBM Corp. Released 2021. IBM SPSS Statistics for Macintosh, Version 28.0. Armonk, NY: IBM Corp

Moreover, the Adjusted R Square of 0.273 depicts that the model explains 27,3% of the variance in the DV. We can furtherly refer to it as a Goodness of Fit.

Additionally, coefficients were further assessed to assess the influence of each of the factors on the criterion variable (Price savings).

H1 evaluates whether a higher variability in lot quantities posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems. The results revealed that higher values of the coefficient of variation in this dimension have a significant and negative impact on the price savings (B= -.017, t=-3.646, p < .001). Hence, H1 was supported.

H2 evaluates weather a higher heterogeneity in times of orders posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems. The results revealed that higher values of the coefficient of variation in this dimension have a significant

and negative impact on the price savings (B= -.008, t=-2.435, p = .015). Hence, also H2 was supported.

H3 evaluates weather higher heterogeneity in orders' delivery terms posed by the procuring authorities negatively correlates with the price savings obtained from centralized procurement systems. The results revealed that higher values of the coefficient of variation in this dimension do have not a significant impact on the price savings (B= -.018 , t=-1.969, p= .051). Hence, H3 was not supported.

H4 evaluates whether a higher number of procuring authorities negatively correlates with the price savings obtained from centralized procurement systems. The results revealed that a higher number of procuring authorities has a significant impact on the price savings, the estimated coefficient is - .002 and p= .005, with a t= -2.804. Hence, H4 was supported. These results are summarized in the table below.

Table 3. Estimated coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.268	.010		25.830	<.001
	n_authorities	-.002	.001	-.201	-2.804	.005
	cv_lotq	-.017	.005	-.167	-3.646	<.001
	cv_ordert	-.008	.003	-.174	-2.435	.015
	cv_deliveryt	-.018	.009	-.087	-1.969	.051
	m_beta	-.010	.007	-.060	-1.482	.139
	contract_v	.053	.008	.313	6.931	<.001

a. Dependent Variable: psavings

Source: IBM Corp. Released 2021. IBM SPSS Statistics for Macintosh, Version 28.0. Armonk, NY: IBM Corp

The model was also controlled by several control variables. The analysis revealed some significant and negative correlations. In particular, the variable referred to the contract value showed a coefficient of 0.053 for a t= 6.931 and p < .001. This means that the contract value is a reliable predictor for the dependent variable (price savings). On the contrary, the variables referred to the market beta and the competition showed no significant relationship with the dependent variable. The effect of the inclusion of the control variable was of moving the adjusted R Square to an higher value and helped to increase the model explanatory value. The results summary for the hypotheses test is presented in Table 4.

Table 4. Hypotheses Results

Hypotheses	Regression Weights	B	t	p-value	Results
H1	cv_lotq ⟶ p_savings	-.017	-3.646	<.001***	Supported
H2	cv_ordert ⟶ p_savings	-.008	-2.435	.015*	Supported
H3	cv_deliveryt ⟶ p_savings	-.01	-1.969	.051	Not Supported
H4	n_auth ⟶ price_savings	-.002	-2.804	.005**	Supported
Adj R Square	.273				
F (6,451)	29.631				

*Note. ***p < .001; **p < .01; *p < .05.*

4.2 Demand Heterogeneity: findings on the variables' relative intensity of impact

The level of intensity by which each variable relates to the predicted outcome can be measured in two ways and it is relevant for the present research to present both cases.
To do that, is possible to make a comparison between the variables' unstandardized and standardized coefficients (or "Unstandardized/Standardized Beta")[9].
Standardized Beta coefficients provide information about the relative importance of variables on a common scale, regardless of their original units of measurement, whereas unstandardized beta coefficients provide information about the magnitude and direction of an effect of a variable on the dependent variable in the original units of measurement.
Regression coefficients, also referred to as unstandardized beta coefficients, are the results of performing an ordinary least squares (OLS) regression using the original, untransformed variables.

[9] Refer to Appendix 2, Table 2 "Standardized Coefficients"

They represent, in the initial units of measurement for X and Y, the change in the dependent variable (Y) resulting from a change of one unit in the independent variable (X).
Unstandardized beta coefficients can be used to compare the relative weights of various variables in a model and to make predictions in the variables' original units.

However, to make contributions that can be used in different contexts, and for which the estimation can be particularly sensitive to variation in the scale as so that the variables can present different original units, a true comparison of the intensity of the correlation should be done based on Standardized Betas.
Standardized Beta coefficients are obtained by standardizing the variables before performing the regression. With this transformation, each variable is given a mean value of 0 and a standard deviation value of 1. Standardized beta coefficients, while holding all other variables constant, represent the change in the dependent variable (Y) associated with a change in the independent variable (X) of one standard deviation. Regardless of the original units of measurement, standardized beta coefficients are useful for comparing the relative importance of various model variables on a common scale.
The analysis referred to the Standardized Betas (see Table 3) revealed that the highest coefficient, of -.201, is the one the variable referred to the number of procuring authorities. This means that higher values indicate a stronger negative impact of the independent variable on the dependent variable (price savings). The negative impact on price savings became lesser and lesser, starting from cv_ordert (-.174) to cv_lotq (-.0167). The analysis presented on the Standardized Beta and the relative intensity of the correlation of dimensions of demand heterogeneity and the price saving is here introduced to explain which factors need to be taken into careful consideration by managers and practitioners in order to improve their decision models.

However, for the case at hand, the order is somewhat reverted since the presence of different units of measures that need to be with necessity associated with the right Unstandardized Beta in order to present a model that can be truly used to explain the variability of the reported outcome in the Dataset (and with fewer errors).
Therefore, considering the Unstandardized Beta, the level of intensity of correlation with the dependent variable (price savings) is, in descending order, greater for cv_lotq (-.017) and lesser and lesser for cv_ordert (-.008) and n_authorities (-.002).

Chapter five - Discussion, limitations, and future research directions

5.1 Discussion of the empirical findings and limitations

The centralization of the procurement function, even if only partly conducted in the use of FAs, resulted in an advantage in terms of cost control.

The analysis supports the idea presented by OECD (2011). The efficiency in public procurement, specifically in terms of cost control, is enhanced when a centralized agency (such as CPB) is tasked with procuring specific goods and services for the benefit of other government agencies. The main results from the analysis conducted for specific military supplies for the Italian Ministry of Defense are presented in the table below, divided by product categories:

Table 5. Reported Savings by product categories

Product Categories	P max	P avg	P min	Quantity	Savings
Antennas	33.389,48 €	865, 04 €	3,88 €	5513	29904, 54 €
Audio Accessories	2947,24 €	512,75 €	12,25 €	439	621,36 €
Batteries	73, 25 €	41,99 €	8,16 €	2922	211,88 €
Cables and Accessories	24667,1 €	2156,49 €	0,78 €	2166	4749,36 €
Chargers	5904, 83 €	1710,03 €	8,73 €	711	2339, 57 €
Coaxial Cables	7226,83 €	845,7 €	7,00 €	6145	3521, 47 €
Control Systems	17184,00 €	3594,45 €	768,42 €	269	2126,29 €
Converter	194,25 €	93,78 €	18,05 €	79	7,28 €
Custodies	22,31 €	20,52 €	19,11 €	161	9,07 €
Full_set	2990,97 €	1037,91 €	25,00 €	1092	1746,55 €
Hardware	2357,52 €	2357,52 €	2357,52 €	16	104, 05 €
lex l11 Accessories	693,06 €	84,27 €	3,87 €	1233	159,34 €
Link rf intersito	978,73 €	332,52 €	3,74 €	538	186,43 €
Mechanical Fans	2750,36 €	2206,54 €	1176, 68 €	138	754,69 €
MTP6650 Accessories	245,46 €	62,11 €	7,35 €	906	149,05 €
Radio Connectors	2959,32 €	1387, 36 €	23,85 €	79	150,41 €
Radio Infrastructures	29804, 27 €	10046,52 €	49,98 €	99	1306,57 €
Receivers	6109,45 €	6109,45 €	6109,45 €	9	133,92 €
Repeaters	5159,68 €	805,43 €	13,50 €	183	620,44 €
Software	109125,00 €	6413,42 €	25,44 €	1254	25722,10 €
Synthesisers	4727,42 €	3389,48 €	2551,34 €	247	2020,34 €
Tel. Infrastructures Wireless	4117,62 €	930,45 €	114,95 €	407	166,54 €
Transmitters	33389,48 €	17878,72 €	10123,34 €	67	2130, 91 €
Trbonet	5454,47 €	780,46 €	22,00 €	1500	1116,99 €
Vehicle systems	11864,06 €	3939,81 €	77,13 €	274	3782, 52 €
Video security	54,73 €	21,27 €	6,365 €	147	6,95 €
				Total Saving	83.748, 62 €

Note: The data refers to the orders placed in the period between March 2021 and February 2023

In this respect, the results are in line with those already highlighted by the previous research of Karjalainen et al. (2009) suggesting that, by aggregating the demand of different procuring authorities, it is possible to benefit from what is defined by the author as *purchasing synergies*. As detailed earlier in Chapter 2, such synergies can result in cost benefits directly attributable to the possibility of quantity discounts from bulk purchases and benefits of reduced variability and complexity along the supply chain.

However, the research aimed to estimate whether, when considering a model that was not purely centralized but decentralized in the execution phase, there was a threat to the aforementioned advantages applicable to purely centralized models.

Such was the objective sought in the consideration of a hybrid design in FA management.

For the estimation of the highlighted consequences, the concept of demand heterogeneity was introduced. In line with what was stated by (The World Bank, 2021), evidence of correlation with systematically lower price savings was found in the specific variables of heterogeneity in lot quantities, times of orders, and the number of procuring authorities, with the exception of heterogeneity in delivery terms, which was not found to be statistically significant.

In particular, the idea introduced by Harvard Business Review (2006) that each new customer adds complexity to the fulfillment process, due to the possibility of customizing its unique requests, is in line with the empirical findings. There is indeed evidence of lower price savings when the number of procuring authorities increases, suggesting a more prudent strategy from the bidding firm in order protect itself from the possibility of efficiency loss[10].

Furthermore, the heterogeneity in batch size and in the interval between ordering times also revealed a significant negative correlation, even if of less intensity. This is in line with the proposition of Pujawan (2004), that the submission of orders for various batch quantities links to more disadvantageous price conditions. Also, there is evidence that the correlation between different ordering policies and the increase in perceived variability in the supply chain relates to each other, in line with the findings of Kelle and Milne (1999) and (Lee et al., 1997).

The findings appear also in accordance with the work of Chen et al. (1998) which sought in these two sources of variability (heterogeneity in lot quantities and times of order) the cause of an inefficient resource allocation, with serious consequences on the effectiveness of the supply

[10] This concept relates to what Thaler (1994) defined as the "Winner's Curse" problem. This might occur if the contractor made an offer based on an overly optimistic forecast, but lately, it recognize that actual production costs are higher than projected ones. To avoid the possibility of the "Winner's Curse" problem companies that are rational, or that aim to maximize their profits, will appropriately consider the level of complexity and uncertainty when submitting a bid for the Framework Agreement.

process. In particular, it is precisely these two dimensions that pose the greatest problems in maintaining those synergy benefits specified above (i.e. *purchasing synergies*).

It is worth emphasizing that the price advantage remain positive, albeit resized by the coefficient with which both correlate. This brings an important insight. Even if orders and timeframes may be fragmented after the award of the contract, the price savings, and thus the validity of using an FA, remains positively influenced by the possibility of specifying exactly the composition of the agreement (goods and services at issue), defining common rules of behavior and being able to count on the benefits in terms of aggregation of demand (demand pooling) for a generally longer timeframe than in a traditional tender.

Contrary to expectations, the heterogeneity in delivery times was not significant in explaining the variance in price savings values. The data analysis revealed a slight dispersion of delivery times within the range of minimum and maximum times set by the FA specified in the individual Accession Acts, and generally for only 4 different values: 30, 45, 60, and 90 days. Therefore, the implications of heterogeneity in this dimension, as portrayed in the works of Deming (1975) and Stevenson (2005), appears not in line with the research findings.

Referring to RQ3, which sought to answer the question of how and in which form sources of demand heterogeneity relates to less favorable price conditions, the analysis offers an important answer: conditions of demand heterogeneity in the form of heterogeneity in the quantity of batches, heterogeneity in order times and in the number of procuring authorities suggest systematically lower price savings.

This negative influence also varies in the level of intensity. Considering these variables on a decreasing scale, the heterogeneity introduced by higher numbers of procuring authorities showed the strongest impact, followed by the heterogeneity in interpurchase timing and lot quantities.

Furthermore, RQ3 aims to estimate which additional contingent factors need to be furtherly considered in the mentioned relationship. Such was the objective of controlling the analysis along specific extraneous variables, that had been highlighted in the literature as potential explanatory factors.

In response to this, the analysis showed that the monetary size of the contract is positively correlated with higher price savings, which supports what was previously reported in the article by Biruk, Jaśkowski, & Czarnigowska (2017). This relationship is logical, as the higher the value of the supply, the greater the attractiveness of the contract, the higher intention for the tendering companies to offer the most advantageous purchasing conditions. At the same time, even in the case where the award took place in a non-competitive field, the greater will be the intention for the

tendering company to maintain reasonable prices so that a particularly fruitful buyer-supplier relationship can flourish. This is in line with regular business and economic practice and theory.

At the same time, the analysis was also controlled for the effect of industry characteristics and the presence and absence of competition. These two dimensions were introduced as possible alternative predictors (Hanàk & Muchovà, 2015; SIGMA, 2016). However, for these two variables the relationship was not significant.

Although the product categories considered differed by industry (some belonging to the semiconductor industry, others to telecommunications and still others to general electronics), still a large proportion of the observations included in the dataset related to special defense supplies and specific modernization of military functions. This suggest that such estimation suffers from the specific characteristics of the field, which often are subject to their *own* dynamics. Nonetheless, implementing this type of analysis in a rigorous manner also required a control on this dimension (SIGMA, 2016).

At the same time, contrary to the current literature, the presence or absence of a competitive field did not show any significant relationship with price savings. This result, and the consequent exclusion of the variable, can be justified by two reasons: on the one hand, the possibility that the binary coding of presence (1) - absence (0) may have been ineffective in capturing significant differences in the dependent variable brought about by the different fields within which two FAs were concluded. On the other hand, the FA concluded with MOTOROLA Solutions Inc., although concluded in a *de facto* competitive contest, suffered from the company's strong market leadership position. Moreover, MOTOROLA Solutions Inc. has a long history of involvement in the approval processes of numerous national and supranational agencies[11]. This means that although the award took place in a competitive field, it is possible that the MOTOROLA company was in a position of particular competitive advantage and significant bargaining power such that, in the data considered, a substantial difference between the two FAs could not be justified, leading to the exclusion of the variable.

5.2 Future research directions

Considering the goals and limitations encompassed in the theoretical and empirical dissertation of the present research, it is possible to continue by considering outlets for future research.

[11] Motorola has been a recognized partner of the United Nations Procurement Division (UNPD) (data on Motorola's procurement activity towards UNPD can be found at https://www.un.org/Depts/ptd/purchase-order-awards/343?field_date_2_value%5Bvalue%5D%5Byear%5D=2022&field_date_2_value_1%5Bvalue%5D%5Bmonth%5D=11&field_text_20_2_value=&field_country_tid_selective=All&field_text_75_2_value=&field_commodity_group_ca_tid_selective=All&items_per_page=10

Indeed the study would have been more effective if associated with a wide range of public procurement practices and central functions. The possibility of performing similar analyses in different contexts could make the analysis more generalizable and provide estimates that are even more decoupled from the specifically public field and/or untethered from sector-specific practices. Also, it would have been ideal to provide insights on differentiated supply chains. This would help in investigate more deeply the specific behavior of the variables along different contexts and for specific peculiarities.

However, due to time and resource limitations, the study only focused on the Italian context, and specifically considering the defense procurement as a sample.

The scope of the research has been also limited in terms of how deeply it examines the variables that affect the execution of Framework Agreements, and the range of the variables taken into account in the study. This, in particular, was due to the amount of information in the data that could be collated for the research, as it was limited by the confidentiality of certain information and specifications. However, within the framework of the specific analysis concerning the variables chosen for analysis, precise and punctual information was provided by the TELEDIFE database especially concerning composition, shipping and order specifications and the authorities involved. Therefore, within the limit of the set of variables considered, the information was particularly accurate and targeted to the purpose sought by the study.

Furthermore, researchers can gain a more comprehensive understanding of the criticalities of hybrid procurement structures and identify opportunities for optimization across the entire supply chain by broadening the scope to include suppliers. Researchers can learn more about suppliers' decision-making processes in a context of heterogeneous demand, such as how they determine production levels, manage inventory, and respond to changes in demand. It is also essential to examine the competitive landscape within the supply chain. Suppliers' behavior and decision-making can be influenced by competitive pressures. This comprehensive viewpoint may eventually result in more effective supply chain management practices and cost savings for all parties involved.

Chapter six - Recommendations and final remarks

The aim of the chapter is to provide specific guidance for practitioners, which will be followed by a concluding section highlighting an overview of the main points and achievements covered in the study.

6.1 Managerial implications

The following points aims to provide recommendations to Central Purchasing Bodies and procuring authorities' executives, in order to benefit from the increased effectiveness of the Framework Agreement and enhance the efficiency of public procurement in practice.
By definition, a Framework Agreement provides a number of benefits to public bodies; however, its hybrid organizational structure poses significant challenges in terms of controlling the level of variability and uncertainty in the supply chain. The goal of controlling the effects or causes of such variability is reasonable in order to improve the FA's performance in terms of efficacy.
In this regard, it is necessary that:

- Practitioners, at all levels, should keep track of the sources of variability that trigger the efficiency of public procurement process. A multifactorial analysis by impact on the objective of cost control should be regular practice in order to assess and correct possible sources of inefficiency;
- Once possible sources have been identified, a cost-benefit analysis must be performed at the CPB level that takes into consideration all possible alternatives made available by the current legal frameworks. In the presented case Consip S.p.A., the specific consideration could move the decision to move specific supplies to alternative procurement models (namely, MePA, closed FA or Frame contracts);
- At the planning level, procuring authorities are recommended to prepare their procurement plans on time, with complete information on the prospected need, to be communicated to the CPB. In addition, they should minimize urgent or unplanned requests to their suppliers. This should be done in such a way that the auction process and the subsequent management of operations by the supplier are conducted in a context of less uncertainty;
- all parties involved should also pay due attention to the issue of coordination in procurement planning activity. In particular, customers in Framework Agreement are expected to create an alignment between the spare needs, which means increase the level of coordination

between the different procuring authorities' objectives. This can be done at the level of the CPB, is demanded to manage and monitor the multi-layered requirements in such a way as to improve overall management along the chain;

- Finally, customers in Framework Agreement are expected to build strong relationships with their suppliers, in so actively engage in exchanging the most update and relevant information. This can be done throughout the central activity of the CPB and/or directly, with specific investment in the wellbeing of the relationship. The role of reducing information asymmetry, with respect to reducing uncertainty, is recognized and affirmed in economic practice.

6.2 Conclusions

In conclusion, the study delivers valuable knowledge regarding the efficiency improvements and specific challenges related to the use of Framework Agreements (FA) in public sector procurement processes.

The goal of the study was to assess whether the hybrid structure of Framework Agreements would result in conditions of demand heterogeneity that may adversely affect the potential to obtain more advantageous price conditions.

The following considerations can be drawn in light of the results.

First, FAs are particularly advantageous for supplies with recurring and standardized needs, as well as for products with significant price fluctuations and ambiguous supply quantities. Procuring authorities have some flexibility in tailoring their supply requirements thanks to the centralization of the award stage and a decentralized approach at the post-award stage. FA is thus distinguished from rigid, purely centralized approaches by its flexibility.

The theoretical dissertation emphasized that the primary efficiency advantages of FA are primarily related to the chance to obtain more favorable price conditions by combining demand from multiple procuring authorities. FAs also contribute to the centralization and simplification of the procurement process for all procuring authorities under the CPB (Centralized Procurement Body).

In addition to reducing redundant tendering, centralizing the procurement process has several other benefits, attributable to the possibility of benefits from purchasing synergies, risk pooling, and of a reduced Bullwhip Effect.

The benefits of this contractual system may be diminished, though, as a result of the decentralized nature of the order execution phase since different procuring authorities may have varying ordering requirements.

The empirical goal was, therefore, to investigate whether the demand heterogeneity for particular supplies, within the FA, could result in a variability that systematically raises prices along the supply chain.

The empirical analysis revealed that heterogeneity in lot quantities, order times, and the number of procuring authorities were negatively correlated with the obtainable price advantages. This relationship's strength varied, with a greater intensity influence to be reconducted to the overall number of the procuring authorities to the variability in the order scheduling and quantity.

A study on additional explanatory factors also revealed that one of the motivating elements in fostering a fruitful buyer-supplier partnership was the contract's monetary value.

The empirical analysis was conducted in the context of military supplies for the modernization of specific infrastructure within the Italian Ministry of Defense.

This provided plenty of room for analysis of a Government supply chain that is particularly susceptible to pressure from the public and the media, as well as for a crucial State function for which cost control is especially important.

The scope for academics and executives is aimed at raising awareness of these dimensions and directing action and investigation towards more compliant technical processes to sustain an effective government procurement management. This outcome would not only ensure a better management of the public budget, but in a broader framework, ensure a more effective allocation of resources for the benefit of the entire community.

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Appendices

Appendix 1. Accession Act sample

ALLEGATO 4 – ATTO DI ADESIONE

REPUBBLICA ITALIANA

MINISTERO DELLA DIFESA

ENTE XXXXXXXXXXXXXX

C.F.XXXXXXXXXXX

ATTO DI ADESIONE ALL'ACCORDO QUADRO xx di Rep. Del xx/xx/xxxx AFFIDATO MEDIANTE PROCEDURA NEGOZIATA SENZA PREVIA PUBBLICAZIONE DI UN BANDO DI GARA, AI SENSI DELL'ART. 18 DEL D.LGS 15 NOVEMBRE 2011 N.208, IN MODALITÀ APPLICATION SERVICE PROVIDER (ASP) DI CONSIP S.P.A. – IMPORTO DEL PRESENTE ATTO DI ADESIONE € xx,xx (xx/xx) IVA INCLUSA.

CIG ACCORDO QUADRO: XXXXXX

CIG DERIVATO: XXXXXXX

L''anno duemilaXX (202X) del mese di xxxxx, alla data della firma resa digitalmente dal rappresentante dell''Amministrazione,

PREMESSO CHE

- il Polo di Mantenimento dei Mezzi di Telecomunicazioni, Elettronici e Optoelettronici (in prosieguo denominato "POLMANTEO") ha stipulato con la Società **MOTOROLA SOLUTIONS ITALIA s.r.l.** (codice fiscale e partita IVA 00743110157) sede legale in Milano, largo Francesco Richini n. 6 – 20122 – pec: motorolasolutionsitalia@legalmail.it (in prosieguo denominato "Società"), l''Accordo quadro in titolo (in prosieguo denominato "A.Q."), cui il presente rappresenta atto di formale adesione;
- è stata inoltrata alla Società, con lettera n. xx in data xxxxxx, la richiesta

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di offerta indicando gli elementi di dettaglio, in termini di prestazioni, obiettivi e caratteristiche tecniche, economiche e qualitative nel rispetto delle previsioni e delle pattuizioni dell'A.Q.; la Società ha fornito riscontro, con offerta n. xx in data xxxxxx;

SIA NOTO

che per far constare quanto sopra e procedere alla stipula del conseguente atto negoziale tra questo XXXXXXXX, rappresentato dal XXXXXXXXXXXXX, e la Società rappresentata dal XXXXXXXXX, in qualità di XXXXXXXXXXX si conviene di comune accordo quanto segue:

ART.1 - OGGETTO E LUOGO DI CONSEGNA

La Società si impegna ad eseguire la fornitura/servizio/prestazione, indicata in allegato "B" al presente atto, secondo le modalità ed alle condizioni riportate nell'A.Q. in titolo. Il luogo di esecuzione della fornitura/servizio deve intendersi XXXXXXXXXXXXXXXX.

ART.2 - DURATA

L'atto avrà una durata di XXX giorni solari (comunque non superiori a 90) con decorrenza dal giorno successivo alla data di ricezione da parte della Società della lettera con cui l'A.D. comunicherà l'avvenuta approvazione dell'atto nei modi di legge.

ART.3 - PAGAMENTO

Le fatture elettroniche dovranno essere intestate e inviate all'Ente ordinante al codice univoco XXXXXXXXXX.

Ai sensi dell'art. 1, comma 2 lett a) e comma 4, del D.Lgs. n. 192/2012, le parti espressamente convengono che il pagamento della presente prestazione, nei termini previsti nell'A.Q., avverrà entro 60 (sessanta) giorni, decorrenti

dalla data della verifica di conformità o di buona esecuzione del servizio, giusta la previsione dell'art. 5 comma 2 della L. 3 maggio 2019, n.37, comunque successivamente alla ricezione delle relative fatture commerciali, secondo i termini e le condizioni disciplinate dall'art. 16 dell'A.Q. I pagamenti saranno effettuati su uno dei conti correnti bancari intestati alla società medesimo come indicato nel relativo articolo dell'A.Q.

Resta inteso che all'atto di ogni singolo pagamento saranno espletati, ove applicabili, gli adempimenti previsti all'art. 48 bis del D.P.R. 29.09.1973, n. 602 e s.m.i. e relativo Regolamento attuativo emanato con D.M. 18.01.2008, n. 40, come indicato nell'A.Q.

Al pagamento si provvederà con i fondi disponibili sul capitolo xxxxx E.F. xxxxx .

ART.4 - ONERI FISCALI E CONTRATTUALI

Sono a carico della Società le spese per la scritturazione del presente atto di adesione, quelle di stampa, di bollo e di registro "in caso d'uso", delle copie della scrittura privata che fossero richieste dalla Società.

ART.5 - DICHIARAZIONE FLUSSI FINANZIARI

Ai fini di quanto previsto dagli artt. 3 e 6 della Legge 13 agosto 2010, n. 136, concernente "Piano straordinario contro le mafie, nonché delega al Governo in materia di normativa antimafia", la Società assume gli obblighi di tracciabilità dei flussi finanziari riferiti al presente accordo quadro e dichiara che sia i conti correnti bancari "dedicati", anche non in via esclusiva, ad essa intestati per il presente accordo quadro e le persone delegate ad operare sugli stessi sono riportate in allegato.

In particolare, in applicazione delle disposizioni recate dal succitato art. 3 tutti

i movimenti finanziari posti in essere dalla Società, riferiti alla presente commessa, devono essere effettuati esclusivamente tramite bonifici bancari o postali ovvero con altri strumenti di incasso o di pagamento idonei a consentire la piena tracciabilità delle operazioni e contenere il Codice Identificativo di Gara (CIG) "derivato" n. XXXXXXXX.

Resta inteso, in ottemperanza al citato dettato legislativo, che il mancato utilizzo del bonifico bancario o postale ovvero degli altri strumenti idonei a consentire la piena tracciabilità delle operazioni costituisce causa di risoluzione del presente accordo quadro.

Nel caso di cessione di credito ai sensi dell'art. 1260 e seguenti del Codice Civile, l'atto di cessione dovrà contenere apposita clausola con la quale il cessionario assume gli obblighi di tracciabilità dei flussi finanziari previsti dalla citata legge. Pertanto, tutti i pagamenti anticipati dal cessionario alla Società dovranno essere effettuati sui conti correnti "dedicati" mediante gli strumenti finanziari consentiti dalla predetta legge e contenere il Codice Identificativo di Gara (CIG) "derivato". Dette informazioni (CIG attribuito alla presente commessa e gli estremi identificativi dei conti correnti dedicati) congiuntamente alle generalità/codice fiscale delle persone delegate ad operare sui citati conti dovranno risultare nell'atto di cessione.

ART.6 - VINCOLO DELL'ATTO NEGOZIALE

Il presente atto, mentre vincola la Società fin dalla sua sottoscrizione, non sarà obbligatorio per l'A.D. se non dopo essere stato approvato nei modi di legge.

Il presente atto negoziale consta di n. XX fogli di carta uso bollo, dattiloscritti su n. XX facciate e n. XX righe della presente, escluse le sottoscrizioni.

Per la Società:

(XXXXXXXXXXX) _____

Per l''Amministrazione Difesa:

(XXXXXXXXXXX) _____

SOMMARIO

	ALLEGATO A – DETTAGLIO DELLA FORNITURA	
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ALLEGATO B - RIEPILOGO DI DETTAGLIO

Accordo Quadro n. : _____ del_____

numero progressivo di controllo (rilasciato da POLMANTEO): _____

CIG "derivato": _____

descrizione e consistenza delle prestazioni (tipologia di fornitura/servizi):_____

nominativo del RUP: _____

nominativo eventuale DEC: _____

luogo di consegna della fornitura/esecuzione del servizio: _____

altri dati ritenuti necessari ai fini della correttezza commerciale dell''atto di adesione: _____

Appendix 2. Testing of Econometric model Assumptions

A set of explanatory variables $x'_i = (x_{i0}, x_{i1}, ..., x_{iK})$ and a dependent variable y_i are assumed to have a linear (in parameters) relationship in the multiple linear regression model.
X_{ik} is also referred to as a regressor, a covariate, and an independent variable. Unless otherwise stated, the first regressor, $x_{i0} = 1$, is a constant. Looking at a sample of N observations where i = 1,..., N, every single observation i follows:

$$y_i = x'_i \beta + u_i$$

where u_i is a scalar known as the error term, x'_i is a (K + 1)-dimensional row vector and is a (K + 1)-dimensional column vector of parameters.
It is possible to express the entire sample of N observations using matrix notation:

$$y = X\beta + u$$

where u is an N-dimensional column vector of error terms, y is an N-dimensional column vector, and X is an N (K + 1) matrix.

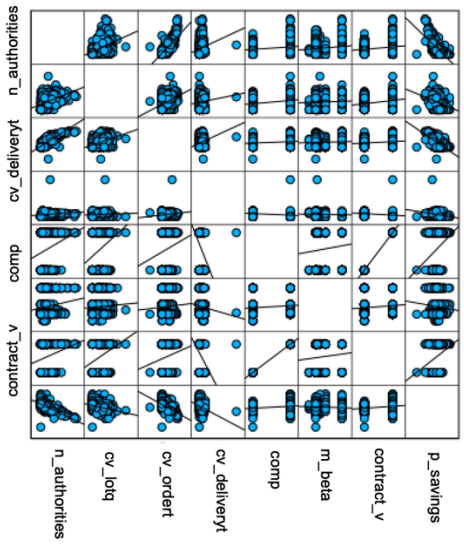
A set of assumptions provides a comprehensive description of the data generation process (dgp). The assumptions are listed below.

OLS1: Linearity

$yi = x'_i\beta + u_i$ and $E[u_i] = 0$

OLS1 bases its analysis on three fundamental tenets: the error term enters in an additive manner, the parameters are constant across individual i, and the functional relationship between the dependent and explanatory variables is linear in terms of parameters. This assumption has been tested by plotting the observations for the dependent and independent variables in a scatterplot.

Figure 5. Test for Linearity: Matrix Scatterplot



The figure above reported the Matrix Scatterplot of all the variables used in the study, in which linear curves have been added to see if the assumption of linearity is verified. For most of the data in Figure 5, there is some kind of linearity, this means that our model *follows a linear distribution* and can be described quite sufficiently by linearly added estimators. The first assumption is met.

OLS2: Exogeneity

a) $u_i|x_i \sim N(0,\sigma_i^2)$

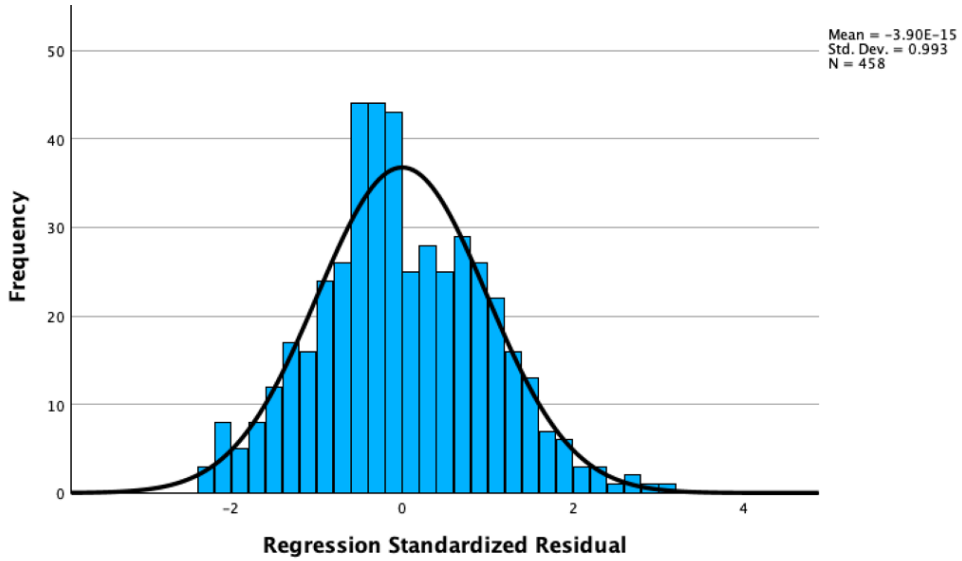
b) $u_i \perp x_i$ (independent)

c) $E[u_i|x_i] = 0$ (mean independent)

d) $Cov[x_i,u_i]=0$ (uncorrelated)

OLS2a assumes that, depending on the explanatory variables, the error term will be normally distributed. This has been tested with a Frequency/Regression standardized residual Histogram. The outcome is presented in the figure below:

Figure 6. Normality test of the error term with a Frequency/Regression standardized residual Histogram

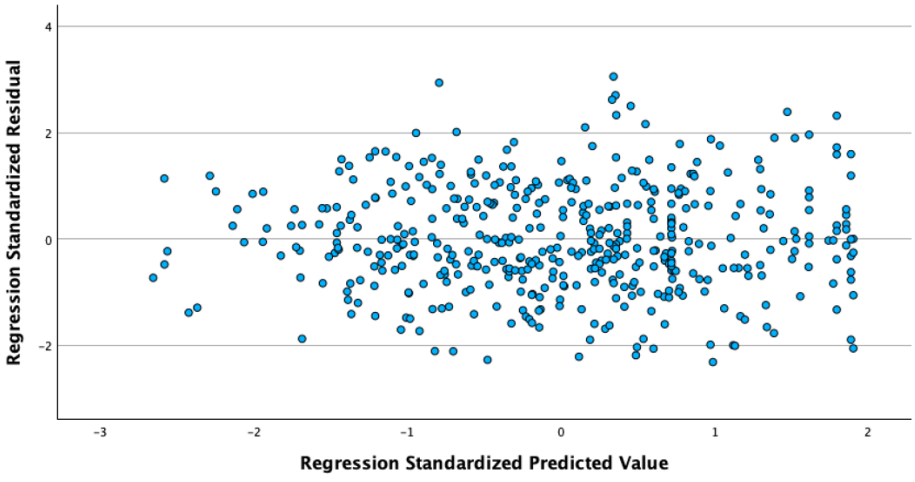


Is possible to argue from Figure 6 that the data follows a normal distribution, so that the mean is approximately 0.

Looking at the results, is possible to conclude that the variable error term *follows normality* (is approximately normal but may not be exactly normal) so condition a) is satisfied.

OLS2b indicates that the error term is not affected by predictors. The test for independent errors has been done with ZRESID/ZPRED Scatterplot presented in Figure 7 below.

Figure 7: ZRESID/ZPRED Scatterplot



The result of the distribution seen in Figure 7 shows that also condition b) is satisfied. According to OLS2c, the error term's mean is unrelated to the explanatory variables. OLS2d denotes a lack of correlation between the explanatory variables and the error term. OLS2c and OLS2d are implied by either OLS2a or OLS2b. OLS2d follows from OLS2c. The results show that the second assumption (OLS2) is met.

OLS3: Error Variance

a) $V\,[u_i|x_i] = \sigma^2 < \infty$ (homoscedasticity)
b) $V\,[u_i|xi] = \sigma_i^2 = g(x_i) < \infty$ (conditional heteroscedasticity)

OLS3a (homoscedasticity) indicates that the error term's variance is constant. When referring to OLS3b (conditional heteroscedasticity), we say that the error term's variance can vary depending on predictors. Because of homoscedasticity, or OLS3a, the error term's variance is fixed. When using OLS3b (conditional heteroscedasticity), the error term's variance can vary depending on the explanatory variables. To test for that we can still refer to the ZRESID/ZPRED Scatterplot presented in Figure 7.
From the graph is possible to assume that, despite the effect of a few number of outliers, the variance of the error term is quite constant between the values of -2.5 and 2 (condition a)) and the scatterplot of the residuals shows a consistent level of variability across the range of predicted values, and for this reason, there is no evidence of conditional heteroscedasticity (condition b)). It can be more challenging to accurately infer the relationship between the independent and dependent variables as a result of conditional heteroscedasticity because it can result in biased and inconsistent estimates of the regression coefficients. From this, is possible to conclude that the third condition (OLS3) is met.

OLS4: Identifiability

$E[x_i x'_i] = QXX$ is positive definite and finite $\text{rank}(X) = K + 1 < N$

The OLS4 makes the assumption that between predictors perfect collinearity is avoided, meaning that no variable can be expressed as a linear combination of the others. According to OLS4, each

explanatory variable provides new information to the study. To check for this hypothesis, an analysis was performed using a specific function of SPSS that help the researcher to conduct a collinearity diagnostic. The results are presented in the table below.

Table 7. Test for multicollinearity: results from Collinearity Diagnostics

Model	Dimension	Eigenvalue	Condition Index	Variance Proportions						
				(Constant)	n_authorities	cv_lotq	cv_ordert	cv_deliveryt	m_beta	Contract value
1	1	5.550	1.000	.00	.00	.01	.00	.01	.00	.00
	2	.561	3.147	.00	.00	.01	.01	.56	.00	.04
	3	.490	3.365	.00	.04	.01	.12	.14	.01	.01
	4	.232	4.892	.00	.02	.93	.03	.01	.00	.01
	5	.084	8.130	.02	.07	.04	.05	.20	.05	.87
	6	.071	8.834	.01	.84	.00	.78	.04	.01	.05
	7	.012	21.414	.96	.02	.00	.01	.04	.93	.03

a. Dependent Variable: psavings

With independent information, it is attempted to determine the dimensions. More specifically, it appears that the X matrix's single value has been decomposed without taking into account its preventive center (Snee, 1983). Multicollinearity is indicated by a number of eigenvalues that are close to 0. It is preferable to use the next column with the Condition Index for the diagnosis because "close to" is not exactly accurate. These are determined using the eigenvalues. A dimension's condition index is calculated by taking the square root of the relationship between its eigenvalue and its largest eigenvalue (Dimension 1). The analysis of the Condition Index is more crucial than its computation. Problems with multicollinearity can be indicated by values above 15, and problems with multicollinearity are strongly indicated by values above 30. The table above showed the absence of significative multicollinearities between the dependent and the independent variables and between independent variables. From this, the last assumption can be considered as met.