# Facility Management Services in UK Hospitals: in-house or outsourcing

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**Abstract**

This paper studies the institutional organization of UK hospitals through traditional procurement and private finance initiatives (PFI). It first describes the UK hospital sector with hard facility management services (e.g. building maintenance, etc.) and soft facility management services (e.g. catering, cleaning, etc.) that can be supplied in-house or outsourced. Builders are also bound to provide partial warranty against construction risk. The paper then shows that a PFI internalizes the externality between builders and hard FM service suppliers. It also requires to pay a risk premium that can become too high under strong hard FM risk. The builder's warranty creates a reverse moral hazard in traditional procurement, which becomes stronger for higher hard FM risk. Traditional procurement provides no incentive to outsource facility management services, whereas a PFI offers incentives for soft facility management services. A PFI procurement is shown to be optimal for small enough and high enough hard FM risk.

**Keywords:** Private finance initiatives, foundation trusts, hospitals, facility management services outsourcing, moral hazard, incomplete contracts, bundling.

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# 1 Introduction

For some years, there has been a tendency among UK hospitals to switch outsourced facility management services back to in-house delivery. As a case in point, Scottish, Welsh and North Ireland health authorities have terminated the outsourcing of cleaning services. In England, hospital staff put pressure on preventing further outsourcing of any type of facility management services (Auffenberg, 2021).[1] These services include hard facility management (hard FM) for maintaining the condition of hospital buildings and soft facility management (soft FM) for hospital cleaning, catering, access and security.[2] The main reason for this trend has been the deterioration of the quality of these services. For instance, the outsourcing of cleaning services is shown to yield lower hygiene standards and more infections than in-house provision (Toffolutti *et al.,* 2017; Elkomy *et al.,* 2019).

Since 1996, the UK government has pushed hospital management toward local interests and private financing. For this reason, it has created a system of local trusts to oversee the implementation of local health services and initiated public service procurement through private finance initiatives (PFIs) that permit local trusts to seek out private capital funding and organize buildings and operations through private entities, called special purpose vehicles (SPVs).[3] Under PFI contracts, construction and hard and soft facility services are delegated to SPVs through a fixed-term contract. In 2018, there were 128 PFI contracts outstanding by the Department of Health and Social Care with a capital value of GBP 12.9 billion, of which 109 were PFI-funded hospitals and care centers (Comptroller and Auditor General, 2020b).[4] This represents 10 percent of England hospitals and care centers. However, many SPVs do not deliver the quality of services prescribed in their contracts. As a case in point, four out of nine surveyed representatives of hospital authorities have declared their dissatisfaction with the con-

[1] From 2008, the Scottish government ceased the usage of private contracts for catering, cleaning and all clinically related soft facility management services, whether funded through Public-Private-Partnerships (PPPs) or not (Scottish Government, 2008). The Welsh government announced its decision "to end competitive tendering for NHS cleaning contracts" (Labour Party and Plaid Cymru, 2007, p. 10). National Hospital Office and Health Service Executive (2006) in the 'Cleaning Manual' advised health organizations to be aware that "the price is not the main determinant in contractor selection and to ensure that quality is always a key consideration" (p. 111). The message in between the lines was that in-house cleaning delivery should be a dominant strategy. NHS England still allows contracting out support services.

[2] For instance, Elkomy *et al.* (2019) report that the share of contracted out cleaning services across 130 English NHS trusts was 37% in 2013.

[3] This paper doesn't discuss the role of care quality commissions and integrated care systems. Nevertheless, they also play an essential role in developing national-level strategies and solutions to improve the health of the local population.

[4] The Departments for Education and of Health and Social Care sponsor the largest number of PFI contracts in England (Comptroller and Auditor General, 2020b).

dition of the hospitals they took over at the end of PFI contracts (Comptroller and Auditor General, 2020b). The deplorable state of hospitals can be attributed to various factors, such as faulty design, poor-quality building materials, lack of maintenance, and inferior workmanship. These issues often stem from opportunistic behavior due to information asymmetry among PFI contracting parties.

The economics literature emphasizes two types of information asymmetries according to whether private information is realized before or after the contract signature (Laffont and Martimort, 2002). In the hospital sector, adverse selection takes place when hospital authorities have less information than investors about future construction and operations at the procurement date. Moral hazard occurs when hospital investors and managers obtain private information about sanitary and economic conditions and hide their decisions and actions from authorities after contract signatures. Both issues are important and deserve extensive research attention (Laffont and Tirole, 1993). Nevertheless, this paper focuses on the moral hazard problem. Indeed, in the UK hospital sector, ex-ante information asymmetry seems less relevant as procurement procedures are competitive, procurement projects and contracts are supervised by government authorities with considerable expertise, and finally, many characteristics of recurrent investors are known to the authorities. In contrast, the risk of changing conditions after contract signature is important, as PFIs include long-term contracts spanning over 25-40 years, which provides ample room for uncertainty to materialize. This leads to substantial cost overruns and delivery delays, as shown in the documented cases of the Royal Liverpool University Hospital and Midland Metropolitan Hospital.[5]

Our research strategy naturally follows the literature on PPPs that consider moral hazard in the context of positive externalities between construction and operation tasks. Hart *et al.* (1997) point out that bundling these activities within the same entity allows for internalization of such positive externalities. Scholars like Iossa and Martimort (2012), Iossa and Martimort (2015), Martimort and Pouyet (2008), and Shi *et al.* (2020) have further explored the role of moral hazard in shaping the contract structures implemented in PPPs.[6] Nonetheless, this

[5]According to the Comptroller and Auditor General (2020a), delays in construction resulted in significant budget increases for two hospitals: the Royal Liverpool University Hospital and the Midland Metropolitan Hospital in Sandwelland. The Royal Liverpool University Hospital, initially planned to start operations in June 2017, faced extensive delays and was finally completed five years later in 2022. During this time period, the project's cost rose from £746 million to £1.06 billion. Likewise, the Midland Metropolitan Hospital experienced substantial delays, with its scheduled opening date of October 2018 being pushed back to July 2022. As a result of these delays, the project exceeded its original budget of £686 million by over £300 million. Similarly, Love and Ika (2022) conducted a study of the misperformance of PFI hospitals in Australia. They identified various factors contributing to the underperformance of hospitals, including ineffective risk management and project governance as well as optimism bias.

[6]Recent studies on two-stage moral hazard include those of Buso and Greco (2021), Hoppe and Schmitz

literature overlooks three important features of hospital facility management. First, hospital projects include three main tasks (building, hard FM, and soft FM services) rather than two (building and operation), as discussed in the literature.[7] Second, public and private operators regularly outsource their activities to private companies. Finally, the builder must offer a warranty, as prescribed by law and/or laid down in many construction contracts.

Our paper discusses these features in the classical framework of PPP analysis. To clarify the discussion, our analysis abstracts from the potential comparative advantages of outsourcing firms, where the latter benefit from cheaper labor. This is motivated by the fact that most authorities promote equal and fair working conditions within their organizations and those of their subcontractors.[8] Importantly, this analysis also allows us to clarify the main role of risks and moral hazard between local health authorities, SPVs, and outsourcing firms concerning facility management services. This paper extends Iossa and Martimort's (2015) model with a three-tier hierarchical principal-agent setup. It provides a theoretical basis for discussing the factors that explain optimal procurement policies for facility management services. Our discussion, therefore, intends to give guidance to authorities on the design of facility procurement and management.

Our model offers the following results. First, foundation trusts choice for PFI depends on the builder's warranty and hard FM risks.[9] There are three effects: the PFI internalizes the externality between builders and hard FM services; the PFI also requires a risk premium that may become too high under strong hard FM risks; finally, the builder's warranty creates a 'reverse' moral hazard that is present in the traditional procurement and becomes stronger for higher hard FM risk. The PFI is then optimal for both sufficiently small and sufficiently high hard FM risks, while traditional procurement is preferred for intermediate risks. Second, traditional procurement gives authorities no incentive to outsource facility management services, whereas PFI structures offer such incentives for soft FM services. This result provides a simple rationale for why authorities taking over expired PFIs may return to an in-house provision of soft FM services. Finally, the PFI structure is adequate to monitor the hard FM and soft FM costs in

(2021), and Martimort and Straub (2016).

[7] A wider variety of tasks at the operating stage is common in other industries. All maintenance tasks may differ according to the quality of the asset and importance of externalities.

[8] In particular, subcontractors are required to pay 'living wages' by the principle of fairness and nondiscrimination ('equal-work equal-pay'). This restriction also stems from the practical difficulty of managing similar workers with unequal remuneration in the same work environment.

[9] We contend that decisions made by authorities at a certain level are significantly influenced by FM service risks. Comptroller and Auditor General (2020a), using the examples of Midland Metropolitan and Royal Liverpool hospitals, illustrates that the original expected share cost borne by taxpayers for building and maintaining hospitals is approximately equivalent to the share of construction costs out of the total expenses (43% and 50%, respectively).

SPVs but is not appropriate to monitor the benefits from quality enhancement in each task because the PFI contract structure does not have sufficient flexibility to monitor each type of quality benefit. This finding offers a new explanation for why insufficient quality is a recurrent issue in PFIs.

The paper is organized as follows. Section 2 presents a literature review, and Section 3 describes the major agents, history of facility management outsourcing in UK hospitals, and builders' warranty lasting. Section 4 lays down the baseline model and develops the salient properties of traditional procurement and PFI. Section 5 discusses the model calibration. Section 6 concludes the paper. Finally, appendices include analytical details, proofs and calibration procedure.

# 2 Literature review

This paper relates to several strands of the economics literature. First, by discussing a multitask principal-agent problem, it relates to the economics literature on agency (Holmstrom and Milgrom, 1991). Agency theory is often not applied to the health care sector because of the complexity of hospital services and their management. Moreover, hospitals differ according to their sizes, equipment and types (general acute hospitals, special medical hospitals and others). They are also characterized by unclear objective functions because of the nexus of managers who pursue quite different interests: profit (Feldstein, 2012), quantity (Reder, 1965), social welfare (Feldstein, 2012), sales (Finkler, 1983), capacity (Lee, 1971; Newhouse, 1970) and income per doctor (Pauly and Redisch, 1973; Pauly, 1968). Nevertheless, our analysis partly abstracts from this difficulty by focusing on the provision of building and facility management services that are provided by trusts and facility management entities whose objectives are somewhat clearer. As will be explained, foundation trusts (henceforth FTs) are governed by a local representative system acting in favor of local health care benefits, whereas SPVs and outsourcing firms are private organizations that seek profits.[10]

This paper also contributes to the literature on privatization. Hart *et al.* (1997) develop the theory of incomplete contracts, which extends the idea of transaction costs pioneered by Williamson (1973, 1979) and that of property rights pioneered by Grossman and Hart (1986). These theories are built on the observation that agents are unable to write all unforeseen contingencies in their contracts. Hart *et al.* (1997) claim that private firms reduce their costs at the expense of quality. In-house provision becomes more efficient when the adverse consequences of cost-cutting on quality become large. This problem is relevant in the health

[10]Essentially, we assume that the complexity of hospital medical affairs does not impact FT behavior concerning the procurement of facility management services.

care sector because the damage to care quality from cost-cutting can be important.

The subsequent literature has further discussed the costs and benefits of PPPs, in which private firms are asked to finance and participate in public projects. The literature recognizes the existence of externalities between the construction and operation of public facilities. When these externalities are positive, the bundling of the two tasks within the same organization and management improves economic efficiency, as the latter are enticed to internalize the externalities (Hart, 2003). Bennett and Iossa (2006) highlight that bundling is an optimal procurement type under positive externalities and unbundling is preferred in the case of negative externalities.[11] Hart (2003) further shows that bundling may indeed be undesirable if the quality of service cannot be well defined in the initial contract, which seems relevant in the case of hospitals. Martimort and Pouyet (2008) discuss ownership and find that bundling is preferred only if the externalities are positive and the private benefits of owning an asset are sufficiently small. Iossa and Martimort (2011) study the optimal payment mechanism for the transport industry and find that PPP projects are associated with higher power incentives and more operational risk. Relatedly, Iossa and Martimort (2015) discuss the issue of procurement with moral hazards, agency costs and risk sharing. They show that bundling and risk transfer are the key features of PPP arrangements and explain the high risk premium observed in those contracts. Välilä (2020) summarizes other theoretical and empirical papers closely related to the results of the previous studies'. This paper contributes several important features of PFIs in the hospital sector: the existence of more than two tasks, the outsourcing of those tasks and the structural warranty of builders.

Finally, this paper relates to the literature on outsourcing. The costs and benefits of outsourcing are discussed again through the lens of agency theory. Outsourcing enhances productive efficiency through stronger competition and higher incentives in ownership (Domberger and Piggott, 1986). Shleifer and Vishny (1994) mention the positive benefits of outsourcing, such as cost reduction and competition strengthening. Schmidt (1996) and Shapiro and Willig (1990) discuss the possibility of cost increases caused by multiple management channels. Laffont and Tirole (1993) highlight the information losses in contracts and the related worsening of the quality of services. This paper discusses a practical instance of information extraction and contracting.

Cost savings arguably constitute the main benefit that encourages public authorities to outsource services. Economics studies have evaluated the existence and magnitude of such cost savings through a comparison of per-unit costs before and after the launch of outsourced

[11] A positive externality appears when higher-quality building materials yield a cost reduction at the maintenance stage. A negative externality arises when fancier and costlier building designs imply an increase in maintenance costs.

services (e.g., Hensher, 1989). However, such comparisons do not take into account confounding factors that impact costs, demand, technology and input prices. Domberger *et al.* (1987) and Szymanski (1996) show that outsourcing refuse (i.e., solid waste) collection yields stronger cost reductions by for-profit than not-for-profit organizations.[12] In contrast, other authors conclude that competitive tendering is not cost-effective, reduces service standards and leads to cost reduction mainly through wage cuts and worse working conditions (e.g., Shaw *et al.*, 1994).

The literature also discusses the benefits of soft FM services outsourcing in the health care sector. In 2022, health care is predominantly delivered in England via trusts and FTs that outsource various nonclinical tasks in hard FM and soft FM services. Cleaning is one of the most frequently outsourced functions across government institutions (Sasse *et al.*, 2019). Despite its ubiquity across the public sector, empirical evidence of the efficiency of outsourcing cleaning services is mostly found within the health care sector. When cleaning was first outsourced, large savings were achieved. For example, Domberger *et al.* (1987) report that competitive tendering of cleaning services by UK hospitals in the mid-1980s generated 34% savings when they were allocated to private providers and only 22% savings when they were assigned to the cleaning services of other public hospitals. More recent evidence also shows cost savings.[13]

Shohet (2003) advocates that the success of a maintenance outsourcing practice depends on the hospital occupancy. Under high occupancy rates, facilities are subject to severe deterioration and require in-house staff to perform corrective maintenance. Under low occupancy rates, outsourcing creates efficiency gains by delegating noncore facility management activities to more cost-efficient firms. Ciarapica *et al.* (2008) show that employing outsourced personnel is costlier for small hospitals, while outsourcing services are more cost-efficient in large hospitals. Domberger *et al.* (1987) show that hospitals outsourcing cleaning, ward orderly and housekeeping services achieve 34 % cost savings with private providers and 22% with public providers. Using audits and surveys, Comptroller and Auditor General (1987) generally finds larger cost reductions with outsourcing to private organizations. Using panel data, Milne and Wright (2004) suggest that outsourcing reduces cleaning costs in Scottish NHS hospitals by

[12] Bae (2010) and Bell and Costas (2006) find similar results for the USA and Spain.

[13] Angeles and Milne (2015) and Christoffersen *et al.* (2007) show cost savings of more than 25%. Milne and Wright (2004) and Toffolutti *et al.* (2017) find cost savings between 7.5% and 10%. Cost savings also depend on the extent of competition at the tendering stage, as each additional bidder can improve costs by an amount between 2.5% and 3.0% (Milne and Wright, 2004; Angeles and Milne, 2015). This possibility applies regardless of whether the final contract was awarded to a private or a public provider. Angeles and Milne (2015) demonstrate the persistence of savings in the cleaning sector. Private providers achieve greater and longer-lasting cost savings in subsequent tenders. The Auditor General for Scotland (2003) shows evidence that cost savings are achieved by employing fewer staff, which is associated with lower-quality cleaning. Toffolutti *et al.* (2017) also find empirical evidence of 28% higher rates of infection in hospitals with outsourced cleaning services. Bourn (2003) finds a slight decrease in quality with privately provided cleaning in Scottish hospitals.

24.4% when outsourcing to for-profit firms and by 17% with not-for-profit firms. Angeles and Milne (2015) find that outsourcing is indeed more cost efficient. However, cost savings are not maintained for subsequent outsourcing contracts (Szymanski and Wilkins, 1993; Szymanski, 1996).

On balance, evidence about hard FM service cost savings suggests that greater private involvement leads to cost savings between 2% and 7%, even after controlling for quality (Blom-Hansen, 2003; Lindholst *et al.*, 2018). An Australian survey from the late 1990s finds that public sector clients that outsource infrastructure maintenance report savings of 6.8% (Domberger and Fernandez, 1999). Moreover, Lindholst *et al.* (2018) claim that increased competition in bidding for maintenance contracts does not reduce costs, although this result may be due to market saturation.

Finally, the role of builder's warranty has not been studied in the context of PPPs, particularly in the health care sector. Hospitals are complex entities requiring the involvement of multiple agents and are usually built under unique bespoke contracts in the UK. The number of collateral warranties signed by the agents participating in the agreement varies between the builder and corresponding suppliers, or in the case of PFI, between the design subcontractor and funder, the building contractor and authority, the building contractor and funder, or others.[14] Nevertheless, the builder's commitment to rectify construction snags during the building liability and limitation periods differs mainly with respect to the time frames. The economics literature covers warranties in the general product context (Emons, 1989; Cooper and Ross, 1985; Dybvig and Lutz, 1993), where warranties perform as insurance (Heal, 1977), signalling (Grossman, 1981, Lutz, 1989), or incentive motives (Priest, 1981; Spence, 1977) for agents. Studies explaining the role of defect warranties in the construction industry within agency theory offer limited discussion.[15] Ong (1997) claims that a longer defect warranty period, more stringent inspection standards and restrictions on the ability to sell the property before its completion can alleviate the number of defects. He explains the limited effectiveness of defect warranties through the inability to meet a specific condition, which is necessary to eliminate the disincentive effects.

In summary, this paper expands the theoretical literature on agency theory, privatization and public private partnerships in several new directions. It also contributes to the literature on outsourcing to private firms.

[14] Our study does not discuss the role of structural warranty, which is usually provided by external party. On the one hand, the construction methods are homogenous, i.e. building process, technology, and materials. On the other hand, home buyers' protection against defects is unique from country to country (Royal *et al.*, 2021; Sommerville, 2008).

[15] Empirical studies typically examine the factors leading to defects during the post-handover period of newly built houses. See, for example, Sommerville and McCosh (2006), and Pan and Thomas (2015).

# 3 Industry description

The National Health Service (NHS) is the national health care system of the United Kingdom. The organization is funded primarily by taxation and provides free or low-cost health care to all legal residents of the UK. For three decades, the NHS has decentralized the procurement of its hospital services through FTs. In this section, we explain salient factors of this hospital provision.

## 3.1 NHS Trusts and Foundation Trusts

In January 1989, the British government published the 'Working for Patients' white paper on health services (Department of Health, 1989). The paper changed the structure of the internal market for UK health care as it proposed transforming hospitals into self-governing 'NHS trusts'. Health authorities then started to act as purchasers of health care services provided by NHS trusts. Each trust is run by a board of directors that oversees one or a few hospitals. From a legal viewpoint, an NHS trust is a public sector corporation that serves a geographical area or a specialized function (for instance, an ambulance service). NHS Trusts are established under the 'National Health Service and Community Care Act 1990'. However, since the Health and Social Care Act 2003, the NHS has transformed NHS trusts into NHS FTs to make those entities even more locally oriented. The transformation of these trusts is overseen by independent institutions sponsored by the NHS.[16] This change ensures elevated levels of services that hospitals must meet to qualify for the transformation. The new status gives trusts greater local autonomy in their governance through the election of local governors who nominate and supervise hospital management. It also grants greater autonomy to raise funds outside the NHS system and allows hospitals to provide services that were not available before within the NHS, such as home care.

Hence, at present, NHS trusts and NHS FTs are both present in the UK. As of 2022, there are 71 trusts and 145 FTs in England. The goal of the UK government is to foster the transition of all trusts into FTs. Although this target has not yet been achieved, the number of trusts has been decreasing and the number of FTs has been increasing. As shown in Figure 1, the transformation process is (slowly) converging. This policy dictates our choice of the NHS FT as the principal object of our research. Thus, we will concentrate on NHS FTs.

[16] These regulatory institutions have included the NHS Trust Development Authority, Monitor, NHS Improvement, NHS England, and NHS England and Improvement. Some of these institutions have been active at different periods and have merged.

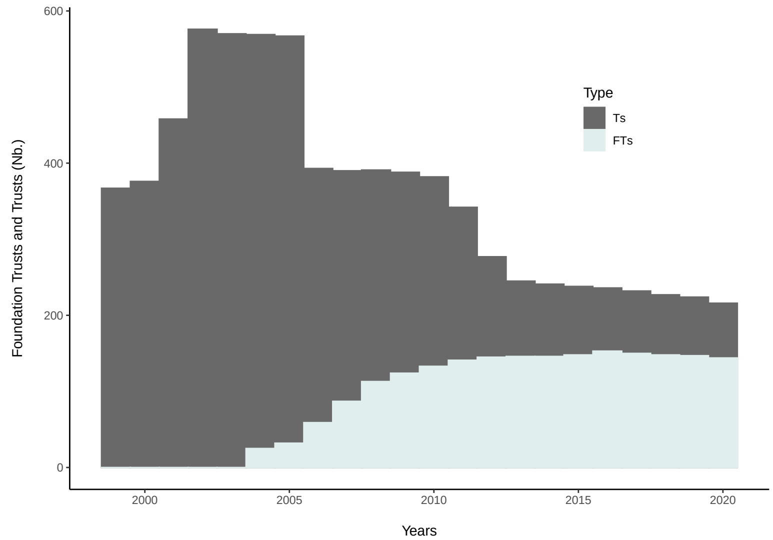


Figure 1: Numbers of Trusts and Foundation Trusts in England.

Source: The Estates Return Information Collection (ERIC), NHS Digital.

## 3.2 FT mission

The Health and Social Care Act 2012 (hereafter abbreviated HSCA 2012) establishes the FT as a 'public benefit corporation' whose principal purpose is "to provide goods and services for the purposes of the health service in England", more specifically, services "provided to individuals for or in connection with the prevention, diagnosis or treatment of illness" or linked to "the promotion and protection of public health" (The Stationery Office, 2012, p. 158). The HSCA 2012 allows an FT to carry out any other activities if they generate additional income to successfully deliver its principal purposes. The Act sets an important criterion that determines fulfillment of the FT's principal purpose, i.e., "total income from the provision of goods and services for the purposes of the health service in England is greater than its total income from the provision of goods and services for any other purposes" (The Stationery Office, 2012, p. 163).

A pitfall of this criterion is the absence of methodology imposed to estimate and compare incomes from activities that may or may not be relevant to health services in England. The Act obliges each FT to mention in its annual reports how non-NHS goods and services have achieved the purposes of the FT. The 'NHS Foundation Trust Annual Reporting Manual' also requires FTs to "include a statement in their annual report that they have met" this criterion (NHS England and NHS Improvement, 2022, p. 29). However, our research reveals that only one FT, the Norfolk and Norwich University Hospital NHS Foundation Trust, has mentioned the income generated from health services provision in their 2019 reports. In summary, this discussion suggests that despite some lack of reporting, FTs seek to maximize health services.

### 3.3 FT decision structure

FTs manage hospitals through the actions of their boards and chief executives. Each FT has two bodies: the Council of Governors (CoGs) and the Board of Directors (BoDs). The HSCA 2012 assigns the CoGs with the power to appoint leading actors to oversee the machinery of the FT while the BoDs are responsible for managing the day-to-day operations of hospitals.

The CoGs consist of elected and appointed governors. Elected governors are chosen by three constituencies, namely, the public, patients and staff members. The constituency of public members comprises a set of residents who live in the area covered by the FT and voluntarily register and vote for a specific set of elected governors. They are split into geographical classes. The constituency of patients is formed only in a fraction of FTs and entails a set of individuals who have used the health services of the FT in recent years.[17] The constituency of staff members includes a set of members who are employees of the FT or exercise regular functions for the FT. They are split into professional classes (e.g., medical, dental, and nursing activities) and vote for another set of elected governors. In contrast, appointed governors are nominated by local authorities, universities, charities and/or clinical commissioning groups. In particular, the HSCA 2012 obliges FTs to appoint at least one member by the local authority and at least one member by a university when a medical or dental school belongs to any hospital managed by the FT. Although each FT's constitution freely defines the numbers of elected and appointed governors, the HSCA 2012 imposes a minimum of three governors for the constituency of the staff members or one for each of its professional classes. The Act also imposes that the constituency of staff members is permitted to elect less than half of the members of the CoGs. This restriction is seen as a fundamental feature of the promotion of a publicly oriented institution and devolution to local citizens. Figure 2 compares the numbers of governors in FTs in 2022 and confirms that elected governors form the strong majority of the members of CoGs.

Although the design of the FTs favors the interests of the local community, the representation of the public is weaker. Indeed, the election turnout and representation rate are significantly lower in the public constituency. As a case in point, Table 1 summarizes the 2020 voting sheets of the Manchester University FT election, where the cast and turnout numbers are much smaller for the public constituency.

We now describe the nomination and duties of the BoDs in charge of FTs' daily operation. The HSCA 2012 first empowers the CoGs to appoint a set of Non-Executive Directors (NEDs), one of whom becomes the Chairman. The NEDs and the Chairman are then called to elect the chief executive officer (CEO) with the approval of the CoGs. Finally, the chairman, the CEO and the NEDs nominate another set of Executive Directors (EDs) for finance, medical practice, nurse and other functions, including a director for estates and facilities (i.e. hard FM and soft

[17] In 2022, only 39 out of 145 FTs include a constituency of patients.

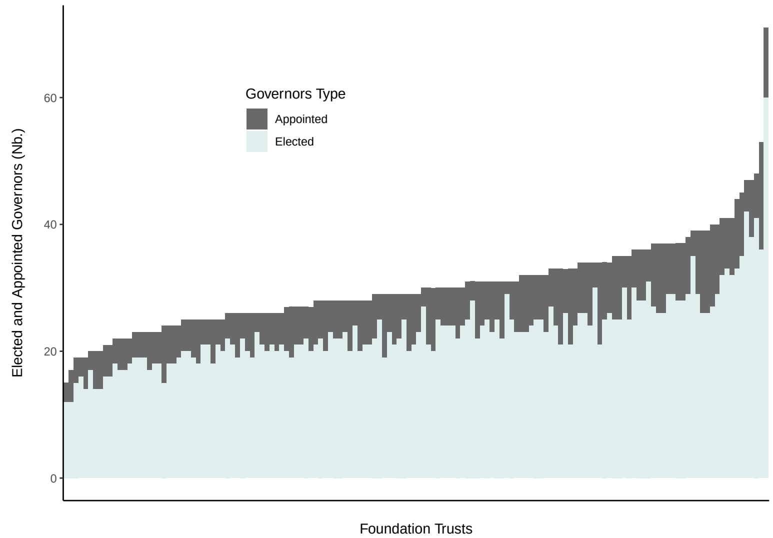


Figure 2: Numbers of elected and appointed governors in 2022.

Note: The dark and light gray bars reports the number of elected and appointed governors in the FTs in England in 2022. Those numbers are extracted from the websites of the 145 FTs active in 2022.
Source: NHS Provider Directory.

FM) when appropriate. According to the Act, the duty of the BoD is "to act with a view to promoting the success of the corporation so as to maximize the benefits for the members of the corporation as a whole and for the public" (The Stationery Office, 2012, p. 153).

Some questions arise about how to measure success and define the benefits of FTs. The success of an FT can indeed be assessed by a simple comparison of annual incomes. It can also be assessed by a comparison of performance indicators published by the FTs in their annual reports. Such comparisons are mostly not adequate because of FTs' heterogeneity in size and specialization. Their success can also be assessed by the finance and governance risk ratings that are published by independent regulators[18], which include patients' waiting times, transfer delays, experience feedback, etc. Similar standardized indicators are reported in FTs' annual reports. However, FTs also report their own indicators. For example, the Manchester University Trust has created a monthly self-assessment audit tool called the Quality Care Round, which reports on cleanliness, communication, and infection control, pain, patient safety, etc.

The above description suggests that FTs are governed by and for the interests of their public communities and staff members. Both groups' concerns regarding hard FM and soft FM services most generally coincide. Indeed, building conditions and cleanliness improve the experiences of both patients and staff members. However, the multiplicity of indicators and the absence of clear definitions for 'success' make challenging any prospect of a clear objective function for FTs.

[18]See the regulatory institutions named in a footnote 16.

| Constituency | Class | Governors | Eligible voters | Turnout | Population | Represen-tation rate |
|---|---|---|---|---|---|---|
| Public | Manchester | 7 | 8799 | 7.1% | 549123 | 0.11% |
| | Trafford | 2 | 3451 | 11.0% | 234140 | 0.16% |
| | Eastern Cheshire | 1 | 1113 | 16.1% | 382090 | 0.05% |
| | Rest of Greater Manchester | 5 | 8065 | 6.3% | 2811773 | 0.02% |
| | Rest of England and Wales | 2 | - | - | | |
| | Total | 19 | 21428 | 10.1% | | |
| Staff | Medical and Dental | 1 | 2358 | 16.3 % | 2358 | 16.3 % |
| | Non-Clinical and Support | 2 | 7540 | 9.6% | 7540 | 9.6% |
| | Nursing and Midwifery | 2 | 7517 | 7.0% | 7517 | 7.0% |
| | Other Clinical | 2 | 8869 | 6.7% | 8869 | 6.7% |
| | Total | 7 | 26224 | 9.9% | | |

TABLE 1: Voting turnout and participation rates in Manchester University NHS FT (2020)

Note: The representation rate is equal to the ratio of eligible voters times turnout divided by total population above age 11.

Source: Civica Election Services and Office for National Statistics.

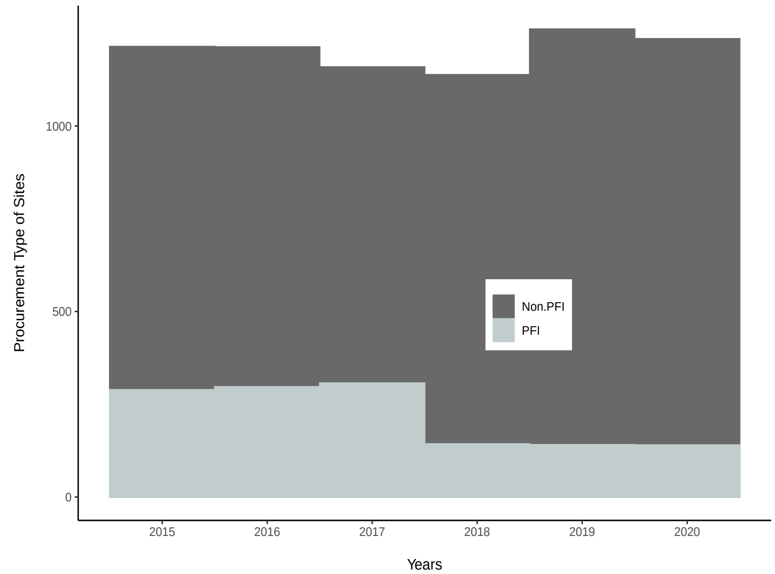


Figure 3: PFI and traditionally procured projects in England.

Note: Light and dark gray represent the PFI and traditionally procured projects of NHS Trusts and FTs. Source: Estates Return Information Collection dataset, NHS Digital.

## 3.4 Private Finance Initiative

As the UK government struggled with rising health care costs in the 1980s, it created PFIs as an alternative form of procuring public hospitals, thus providing innovative ways to control costs and improve services. Under a PFI program, a trust or foundation trust tenders for a private firm, called the Special Purpose Vehicle (SPV), to finance and construct a new hospital, maintain the facility, and provide nonclinical services such as laundry, security, parking, and catering. The SPV receives annual payments for 15-25 years as a reimbursement for its capital costs and its recurrent costs for maintenance and services. However, the authorities in charge still manage medical services.

An NHS trust or FT generally oversees more than one hospital and health care center. Hence, each trust and FT may hold several PFI contracts, generally one for each project at a hospital or health care center. Figure 3 displays the evolution of the number of projects at trusts and FTs. Around 20% of these projects are PFI projects while the majority continue to be implemented through traditional procurement methods.

## 3.5 Special Purpose Vehicle

The SPV is the legal entity that is the counterpart to a PFI project contract. It is a UK-incorporated limited company created for the PFI project and managing its activities. The FT contracts the SPV to implement the PFI project that shall build and maintain a hospital(s).

The SPV is also in charge of financing the project with banks or bond holders. The SPV raises funds from lenders and shareholders and sets up its equity and debt levels. It usually chooses a high debt leverage that makes it averse to cost fluctuations resulting from the construction and operation risks that it bears on behalf of the FT. This risk transfer is reflected in the risk premium that is required in the contract with the FT.

Although the SPV formally has no employees, day-to-day management activities are subcontracted to a 'management services company' with limited decision-making power. The shareholders of the SPV are the capital investors who participate in the tender for the PFI contract. Often, these investors are also the subcontractors of the SPVs, who are in charge of construction and hard FM services. SPVs are highly leveraged so that returns on investment are important and investors are averse to fluctuations of revenues and costs. The final PFI model is designed to be self-monitoring as the SPV is responsible for reporting the hospital's performance. In summary, the distinctiveness of the PFI is the strong collaboration between SPV investors, builders and management service companies in setting up and operating an infrastructure project. This feature calls for understanding the SPV behavior as a risk averse management team that bundles construction and hard FM tasks.

The authority pays back private investors using regular transfers, called unitary charges, only after the SPV has delivered its infrastructure. The unitary charges are linked to inflation and agreed upon at the start of the PFI contract. The PFI program permits the financing of public hospitals and therefore enables local authorities to free up resources for other public projects with insufficient capital budgets. Comptroller and Auditor General (2018) shows that the PFI increases budget flexibility in the short run while it does the opposite in the long term because PFI maintenance costs are growing over time and constrain government budgets again.

The main economic virtue of PFIs advocated in the literature is the bundling of hospital construction and hard FM services. Such bundling gives incentives to the private partners to reduce project costs between construction and operation stages (Hart, 2003). Such cost savings, however, do not always happen because the complexity and rigidity of the PFI contract. In addition, the collaboration between SPV stakeholders is not always very good. Indeed, cost-reducing and quality-enhancing interactions with construction and hard FM suppliers have been prevented by the management and investors of the SPV (including creditors) (Comptroller and Auditor General, 2018). Finally, the maintenance risk is fully transferred to the private sector as the SPV must repair and replace assets' facilities during the contract.[19] As mentioned, this fact induces additional costs that are reflected in the risk premium negotiated in the PFI

[19] As a case in point, the House of Commons Treasury Committee (2011, p. 29) states that "the obvious risks to transfer to the private sector are those they are best able to manage and cost. So infrastructure construction risks (delay, price, quality), infrastructure maintenance risks, infrastructure operating risks and infrastructure financing risks are best put to the private sector rather than retained in the public sector."

contract.[20]

## 3.6 Outsourcing facility management

There is always a need for NHS provider organizations to consider what actions they can undertake to deliver long-term financial viability (NHS England, 2019). One initiative could be outsourcing to provide nonclinical services.

Contracting out of public services began in the late 1970s (TUC, 2015). Margaret Thatcher's government officially instructed health authorities to introduce competitive tendering for all support services in 1983 (Toffolutti *et al.*, 2017), with the main objective to make "maximum possible savings by putting services like laundry, catering and hospital cleaning out to competitive tender" (Conservative party, 1983). The introduction of compulsory competitive tendering in the local government by the Local Government Acts 1988 and 1992 initiated a move by both the central and local governments to outsource services to private sector providers (TUC, 2015).

In the case of hospital FTs, the structure of the outsourcing process is as follows. The decision to outsource is made by the BoD on the recommendations of the hard FM and soft FM teams. The decision is argued by an appraisal exercise and business case that assess the costs and benefits. In practice, the decision is based mostly on price, quality of service, implementation, innovation and technology. A key feature of outsourcing contracts is the existence of a 'service level agreement' where the quality and volume of services are described in detail. The contracts define key performance indicators (KPIs) that the firm must achieve to avoid penalties. This feature contrasts with the objectives of in-house facility management services that are often poorly documented.

The outsourcing process varies according to the numbers of outsourced services, contracts and suppliers (Ancarani and Capaldo, 2005). In the majority of cases, a contract specifies a bundle of services. Some suppliers accept more than one contract. In UK hospital facility management, outsourcing contracts have an average duration of four or five years (Wiggins, 2020). The FT organizes a tender for each contract. Various private firms usually participate in the tendering process while bids by other public firms are also invited.

Payments to outsourcing firms differ according to each FT and facility management service. There is no standard model for outsourcing contracts. The latter are bespoke according to the objectives of the FT or SPV. They vary from fixed cost, cost plus and cost plus guarantee to fixed cost per user, performance-based and 'Nil' subsidy (Wiggins, 2020). Penalties are foreseen

[20] Some observers have reported additional cost items that raise the total cost of the PFI. For Comptroller and Auditor General (2018), insurance, cash management, external advisers, lender fees, management and administration fees are also important cost items specific to PFIs.

for the cases where outsourcing firms do not achieve the KPIs. In our model below, we simplify the contract complexity by assuming that KPI are always met. Moreover, we consider two contracts that separately bundle the tasks of hard FM and soft FM services.

Outsourcing is present in both PFIs and traditionally procured hospitals. However, it is more important in PFIs. Table 2 shows that laundry and linen services are more often outsourced in PFIs. Traditional procurement uses more in-house delivery. Rationals in this context are studied in the theoretical model below.

| | 2017 | | 2018 | | 2019 | | 2020 | |
|---|---|---|---|---|---|---|---|---|
| Procurement type (%) | PFI | Trad.l | PFI | Trad. | PFI | Trad. | PFI | Trad. |
| Outsourced | 0.83 | 0.77 | 0.83 | 0.77 | 0.82 | 0.76 | 0.83 | 0.80 |
| Mix in-house/outsourced | 0.17 | 0.23 | 0.17 | 0.23 | 0.18 | 0.24 | 0.17 | 0.20 |
| In-house | 0.08 | 0.12 | 0.08 | 0.11 | 0.07 | 0.10 | 0.06 | 0.02 |

TABLE 2: Outsourcing of laundry and linen services within healthcare sites in England

Note: Trad. means traditional procurement.

Source: Estates Returns Information Collection dataset, NHS Digital.

### 3.7 Builder's warranty

Once the construction of a hospital is completed, a certificate of practical completion is issued and triggers the start of a 'rectification period' (defects liability period). It typically lasts from 6 to 24 months for traditionally procured hospitals and 12 months for PFI contracts (The Stationery Office, 2007). During this period, the hospital's owner, the FT, can require the builder to remedy defects in the works that have been carried out under the contract at its own cost. The rectification period is not the end of a contractor's liability for defects arising in its works. Afterward, the builder bears statutory responsibility for rectification of defects that may arise in workmanship and materials, which lasts for a 'limitation period' of 6 to 12 years, depending on the contract type (The Stationery Office, 1980). Moreover, manufacturers issue an additional warranty on materials used by the constructor, e.g., roof, windows, building envelope, etc. For example, roofing constructors often install a single polymembrane roof on which the manufacturer provides a 20-year warranty. If there are issues with the roof during the defects liability period, the builder would be obliged to rectify the defects at no cost to the FT. During the limitation period thereafter, there is an option to pursue the original contractor for defects in either workmanship or materials or as an alternative to rely on the manufacturer's warranty.

# 4 The model

In this section, we present the decision variables and payoffs of the foundation trust, Private Finance Initiative entity, hospitals and outsourcing firms. We first study the first-best allocation as a benchmark case and then discuss traditional procurement and PFI.

The FT chooses between traditional procurement and PFI contract.[21] The FT represents the authority interests and maximizes the social net benefit. It is assumed to be risk neutral.[22] In contrast, the builder and outsourcing facility management firms are entities run by risk averse managers endowed with the utility function $u(x) = -e^{-\rho x}$, where $x \in \mathbb{R}^+$ is their income and $\rho > 0$ is their (common) constant absolute risk aversion parameter ($\rho = -u''/u'$).[23] Random variables are denoted by a tilda $\sim$. When the deterministic income $x$ is added, an i.i.d. random shock $\widetilde{\varepsilon}$, that follows a normal distribution with zero mean and variance $\sigma^2$, the expected utility $\mathrm{E}\left[u(x + y\widetilde{\varepsilon})\right]$ with $y \in \mathbb{R}$ is given by $u\left(x - \frac{1}{2}\rho\sigma^2 y^2\right)$ (see Appendix A). The expression $x - \frac{1}{2}\rho\sigma^2 y^2$ is referred to as the certainty equivalent. The term $\rho\sigma^2 y^2/2$ is the risk premium. This premium is nil in the absence of risk aversion. All managers have an outside option with zero values.

[21] For simplicity, we do not model an extensive decision procedure of the NHS hospital procurement choice. In reality, for all capital projects that cost over GBP 25 (40 million from 2004), the FT must develop a Strategic Outline Case (SOC). This case discusses the FT's strategic context, health services needs, formulation of options and cost affordability. This document states and evaluates funding options, procurement routes, and PFI costs and benefits. The Department of Health approves or rejects SOC, considering the risk assessment delivered by Monitor, an executive non-departmental public body sponsored by the Department of Health. Subsequently, HM Treasury endorses the SOC. A similar course of actions is taken to validate the Outline Business Case (OBS) before publication in the Official Journal of the European Communities (OJEC), which leads to a call for an official bidding process.

[22] The FT has significant independence from the Department of Health because it has the power to retain and redistribute project surpluses, as well as borrow money and reinvest it across its projects. Furthermore, including PFIs in the FTs' governance brings additional support from the Department of Health. For instance, in February 2012, seven FTs with 'unaffordable' PFI schemes were eligible for central support for their PFI-related costs (Comptroller and Auditor General, 2012). For FTs not involved in PFI management, there is always an opportunity to develop new business in case of financial balance breaches. Moreover, the regulating institution Monitor identifies and assesses governance and financial risks in FTs. If Monitor discovers that any FT breaches their regulatory conditions (governance or financial), it can intervene, e.g. by forcing FTs to an independent review of their governance arrangements or by requiring them to develop a recovery plan (Comptroller and Auditor General, 2014).

[23] The risk-aversion of outsourcing firm managers stems from their reputation risk. They sign contracts with the FT on a 5-years basis with the expectation of a prolongation in case of satisfactory services. The SPVs are highly indebted and can be punished for unsatisfactory services by reduced unitary-charge payments. The CARA utility function is convenient when the environment is multitask and contracts are linear in their variables (see Holmström and Milgrom, 1987, 1991).

Hospital activity yields the social benefit

$$B = b_0 + b_B e_B + b_H e_H + b_S e_S, \tag{1}$$

where $b_0 \geq 0$ is the social benefit that the hospital generates in the absence of efforts from any agent. For instance, this value represents the benefit from hospital beds that the FT supplies in its particular region. The social benefit may increase with the builder's effort in enhancing the building *quality* ($e_B \geq 0$) and with the hard FM and soft FM managers' efforts in raising the *quality* of hard and soft facility services ($e_H,\ e_S \geq 0$).[24] These benefits represent the construction quality, the speed of the repair of the building and its facilities, and the quality of the catered food or the friendliness of the cleaning staff. All marginal benefits from quality enhancements are positive ($b_B, b_H, b_S > 0$).[25] Importantly, we assume in this text that this type of quality items cannot be contracted upon.[26]

The soft FM takes care with catering, cleaning, car parking, etc., at an observable, verifiable and idiosyncratic cost

$$\widetilde{C}_S = \gamma_0 - \gamma_S e_S + \widetilde{\varepsilon}_S, \tag{2}$$

where $\gamma_0 \geq 0$ is the base level expenses of soft FM services and $\widetilde{\varepsilon}_S$ is an i.i.d. random shock that is normally distributed with zero mean and variance $\sigma_S^2$. The cost of soft FM depends only on the efforts of its manager, which is measured by the parameter $\gamma_S$.[27] She exerts the unobservable and unverifiable effort $e_S$ and incurs a private cost equal to $e_S^2/2$. When she receives a transfer $T_S$, her utility is given by $u(T_S - \widetilde{C}_S - e_S^2/2)$.

The hard FM manager takes care with hospital building maintenance and incurs an observable, verifiable and idiosyncratic cost given by

$$\widetilde{C}_H = \delta_0 - \delta_B e_B - \delta_H e_H + \widetilde{\varepsilon}_H, \tag{3}$$

where $e_B$ and $e_H$ represent the efforts of the builder and hard FM manager, respectively. In this expression, $\delta_0 \geq 0$ represents the base level expenses of hard FM services. The cost is subject to an i.i.d. random shock, $\widetilde{\varepsilon}_H$, is normally distributed with zero mean and variance $\sigma_H^2$. The hard FM costs decrease with the effort of the manager ($\delta_H > 0$). The model also includes a positive

[24] In particular, for soft FM services, including chocolate on the patients' menu could increase their happiness level; for hard FM services, the color of the walls and paintings in the ensuite rooms stimulate the patients' mood.

[25] In other words, social benefit growth follows a rise in infrastructure quality-enhancing, hard FM and soft FM efforts.

[26] Other types of quality items can be contracted upon, for example, with KPIs: the concrete chemical composition, the calory content of food, the nurse presence, patients-perceived service quality, etc. Those are assumed to be included in the term $b_0$.

[27] For simplicity, we assume no impact of the builder's effort on soft FM services.

externality between the builder and hard FM through the parameter $\delta_B > 0$. For example, the selection of a more costly but more reliable lift, roof, window, etc., reduces the costs of their maintenance.[28] For several years after the construction, the hard FM can use the warranty for building defects so that the builder pays to fix those problems. We capture this fact in the assumption that the hard FM services bear the share $\theta \in [0, 1]$ of the hard FM's verifiable cost while the builder covers the remainder.[29] A full warranty ($\theta = 0$) implies insurance by the builder for the entire period of asset management. In contrast, the absence of the builder's warranty ($\theta = 1$) gives the whole responsibility to the operator if a shock occurs during this period.[30] The builder's insurance coverage period expands with smaller $\theta$. Finally, the hard FM exerts the unobservable and unverifiable effort $e_H$ with a private cost equal to $e_H^2/2$. When he receives a transfer $T_H$, the hard FM manager has a utility given by $u(T_H - \theta\widetilde{C}_H - e_H^2/2)$.

In this text, we do not discuss the risk in the construction process borne by the builder because we focus on the issue of FM services. We therefore consider that the production cost of the hospital building has a deterministic value $\phi_0 > 0$. The builder nevertheless covers the idiosyncratic cost of hard FM services through the warranty. The builder's cost is therefore equal to

$$\widetilde{C}_B = \phi_0 + (1 - \theta)\,\widetilde{C}_H. \tag{4}$$

The builder can improve the building quality by exerting an effort $e_B$ that will impact facility management. This effort is neither observable nor verifiable and can therefore not be contracted. The cost of his effort is given by $e_B^2/2$. When he receives a monetary transfer $T_B$, the builder has a utility equal to $u\left(T_B - \widetilde{C}_B - e_B^2/2\right)$.

Finally, the FT has a payoff that depends on the hospital social benefit $B$ and the costs and transfers during the project. We look at two scenarios in which the FT delivers the hospital either in a traditional way or through a PFI contract. In the first scenario, the FT builds and maintains the hospital using public funding. It delegates the construction work and either provides in-house hospital maintenance or outsources the work. In the second scenario, the FT makes a take-or-leave-it contract to an SPV, which is a consortium of builder and hard FM service firms. The SPV then acts as the hospital's management company and its management makes decisions at both the construction and operating stages. SPVs are usually

[28]In practice, the builder's effort has a large impact on hard FM services but a small impact on soft FM services. For instance, combined heat and power systems reduce the cost of hard FM services. These systems implement energy-efficient technologies that capture the heat, generate electricity and thermal energy that is used for space heating, cooling, domestic hot water and industrial processes.

[29]Consider a 40-year hospital project with a 10-year warranty and with hard FM maintaining only the hospital structure. This case would give a value of $\theta = 10/40$.

[30]In practice, the builder's warranty decreases with time, stopping after a definite period. Such a pattern does not qualitatively alter our results in a PFI since the PFI remains responsible for the hospital defects until the contract ends. See below.

highly leveraged and avoid generating losses. To capture the fact that their management teams are very careful about idiosyncratic cost overruns, we assume that the SPV consortium management is risk averse. For simplicity, we assume the latter has the same risk aversion parameter $\rho$ as the other managers. The SPV has the possibility to outsource soft FM services.[31] Before discussing those scenarios, we first analyze the optimal net benefit when the FT is able to exert efforts by itself.

## 4.1 First-Best

We begin by discussing the effort levels in the first best allocation. We show that those effort levels increase with the unit benefit and unit cost of efforts while the type of warranty doesn't matter.

In the first-best, the FT performs all construction and maintenance tasks by itself and incurs the cost of the respective efforts.[32] It is represented by the following program:

$$\max_{e_B(\cdot),e_H(\cdot),e_S(\cdot)} \mathrm{E}[B - \widetilde{C}_B - \theta\widetilde{C}_H - \widetilde{C}_S - \frac{1}{2}e_B(\cdot)^2 - \frac{1}{2}e_H(\cdot)^2 - \frac{1}{2}e_S(\cdot)^2], \tag{5}$$

where $\mathrm{E}[\cdot]$ denotes the expectation operator over both random variables $\widetilde{\varepsilon}_H$ and $\widetilde{\varepsilon}_S$, while $e_i(\cdot)$, $i \in \{B, H, S\}$, denotes the effort levels as functions of the realization of the random variables. Since random shocks are linear in the above objective function, the optimal effort levels are independent of the shocks. Solving the order conditions of this objective function gives the following first-best effort levels:

$$e_B^{FB} = b_B + \delta_B \qquad \text{and} \qquad e_H^{FB} = b_H + \delta_H \qquad \text{and} \qquad e_S^{FB} = b_S + \gamma_S. \tag{6}$$

The first-best efforts increase with the marginal benefits from quality enhancement $(b_B, b_H, b_S)$ and marginal cost reduction of efforts in each task $(\delta_B, \delta_H, \gamma_S)$. The first-best net benefit is then written as

$$W^{FB} = b_0 - \phi_0 - \delta_0 - \gamma_0 + \frac{1}{2}(b_B + \gamma_B)^2 + \frac{1}{2}(b_S + \gamma_S)^2 + \frac{1}{2}(b_H + \gamma_H)^2.$$

The first three terms report benefit and cost in the absence of effort. The next three terms then reflect the net benefit from efforts in quality enhancement and cost reduction.

## 4.2 Traditional Procurement

We now study the case of traditional procurement of UK hospitals. Under traditional procurement, the FT delegates the realization of hospital construction to the builder. After the

[31] The SPV does not outsource hard FM services under PFI to internalize the positive externality generated between builder and hard FM services.

[32] The FT can achieve this outcome by observing efforts and offering contracts after the shocks realization.

construction is terminated, the FT either performs the hard FM and soft FM services in-house or outsources them. The FT proposes compensations that are linked to observed costs. We first describe the compensation structure and the objective and constraints of the FT and then solve the equilibrium by backward induction. We highlight the FT's incentives for in-house hard FM and soft FM services and the presence of a 'reverse' moral hazard generated by the builder's warranty.

The FT proposes a contract to the builder that links the compensation with observed costs. We consider that the FT offers a fixed payment contract $t_B = \alpha_B \in \mathbb{R}$. Under outsourcing, the contracts to the hard FM and soft FM depend on their respective shares of verifiable costs: $t_H(\widetilde{C}_H) = \alpha_H + (1 - \beta_H)\left(\theta \widetilde{C}_H\right)$ and $t_S(\widetilde{C}_S) = \alpha_S + (1 - \beta_S)\widetilde{C}_S$, where $\alpha_H$ and $\alpha_S \in \mathbb{R}$ are fixed compensations and $\beta_H$ and $\beta_S \in [0, 1]$ measure the powers of the contracts.[33] When these powers are nil, the transfers fully reimburse the costs and give no incentives to the agents to reduce their costs. When these powers equal one, the transfers do not repay for the costs and entice the agents to reduce their costs. Note that the cost structure is the same in traditional procurement and outsourcing, as FTs make the commitment to offer equal wages for equal work to employees of the FTs and outsourcing firms. The FT's problem is therefore to choose whether to outsource hard FM and soft FM activities or not and to set the contract variables $(\alpha_B, \alpha_H, \alpha_S, \beta_H, \beta_S)$ that maximize its social net benefit and entice the builder and possible outsourcing hard FM and soft FM firms to accept their contracts.

Let us denote by $V$ the net benefit in the second stage when the builder's effort is realized. Hence, the FT solves the following maximization program:

$$W^* = \max_{\alpha_B} \mathrm{E}[V - t_B]$$

subject to the builder's participation and incentive constraints

$$\max_{e_B(\cdot) \geq 0} \mathrm{E}\left[u(t_B - \widetilde{C}_B - e_B(\cdot)^2/2)\right] \geq u(0).$$

In the second stage, the FT chooses a type of FM procurement that brings the highest net benefit level:

$$V = \max_{k,l \in \{i,o\}} V^{kl},$$

where the superscripts $^o$ and $^i$ respectively denote the outsourcing and in-house delivery of hard

[33] In the health care sector, it is common for the government to provide full-cost coverage contracts for facility management services. However, if either hard FM or soft FM firms fail to meet all the agreed Key Performance Indicators (KPIs) outlined in the contract and incur penalties, this would be considered in our model as an instance where the government does not fully cover costs. For more information on PFI payment mechanisms and performance measurement methods under a PFI, refer to Oyedele (2013).

FM and soft FM services. First, insourcing hard FM and soft FM implies

$$V^{ii} \equiv \max_{\{e_H(\cdot), e_S(\cdot)\}} \mathrm{E}[B - \theta\widetilde{C}_H - e_H(\cdot)^2/2 - \widetilde{C}_S - e_S(\cdot)^2/2].$$

Second, outsourcing hard FM and insourcing soft FM involve

$$\begin{aligned} V^{oi} \equiv & \max_{\{e_S(\cdot), \alpha_H, \beta_H\}} \mathrm{E}[B - t_H(\widetilde{C}_H) - \widetilde{C}_S - e_S(\cdot)^2/2] \\ & \text{s.t. } \mathrm{E}[\max_{e_H(\cdot)} u(t_H(\widetilde{C}_H) - \theta\widetilde{C}_H - e_H(\cdot)^2/2)] \geq u(0). \end{aligned}$$

Third, outsourcing soft FM and insourcing hard FM imply

$$\begin{aligned} V^{io} \equiv & \max_{\{e_H(\cdot), \alpha_S, \beta_S\}} \mathrm{E}[B - \theta\widetilde{C}_H - \frac{e_H^2}{2} - t_S(\widetilde{C}_S)] \\ & \text{s.t. } \mathrm{E}[\max_{e_S(\cdot)} u(t_S(\widetilde{C}_S) - \widetilde{C}_S - e_S(\cdot)^2/2)] \geq u(0). \end{aligned}$$

Finally, outsourcing both soft FM and hard FM is defined by

$$\begin{aligned} V^{oo} \equiv & \max_{\{\alpha_H, \beta_H, \alpha_S, \beta_S\}} \mathrm{E}[B - t_H(\widetilde{C}_H) - t_S(\widetilde{C}_S)] \\ & \text{s.t.. } E[\max_{e_H(\cdot)} u(t_H(\widetilde{C}_H) - \theta\widetilde{C}_H - e_H(\cdot)^2/2)] \geq u(0), \\ & \qquad E[\max_{e_S(\cdot)} u(t_S(\widetilde{C}_S) - \widetilde{C}_S - e_S(\cdot)^2/2)] \geq u(0). \end{aligned}$$

We first solve the second stage of this program and show that in-house facility management is preferred by the FT. We then solve the first stage with the FT's agency issue with the builder.

### 4.2.1 Second stage

In the second stage, the FT maximizes the net social benefit $V$ by choosing the procurement type of facility management services. In the case of outsourcing, the risk neutral FT must offer a risk premium to the risk averse outsourcing firms to entice them to participate. It also faces a moral hazard problem because it loses control of the effort levels in outsourcing firms, which shifts the cost distributions. However, the choice of contract parameters allows the FT to partly alleviate this issue. It turns out that outsourcing is not a good option. We explain this finding in the following paragraphs. The analytical details are provided in Appendix B.

Under traditional procurement, the FT perfectly monitors the effort of in-house facility management services. In contrast, when the FT outsources hard FM services, it pays a risk premium to the hard FM manager, which can be shown to be equal to $\rho\beta_H^2\theta^2\sigma_H^2/2$ and therefore to increase with risk variance and contract power $\beta_H$. Considering this premium, the FT sets the contract power to $\beta_H^o = \delta_H(b_H + \theta\delta_H)/\left[\theta\left(\delta_H^2 + \rho\sigma_H^2\right)\right]$, which falls with higher risk to mitigate the risk premium. Finally, the hard FM manager chooses an effort equal to $e_H^o = \delta_H^2(b_H + \theta\delta_H)/\left(\delta_H^2 + \rho\sigma_H^2\right)$, which also decreases with risk variance. Hence, outsourcing leads to an effort level that decreases with stronger risk. Efforts and payoffs can be computed for each outsourcing configuration. The second stage payoff of the FT is given by

$$V^{kl*} = b_0 - (\theta\delta_0 + \gamma_0 + \phi_0) + (b_B + \theta\delta_B)e_B + \frac{I_H^k}{2}(b_H + \theta\delta_H)^2 + \frac{I_S^l}{2}(b_S + \gamma_S)^2$$

where

$$I_H^k = \begin{cases} 1 & \text{if} \quad k = i \\ \frac{\delta_H^2}{\delta_H^2 + \rho_H\sigma_H^2} < 1 & \text{if} \quad k = o \end{cases}$$

and

$$I_S^l = \begin{cases} 1 & \text{if} \quad l = i \\ \frac{\gamma_S^2}{\gamma_S^2 + \rho_S\sigma_S^2} < 1 & \text{if} \quad l = o \end{cases} .$$

To get intuition, assume no warranty so that the hard FM pays the full cost of its services: $\theta = 1$. Then, in the absence of risk ($\sigma_H^2 = \sigma_S^2 = 0$), the FT achieves the same net benefit from facility management services as in the first-best (see the last two terms in $V^{kl*}$). Outsourcing facility management yields the first-best outcome, as contracts can be set to encourage adequate efforts. However, in the presence of risk, the FT must compensate for risk taking and therefore reduce the power of the contracts so that the net benefit falls (as $I_H^k$ falls). The last expression shows that outsourcing is always more costly for the FT and in-house procurement is preferred. Therefore, $V^* = V^{*ii}$. To sum up, the FT's outsourcing decision depends on FM risks and their costs. The FT is unlikely to outsource given the risk premium it is obliged to grant to outside firms.

**Proposition 1** *Under traditional procurement, the FT delivers the hard FM and soft FM services in-house.*

#### 4.2.2 First stage

In the first stage, the FT chooses to maximize the net benefit $V^*$ subject to the incentive and participation constraints of the builder. In equilibrium, the builder exerts the effort level $e_B^* = \delta_B(1-\theta)$. The builder indeed has an incentive to exert a positive effort because his effort decreases the hard FM cost, which in turn reduces his cost of the warranty. Finally, the FT sets the fixed compensation $\alpha_B$ such that the builder participates. Consequently, the FT obtains the net benefit

$$\begin{aligned}
\mathrm{E}W^{*} &= b_0 - (\delta_0 + \gamma_0 + \phi_0) + \frac{1}{2}(b_S + \gamma_S)^2 + \frac{1}{2}(b_H + \delta_H)^2 \\
&+ \frac{1}{2}(1-\theta)\left[2\delta_B b_B + (1+\theta)\,\delta_B^2 - (1-\theta)\,\delta_H^2\right] \\
&- \frac{1}{2}\rho\,(1-\theta)^2\,\sigma_H^2.
\end{aligned}$$

In the absence of a warranty ($\theta = 1$) and hard FM risk ($\sigma_H^2 = 0$), this expression matches the first-best net benefit achieved in hard FM and soft FM services (see the first line). The FT exerts adequate efforts in hard FM and soft FM but is unable to entice efforts in the building process.

In the presence of the warranty ($\theta > 0$), two effects are apparent. On the one hand, the hard FM risk decreases the net benefit because the FT must compensate the builder for the hard FM risk after construction (see the third line). On the other hand, the warranty also incentivizes the builder to internalize the cost of hard FM services (second line). However, this effect is not clear because the warranty gives the hard FM manager lower incentives to exert effort. Indeed, there exists a 'reverse' moral hazard as the warranty shifts to the builder a share of the hard FM cost that is also subject to the effort exerted by the hard FM manager. To fix ideas, suppose that the builder's effort does not impact the benefit ($b_B = 0$). In this case, the second line in the above expression simplifies to $(1-\theta)\left(\delta_B^2 - \delta_H^2\right)/2$. Accordingly, a (further) strengthening of the warranty increases the FT's net benefit if and only if $\delta_B > \delta_H$, that is, if the externality between building and hard FM services is strong enough compared to the possible cost reduction of hard FM services. Otherwise, it decreases the FT's net benefit.

## 4.3 Private Finance Initiative

We now study the PFI contracts in which the FT delegates hospitals' construction and operation to a consortium of building and management entities. We highlight the consortium's incentive to outsource soft FM services and the FT's incentives to use higher power contracts when quality enhancements impact the FT's benefit. We first describe the PFI's institutional and contract structures and present the FT's objective and constraints. We then solve the game by backward induction and discuss the equilibrium decisions and payoffs.

In a PFI, the project is implemented by the SPV consortium that represents the interests of both the builder and hard FM firm. The SPV collects the transfers and pays its costs. The FT observes and verifies the costs of building and facility services, $\widetilde{C}_B$, $\widetilde{C}_S$ and $\widetilde{C}_H$. It offers to the SPV a contract based on reported cost; that is, $t(\widetilde{C}_B, \widetilde{C}_S, \widetilde{C}_H) = \alpha + (1-\beta)(\widetilde{C}_B + \theta\widetilde{C}_H + \widetilde{C}_S)$ where $\alpha$ is a fixed compensation and $\beta$ is the power of the contract ($\beta > 0$).[34] In turn, the

[34] In our model, we focus on PFI contracts conditioned on cost rather than quality.We justify this approach

SPV management supervises the construction of the hospital and runs the facility management services. Because of its structure, the SPV supervises the construction and supplies hard FM services in-house. However, It can operate soft FM services outside its structure. In this case, the contract structure between the SPV and soft FM firm is given by the transfer scheme $t_S(\widetilde{C}_S) = \alpha_S + (1-\beta_S)\widetilde{C}_S$, where $\alpha_S$ and $\beta_S$ represent the fixed compensation and power of this contract. It is important to note that the cost structures of the SPV and outsourcing firms are the same as in the traditional procurement, as, in practice, most FTs are committed to the equal-work equal-pay principle. Additionally, cost verifiability is also identical in both the SPVs and outsourcing firms.

The FT maximizes the net benefit from the hospital project. That is,

$$W^{**} = \max_{\alpha,\beta} \mathrm{E}\left[B - t(\widetilde{C}_B, \widetilde{C}_S, \widetilde{C}_H)\right]$$

subject to SPV' outsourcing choice

$$\max\{V^i, V^o\} \geq u(0)$$

where, under in-house soft FM, the SPV management has utility

$$V^i = \max_{e_B(\cdot),e_H(\cdot),e_S(\cdot)} \mathrm{E}\, u[t(\widetilde{C}_B, \widetilde{C}_S, \widetilde{C}_H) - \widetilde{C}_B - \frac{e_B(\cdot)^2}{2} - \theta\widetilde{C}_H - \frac{e_H(\cdot)^2}{2} - \widetilde{C}_S - \frac{e_S(\cdot)^2}{2}] \geq u(0)$$

and, under outsourced soft FM, it gets

$$V^o = \max_{e_B(\cdot),e_{H(\cdot)},\alpha_S,\beta_S} \mathrm{E}\, u[t(\widetilde{C}_B, \widetilde{C}_S, \widetilde{C}_H) - \widetilde{C}_B - \frac{e_B(\cdot)^2}{2} - \theta\widetilde{C}_H - \frac{e_H(\cdot)^2}{2} - t_S(\widetilde{C}_S)] \geq u(0)$$

s.t.

$$\mathrm{E}\,[\max_{e_S(\cdot)} u(t_S(\widetilde{C}_S) - \widetilde{C}_S - \frac{e_S(\cdot)^2}{2})] \geq u(0).$$

As discussed in the literature, the advantage of the PFI is to bundle the tasks of construction and hard FM within the SPV structure. This entices its management to internalize the externality between these two tasks. However, the SPV is operated by risk averse management, necessitating compensation for the risks it must undertake. We begin by solving the second stage regarding the outsourcing choice and then solve for the transfer structure in the first stage.

by examining the unitary charge payments made to reimburse the SPV for its operating expenses. While these payments are often linked to KPIs, we assume that contracts can be treated as cost-oriented for two main reasons. First, the penalties or deductions associated with failing KPIs tend to be small and can be reduced by renegotiation or compensation for additional services (Robinson and Scott, 2009). As an example, Pollock and Price (2009, p. 176) quote an NAO report stating that "Twelve of the nineteen first-wave PFI hospitals did not believe that the level of deduction that they can impose is sufficient to incentivize the contractors to provide a satisfactory level of performance." Second, the interpretation of output/performance specifications often hinders the FT from accurately assessing the agent's effort level (Robinson and Scott, 2009). To note, Iossa and Martimort (2012, 2015) extensively discussed models with compensation conditional on KPIs.

#### 4.3.1 Second stage

In the second stage, the SPV has the capability to perform all tasks in-house. In this scenario, the effort levels of its management are pulled by the power $\beta$ of the SPV contract, as indicated by $e_H^{**} = \beta\delta_H$ and $e_S^{**} = \beta\gamma_S$, while $e_B^{**} = \beta\delta_B$ (see details in Appendix C). The builder is enticed to exert more effort under stronger externalities between construction and hard FM services (higher $\delta_B > 0$). The SPV management's utility is then given by

$$V^{i**} = u \left[ \begin{array}{c} \alpha - \beta(\gamma_0 + \delta_0 + \phi_0) + \frac{1}{2}\beta^2\delta_B^2 + \frac{1}{2}\beta^2\delta_H^2 + \frac{1}{2}\beta^2\gamma_S^2 \\ -\frac{1}{2}\rho\beta^2\left(\sigma_H^2 + \sigma_S^2\right) \end{array} \right].$$

-

The SPV can also outsource soft FM services. In this situation, it can be shown that its management exerts exactly the same effort levels on the in-house tasks as $e_H^{**} = \beta\delta_H$ and $e_B^{**} = \beta\delta_B$. However, the effort for outsourced soft FM services here depends on the contract power $\beta_S$ proposed to the outsourcing soft FM. It is shown that $e_S^{**} = \beta_S\gamma_S$. The SPV chooses a transfer level $\alpha_S^{**}$ that exactly compensates the outsourcing firm's manager for the cost of soft FM services, her effort and her risk taking. In the end, the SPV optimally sets the contract power to $\beta_S^{**} = \beta I_S^{**} \in [0, \beta]$ where

$$I_S^{**} = \frac{\gamma_S^2 + \rho\sigma_S^2}{\gamma_S^2 + 2\rho\sigma_S^2} \in [0, 1],$$

which is a decreasing function of risk variance. In the absence of risk, this contract power exactly matches the one imposed on the SPV by the FT, i.e. $\beta_S^{**} = \beta^{**}$. In the presence of risk, the SPV benefits from sharing the soft FM service risk with the outsourcing firm. However, since higher risk augments the latter's risk premium, the SPV finds it optimal to reduce the contract power with higher risk variance (as $\beta_S^{**}$ falls with $\sigma_S^2$). In the end, the SPV gets the utility

$$V^{o**} = u \left[ \begin{array}{c} \alpha - \beta(\gamma_0 + \delta_0 + \phi_0) + \frac{1}{2}\beta^2\delta_B^2 + \frac{1}{2}\beta^2\delta_H^2 + \frac{1}{2}\beta^2\gamma_S^2 \\ -\frac{1}{2}\rho\beta^2\left(\sigma_H^2 + \sigma_S^2\right) + \frac{1}{2}\beta^2\rho\sigma_S^2\frac{\rho\sigma_S^2}{\gamma_S^2 + 2\rho\sigma_S^2} \end{array} \right].$$

-

Comparing those utility levels, it can be observed that SPV management prefers to outsource soft FM services, as the inequality $V^{o**} > V^{i**}$ holds.

**Proposition 2** *Under Private Finance Initiative, the SPV outsources soft FM services.*

This result contrasts with the FT's choice of in-house soft FM services under traditional procurement. The main explanation lies in differences in risk preferences. The SPV, being risk averse, prefers to transfer its exposure to soft FM risk to subcontractors, ensuring more stable operations. In contrast, the FT, being risk neutral, is willing to bear the full risk associated with providing in-house soft FM services. As a result, when FT authorities consider taking over the management of failing PFIs, they are inclined to bring outsourced FM services back in-house. This decision aligns with the risk neutral stance of the authorities, who can manage the soft FM services internally without the need to transfer risk to subcontractors. Consequently, in-house provision leads to greater control over operations and costs for the authorities.

### 4.3.2 First stage

In the first stage, the FT decides about the contract parameters applied to the SPV. It is optimal for the FT to increase the fixed transfer $\alpha$ until the SPV's participation constraint binds. The expected net benefit of the FT can be written as

$$\mathrm{E}W^{**}=\left[\begin{array}{c} b_0-\gamma_0-\delta_0 \\ +\left(b_B+\delta_B\right)e_B^{**}+\left(b_H+\delta_H\right)e_H^{**}+\left(b_S+\gamma_S\right)e_S^{**} \\ -\frac{e_B^{**2}}{2}-\frac{e_H^{**2}}{2}-\frac{e_S^{**2}}{2} \\ -\frac{1}{2}\rho\sigma_H^2\beta^2-\frac{1}{2}\rho\beta_S^2\sigma_S^2-\frac{1}{2}\rho\sigma_S^2\left(\beta_S-\beta\right)^2 \end{array}\right].$$

The first three lines of this expression follow the same structure as the net benefit structure in the first-best but with distorted effort levels. The last line expresses additional distortions due to moral hazard and risk. The contract power that maximizes this expected net benefit is given by

$$\beta^{**}=\frac{\left(b_B+\delta_B\right)\delta_B+\left(b_H+\delta_H\right)\delta_H+\left(b_S+\gamma_S\right)I_S^{**}\delta_S}{\delta_B^2+\delta_H^2+\gamma_S^2 I_S^{**}+\rho\sigma_H^2+\rho\sigma_S^2\left(1-I_S^{**}\right)}. \tag{7}$$

The FT has only a single contract power parameter to restore efficiency in three tasks. This parameter, therefore, combines the correction for inefficiency in each task delegation. Suppose that marginal benefits from quality enhancement are absent ($b_i=0$, $i=H,S,B$). Then, the FT sets a contract with power $\beta^{**}=1$ if there is no risk ($\sigma_H^2=\sigma_S^2=0$). That is, the SPV supports the total cost of building and facility management, thereby incentivizing the reduction of its total cost. However, an increase in hard FM risk $\sigma_H^2$ decreases this power because the FT has incentives to mitigate the risk borne by the SPV. The presence of soft FM risk is, however, ambiguous. Indeed, $\sigma_S^2$ reduces the numerator of (7), while it raises its denominator for strong risks when $\rho\sigma_S^2/\gamma_S^2>0.36$ and reduces it for lower risks.[35] Hence, an increase in soft FM risks reduces the contract power only if those risks are already strong enough. If the latter are weak, the effect of stronger soft FM risk is ambiguous. Assuming away the effects in the building and hard FM ($\delta_B=\delta_H=0$), it can further be shown that $\beta^{**}$ falls with additional soft FM risk

[35] The part of the denominator that depends on $\rho\sigma_S^2$ is given by $\left(I_S^{**}\delta_S\right)^2+\rho\sigma_S^2\left(1+\left(I_S^{**}-1\right)2I_S^{**}\right)$, which can be rewritten as $\delta_S^2\left[\frac{z+z^2+1}{2z+1}\right]$, where $z=\rho\sigma_S^2/\gamma_S^2$. This can be shown to decrease on for $0\le z\le\left(\sqrt{3}-1\right)/2$ and increase for $z$ above this value.

$\sigma_S^2$.[36]

Finally, in the presence of marginal benefits from quality enhancement ($b_i > 0$, $i = H, S, B$), the FT raises the contract power above 1 when there are no risks. The FT shifts more than the total cost to the SPV to entice the SPV to internalize the social benefits. In this case, risk variance decreases the contract power.

The optimal net benefit is then given by

$$\begin{aligned}\mathrm{E}W^{**} &= b_0 - (\delta_0 + \gamma_0 + \phi_0) + \frac{1}{2}\left(\beta^{**}\delta_B\right)^2 + \frac{1}{2}\left(\beta^{**}\delta_H\right)^2 + \frac{1}{2}\left(\beta^{**}\gamma_S\right)^2 \\ &+ \frac{1}{2}\rho\sigma_H^2\left(\beta^{**}\right)^2 - \frac{1}{2}\rho\sigma_S^2\left(\beta^{**}\right)^2\frac{\gamma_S^2 - \rho\sigma_S^2}{\gamma_S^2 + 2\rho\sigma_S^2}.\end{aligned}$$

In the absence of marginal benefits from quality enhancement and risk ($b_i = \sigma_i^2 = 0$, $i = H, S, B$), the net benefit matches the value of the first-best net benefit. As highlighted in the literature, the PFI structure permits to internalize the externality between the builder and the facility management services, restori efficiency in hospital service procurement. The SPV is given a contract with power $\beta^{**} = 1$, allowing it to fully benefit from cost reductions.

## 4.4 Structure of Foundation Trust

We now compare traditional procurement with the PFI. The FT chooses the PFI if $\mathrm{E}W^{**} \geq \mathrm{E}W^{*}$. Here, we discuss the preference for PFI for each type of risk included in the project and in the presence of a net benefit for quality enhancement.

First, suppose there is no marginal benefit of quality enhancement and no risk ($b_i = \sigma_i^2 = 0$, $i = H, S, B$). In this case, the choice for PFI can be summarized by its net benefit advantage

$$\mathrm{E}W^{**} - \mathrm{E}W^{*} = \frac{1}{2}\left[\delta_B^2\theta^2 + \delta_H^2(1-\theta)^2\right] > 0. \tag{8}$$

Hence, the PFI is always preferred. Under no warranty ($\theta = 1$), the advantage of the PFI structure is related to the importance of the externality between builder and hard FM services (i.e. $\delta_B$) that the PFI internalizes. Under full warranty ($\theta = 0$), the advantage lies in the importance of marginal cost reductions in hard FM services (i.e. $\delta_H$) that are not implemented in traditional procurement. Note that the above expression is a U-shaped function of the warranty parameter $\theta$. So, the advantage is maximal either for full or no warranty.

Let us add the hard FM risk ($b_i = 0$, $i = H, S, B$, $\sigma_S^2 = 0$ and $\sigma_H^2 > 0$) so that

$$\begin{aligned}\mathrm{E}W^{**} - \mathrm{E}W^{*} &= \frac{1}{2}\left[\delta_B^2\theta^2 + \delta_H^2\left(1-\theta\right)^2\right] \\ &- \frac{1}{2}\rho\sigma_H^2\left[1 - (1-\theta)^2 - \frac{\rho\sigma_H^2}{\delta_B^2 + \delta_H^2 + \gamma_S^2 + \rho\sigma_H^2}\right],\end{aligned} \tag{9}$$

[36] If $\delta_B = \delta_H = 0$, $\beta^{**}$ simplifies to $\left(\gamma_S + b_S\right)/\delta_S * (z+1) / \left(z^2 + z + 1\right)$ where $z = \rho\sigma_S^2$. This is decreasing in $z$.

where the first line replicates (8). It can be shown that the second line is a negative and decreasing function for $\theta = 1$, a convex function taking negative and positive values for $\theta > 1$, and positive increasing function for $\theta = 1$ (see Appendix D). This yields the following proposition. Let

$$\overline{\theta} = 1/\left(1 + \sqrt{1 + \gamma_S^2/\delta_H^2}\right).$$

-

**Proposition 3** *Suppose no soft FM risk. Then, in the absence of a warranty ($\theta = 1$), the FT prefers the PFI if the externality between the builder and hard FM is strong ($\delta_B > 1$). Otherwise ($\delta_B \leq 1$), it chooses PFI only for low enough hard FM risk. In the presence of weak warranty ($\theta \in (\overline{\theta}, 1)$), the FT prefers the PFI either for sufficiently low or high hard FM risks and chooses traditional procurement for intermediate hard FM risks. Finally, in the presence of a strong warranty ($\theta \in [0, \overline{\theta})$), it always prefers the PFI.*

**Proof:** Appendix D.

The intuition goes as it follows. For small hard FM risks, the PFI is always preferred because it internalizes better the externality between the builder and hard FM. For larger risks, traditional procurement is favored because the risk neutral FT is a better entity to bear risk. However, traditional procurement transfers hard FM risk to the builder and is exposed to reverse moral hazard in the presence of a warranty. This effect dominates, and traditional procurement is avoided when the hard FM risks become very important or the warranty is very strong.

Now, let's include only soft FM risks ($b_i = 0$, $i = H, S, B$ while $\sigma_H = 0$). Then, we can write the net benefit advantage of PFI as

$$\mathrm{E}W^{**} - \mathrm{E}W^{*} = \frac{1}{2}\left(\delta_B^2\theta^2 + \delta_H^2(1-\theta)^2\right) - \frac{1}{2}F,$$

where

$$F = \frac{1}{\dfrac{1}{\rho\sigma_S^2\left(1 - I_S\right)} + \dfrac{1}{\delta_B^2 + \delta_H^2 + I_S\gamma_S^2}} + \left(1 - I_S\right)\gamma_S^2 > 0.$$

The first term reflects the above trade-off resulting from the externality between builder and hard FM services, which favors the PFI structure. The second term encapsulates the effect of the risk and moral hazard in the outsourced soft FM services. In the absence of soft FM risks ($\sigma_S^2 = 0$), we get $I_S = 1$ and $F = 0$, so that we find the trade-off explained in (8). When the externality between builder and hard FM vanishes ($\delta_B = \delta_H = 0$), only the issue of soft FM outsourcing remains. The first term vanishes, while the second term is positive. Hence, traditional procurement is preferred. Indeed, the risk neutral FT is a better entity to manage

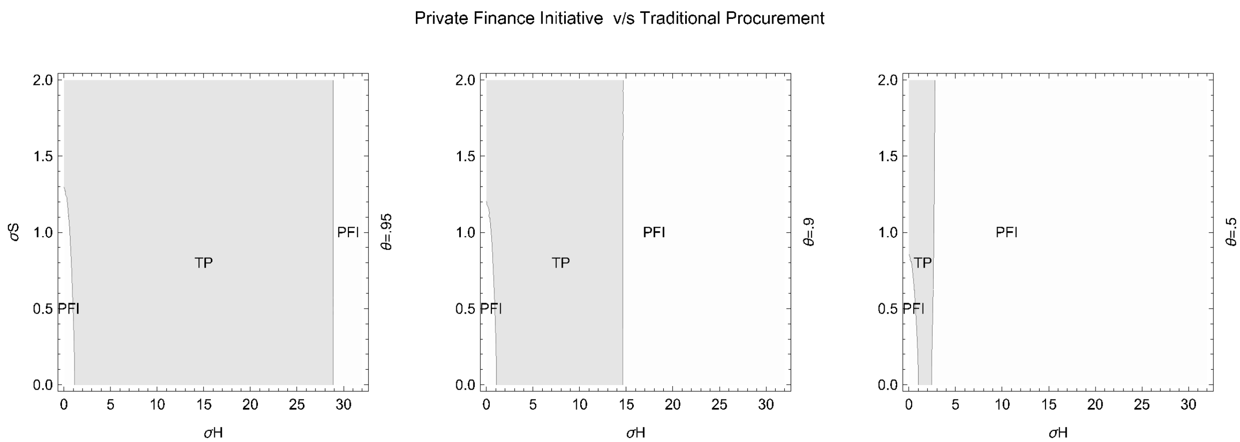


Figure 4: PFI v/s Traditional procurement.

the risk of soft FM. Then, there exists a threshold for the variance $\sigma_S^2$ such that PFI is preferred if and only if $\sigma_S^2$ is lower than this threshold.

**Proposition 4** *Suppose no hard FM risk. Then, the FT prefers the PFI for sufficiently low soft FM risk and traditional procurement for higher soft FM risk.*

**Proof:** Appendix D.

Figure 4 displays the set of risk parameters supporting traditional procurement and PFI. Each panel is produced for a different warranty. The panels confirm the above propositions when one risk dimension is considered: when soft FM risks are nil, the PFI is preferred for low and high hard FM risks; when hard FM risks are nil, the PFI is preferred for low soft FM risks. Figure 4 further shows the model properties with two risk dimensions. It indicates that, on the one hand, the PFI is preferred for low risks in both hard FM and soft FM services, and on the other hand, the PFI is preferred for high hard FM risks. Figure 4 also demonstrates that the FT prefers PFI for a stronger warranty (lower $\theta$).

In the presence of quality effects and the absence of cost reduction potential ($b_B, b_H, b_S, \sigma_H, \sigma_S > 0$ and $\delta_B = \gamma_H = \gamma_S = 0$), we have

$$\mathrm{E}W^{**} - \mathrm{E}W^{*} = -\frac{1}{2}b_H^2 - \frac{1}{2}b_S^2 + \frac{1}{2}\rho\sigma_H^2(1-\theta)^2.$$

Hence, traditional procurement is preferred for sufficiently small hard FM risks and weak warranty. This result reflects the fact that the PFI is not an appropriate structure when hard FM and soft FM service quality is at stake. In this case, the FT sets the power of the SPV contract, $\beta^{**}$, to zero. The SPV has no incentive to exert effort in any quality-enhancing activities. Note that the effect of builder's quality is not apparent in this comparison. In the presence of a warranty, stronger hard FM risk increases the net benefit of a PFI. Indeed, on the one hand, PFI is reimbursed with the risk premium. A higher risk leads to a larger risk premium paid by the authority. On the other hand, the longevity and diversity of services covered under the warranty in the contract assume higher compensation from the SPV side in case of unforeseen circumstances, e.g. building damages and a more costly transfer from the authority side.

**Proposition 5** *Suppose no cost reduction potential. Then, the FT prefers traditional procurement if the hard FM risk and warranty level are not too strong.*

# 5 A calibration

The above theoretical analysis gives insight for the full set of parameter values of the model. In this section, we apply the model to reasonable parameter values that match existing projects. Towards this aim, we calibrate the model to the example of the Trafford General Hospital of the Manchester University NHS FT, which operates under traditional procurement and with in-house facility management. In 2020, this FT incurred 7.0 Mo and 4.3 Mo GBP respectively in hard FM and soft FM costs. For this calibration, we assume that the standard deviation of the cost of each facility management service is equal to 5% of its total cost and the cost reductions from management efforts are of the same order, i.e. 5% of total costs. We consider a constant absolute risk aversion coefficient of $\rho = 0.18$, which constitutes a lower bound for high income individuals and risky asset (see Eisenhauer and Ventura, 2003). This means that hard FM and soft FM operators would require a risk premium equal to 3.1% of the cost standard deviation, which is reasonable. We assume away quality benefits in the calibration and calibrate the parameters $\delta_B$, $\delta_H$ and $\gamma_S$ to match the first best allocation. Parameter computations and values are reported in Appendix E.

Figure 5 displays the values of standard deviation in hard FM and soft FM costs for which the FT prefers traditional procurement or adopts PFI. Standard deviations are normalized with respect to the expected cost of each facility management service. Each curve displays the locus of standard deviation values for which the FT payoffs are equal in both situations for a specific and realistic value of warranty $\theta \in \{1,0.9,0.8,0.7\}$. The bold dot in the bottom left of Figure 5 shows the values of those cost standard deviations that we use in the above calibration. Since this point lies below the curves for any $\theta$, PFI is preferred for the considered cost uncertainties. The existence of warranty shrinks the set of values where the PFI dominates. Figure 5 nevertheless shows that PFI is preferred for cost standard deviations smaller than half of the facility management service costs. In other words, traditional procurement is preferred for risks that are far away from the present calibration costs. However, Figure 5 suggests a strong dominance of the PFI for the cost uncertainties as assumed in the calibration.

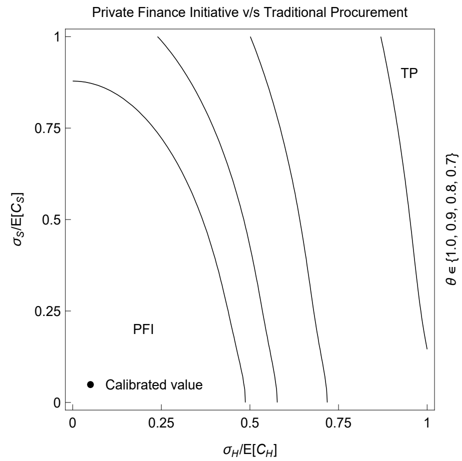


Figure 5: PFI v/s Traditional procurement.

The cost contracts are less likely to monitor properly the operators action in the presence of quality benefits. This makes PFI a less appropriate structure for the FT. To discuss this point, we present Figure 6 that displays the set of marginal benefit parameters $b_H$ and $b_S$ of effort in hard FM and soft FM for which PFI is preferred to traditional procurement. Each curve displays the locus of those parameters for which PFI and traditional procurement yield to the same FT's net benefit for a specific warranty $\theta$. The curves mainly reflect the elliptic structure of equation (9). The FT prefers PFI for parameters below each curve. We also add a bold dot (bottom left) that points to the parameter values $b_H$ and $b_S$ for which the quality benefit $b_H e_H$ and $b_S e_S$ are equal to 5% of the total costs of respectively hard FM and soft FM costs (computed in the first best). Since this point lies largely below the curves, it is apparent that a PFI implementation is a better option for the FT in such a range of parameters. In other words, quality benefits are not large enough to entice the FT to choose traditional procurement. To sum up, the present calibrated example on the Trafford General Hospital supports a move to PFI.

# 6 Conclusion

This paper describes the context and structures of FTs and PFI projects in the UK health system. It focuses on the delegation of construction and hard and soft facility management to SPVs and outsourcing firms in hospital and health care centers. It studies those delegation processes in the light of the agency theory that includes risk and moral hazard problems between FTs, SPVs and outsourcing firms. It considers three novel features specific to the sector: the delegation of multiple services, the outsourcing of facility services (three-tier delegation) and the possibility of warranty by builders.

The paper shows that the choice of PFI depends on the warranty, which encompasses a

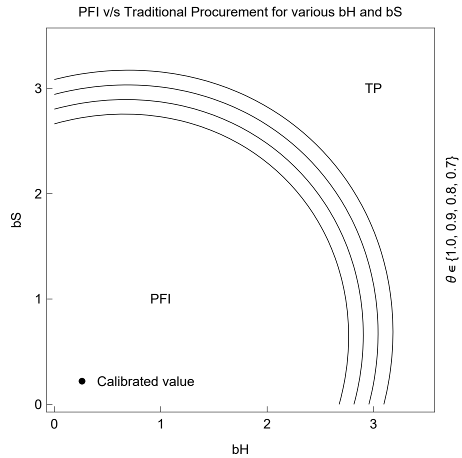


Figure 6: PFI v/s Traditional procurement for various $b_H$ and $b_S$.

'reverse' moral hazard issue. The incentives to outsource facility management services is also shown to be weaker in traditional procurement, as confirmed by some data analysis. Finally, PFIs show insufficient quality, which is a regular claim by the observers at the health care sector.

Our stylized model abstracts from the issue of construction risk for expositional purposes. In general, construction costs are on par with maintenance costs and make up half of the total life cycle expenses. However, the role of construction risks is well discussed in many contributions so that its inclusion in this model would not enhance the paper's contribution. The paper also sets the path for new research directions about the role of economies of scope and wage advantages in outsourcing firms, quality monitoring (KPIs), and insurance contracts within PFIs. Additional discussions about the nature of economic shocks and the type of hospital procurement preferred by policymakers are also worth further investigation.

# Appendix A Certainty equivalent

In this appendix, we remind the proof of certainty equivalent and risk premium under constant absolute risk aversion and normal risk distribution. We have that $E\left[u(a+b\widetilde{\varepsilon})\right] = \int e^{-\rho(a+b\widetilde{\varepsilon})} \frac{1}{\pi\sqrt{2\pi}} e^{-\frac{1}{2}(\widetilde{\varepsilon}/\sigma)^2} d\widetilde{\varepsilon} = e^{-\rho a} \int \frac{1}{\pi\sqrt{2\pi}} e^{-\rho b\widetilde{\varepsilon}-\frac{1}{2}(\widetilde{\varepsilon}/\sigma)^2} d\widetilde{\varepsilon} = e^{-\rho a} \int \frac{1}{\pi\sqrt{2\pi}} e^{\frac{1}{2}(\rho\sigma b)^2-\frac{1}{2}\left((\widetilde{\varepsilon}/\sigma+\rho\sigma b)^2\right)} d\widetilde{\varepsilon} = e^{-\rho a+\frac{1}{2}(\rho\sigma b)^2} \int \frac{1}{\pi\sqrt{2\pi}} e^{-\frac{1}{2}\left((\widetilde{\varepsilon}/\sigma+\rho\sigma b)^2\right)} d\widetilde{\varepsilon} = e^{-\rho\left(a-\frac{1}{2}\sigma^2 b^2\right)} = u\left(a-\frac{1}{2}\sigma^2 b^2\right)$.

# Appendix B Traditional procurement

In this appendix, we provide the detailed analysis of the traditional procurement of FT's hospital. We compute the FT's payoff of the four cases reported in the second stage and then analyze the first stage.

### Second stage with all insourced facilities: case $(k,l)=(i,i)$

We have $V^{ii} = \max_{\{e_H(\cdot),e_S(\cdot)\}} \mathrm{E}[b_0+b_Be_B+b_He_H+b_Se_S-\theta\left(\delta_0-\delta_Be_B-\delta_He_H+\widetilde{\varepsilon}_H\right)-\frac{1}{2}e_H(\cdot)^2 - \left(\gamma_0-\gamma_Se_S+\widetilde{\varepsilon}_S\right)-\frac{1}{2}e_S(\cdot)^2]$, which is equivalent to $= \max_{\{e_H(\cdot),e_S(\cdot)\}}[b_0+b_Be_B+b_He_H+b_Se_S-\theta\left(\delta_0-\delta_Be_B-\delta_He_H\right)-\frac{1}{2}e_H^2-\left(\gamma_0-\gamma_Se_S\right)-\frac{1}{2}e_S^2]$, where the second line takes into account the expectation of the risk neutral FT and does not depend on the shock realization. The first order conditions are given by $b_H+\theta\delta_H-e_H=0$ and $b_S+\gamma_S-e_S=0$. So, $e_H^{ii*}=b_H+\theta\delta_H$ and $e_S^{ii*}=b_S+\gamma_S$. The welfare value is

$$V^{ii*} = b_0-\theta\delta_0-\gamma_0+\left(b_B+\theta\delta_B\right)e_B+\frac{1}{2}\left(b_H+\theta\delta_H\right)^2+\frac{1}{2}\left(b_S+\gamma_S\right)^2.$$

### Second stage with mixed insourcing: case $(k,l)=(o,i)$

The FT has the program $V^{oi} = \max_{\{\alpha_H,\beta_H,e_S(\cdot)\}} \mathbf{E}[B-t_H(\widetilde{C}_H)-\widetilde{C}_S-\frac{1}{2}e_S(\cdot)^2]$ s.t.$U^{oi} = \mathrm{E}[\max_{e_H(\cdot)} u(t_H(\widetilde{C}_H)-\theta\widetilde{C}_H-\frac{1}{2}e_H(\cdot)^2)] \geq u(0)$. The outsourcing firm's effort is given by $e_H^*(\cdot) = \arg\max_{e_H(\cdot)} u(\alpha_H+(1-\beta_H)\theta\widetilde{C}_H-\theta\widetilde{C}_H-\frac{1}{2}e_H(\cdot)^2)$, which is also $\arg\max_{e_H(\cdot)} \alpha_H - \beta_H\theta\left(\delta_0-\delta_Be_B-\delta_He_H(\cdot)+\widetilde{\varepsilon}_H\right)-\frac{1}{2}e_H(\cdot)^2$. So, one finds that $e_H^{oi*}(\cdot)=e_H^{oi*}=\beta_H\theta\delta_H$, which does not depend on the shock realization. Then, the hard FM manager's utility is given by

$$\begin{aligned} U^{oi} &= \mathrm{E}\left[u\left(\alpha_H-\beta_H\theta\left(\delta_0-\delta_Be_B-\delta_He_H^{oi*}+\widetilde{\varepsilon}_H\right)-\frac{1}{2}\left(e_H^{oi*}\right)^2\right)\right] \\ &= u\left(\alpha_H-\beta_H\theta\delta_0+\beta_H\theta\delta_Be_B+\frac{1}{2}\left(e_H^{oi*}\right)^2-\frac{1}{2}\rho\sigma_H^2\beta_H^2\theta^2\right), \end{aligned}$$

where we use the property $\mathbf{E}\left[u(a+b\widetilde{\varepsilon}_H)\right]$ with $a$ and $b \in \mathbb{R}$ is given by $u\left(a-\frac{1}{2}\rho\sigma_H^2 b^2\right)$. The FT finally has the program

$$\max_{\alpha_H,\beta_H,e_S(\cdot)} V^{oi} = \mathrm{E}[B-\alpha_H-(1-\beta_H)\,\theta\widetilde{C}_H-\widetilde{C}_S-\frac{1}{2}e_S(\cdot)^2] \ \text{ s.t. } U^{oi} \geq u(0).$$

The FT optimally sets $\alpha_H$ such that the constraint is binding. So, the program becomes $\max \beta_H, e_S(\widetilde{\varepsilon}_S.\mathrm{E}[b_0+b_Be_B+b_He_H^{oi*}+b_Se_S(\widetilde{\varepsilon}_S)-\beta_H\theta\delta_0+\beta_H\theta\delta_Be_B+\frac{1}{2}\left(e_H^{oi*}\right)^2-\dfrac{1}{2}\rho\sigma_H^2\beta_H^2\theta^2-(1-\beta_H)\theta\left(\delta_0-\delta_Be_B-\delta_He_H^{oi*}+\widetilde{\varepsilon}_H\right)-\left(\gamma_0-\gamma_Se_S(\widetilde{\varepsilon}_S)+\widetilde{\varepsilon}_S\right)-\frac{1}{2}e_S(\widetilde{\varepsilon}_S)^2]$. This objective function is concave in $e_S(\cdot)$ and yields the optimal $e_S^{oi*}(\cdot)=e_S^{oi*}=b_S+\gamma_S$. Given that $e_H^{oi*}=\beta_H\theta\delta_H$, the objective is also concave in $\beta_H$. In this case, the optimal contract power is given by

$$\beta_H^* = (b_H+\theta\delta_H)\,\frac{\delta_H}{\theta\left(\delta_H^2+\rho\sigma_H^2\right)}.$$

The net benefit is given by

$$V^{oi*} = b_0-\delta_0\theta-\gamma_0+(b_B+\delta_B\theta)e_B+\frac{1}{2}(b_S+\gamma_S)^2+\frac{1}{2}\left(b_H+\delta_H\theta\right)^2\frac{\delta_H^2}{\delta_H^2+\rho\sigma_H^2}.$$

## Second stage with other cases $(k,l)=(i,o)$ and $(o,o)$.

The cases $(i,o)$ and $(o,o)$ are obtained in the same way as above. We get

$$V^{io*} = b_0-\delta_0\theta-\gamma_0+(b_B+\delta_B\theta)e_B+\frac{1}{2}(b_S+\gamma_S)^2\frac{\gamma_S^2}{\gamma_S^2+\rho\sigma_S^2}+\frac{1}{2}(b_H+\delta_H\theta)^2$$

and

$$V^{oo*} = b_0-\delta_0\theta-\gamma_0+(b_B+\delta_B\theta)e_B+\frac{1}{2}(b_S+\gamma_S)^2\frac{\gamma_S^2}{\gamma_S^2+\rho\sigma_S^2}+\frac{1}{2}\left(b_H+\delta_H\theta\right)^2\frac{\delta_H^2}{\delta_H^2+\rho\sigma_H^2}.$$

Comparing the payoffs $V^{lk*}$, $l,k\in\{i,o\}$, one can see that insourcing is preferred: $V=V^{ii*}$. This gives Proposition 1.

## First stage with builder and FT

Let us denote by $V$ the optimal net benefit in the second stage when the builder's effort is realized. The FT solves the following maximization program with $V=V^{ii*}$: $W^*=\max_{\alpha_B}\mathrm{E}[V-t_B]$ subject to the builder's participation and incentive constraints $\max_{e_B(\cdot)\geq 0}U_B=\mathrm{E}\left[u(t_B-\tilde{C}_B-\frac{1}{2}e_B(\cdot)^2)\right]\geq u(0)$. Replacing for the transfer $t_B=\alpha_B$ and the builder's cost $\tilde{C}_B=\phi_0+(1-\theta)\tilde{C}_H$, we successively get the builder's utility: $U_B=\mathrm{E}[u(\alpha_B-\phi_0-(1-\theta)\widetilde{C}_H-\dfrac{1}{2}e_B^2)]$. Given that the $\mathrm{E}[\widetilde{\varepsilon}_H]=0$ and $\mathrm{E}\left[u(a+b\widetilde{\varepsilon}_H)\right]=u\left(a-\frac{1}{2}\rho\sigma_H^2b^2\right)$, this yields $U_B=u[\alpha_B-\phi_0-(1-\theta)\left(\delta_0-\delta_Be_B-\delta_He_H\right)-\dfrac{1}{2}e_B^2-\dfrac{1}{2}\rho\sigma_H^2(1-\theta)^2]$. The builder's optimal effort $e_B^*=(1-\theta)\delta_B$ maximizes this utility level.

The FT optimally sets $\alpha_B$ such that the builder's participation constraint is binding. Using $\mathrm{E}[\widetilde{\varepsilon}_H] = 0$ and $e_H^{ii*} = b_H + \theta\delta_H$, the FT's net benefit simplifies to $W^* = \max \mathrm{E}[V - \alpha_B] = \mathrm{E}[b_0 - \theta\delta_0 - \gamma_0 + (b_B + \theta\delta_B)e_B^* + \frac{1}{2}(b_H + \theta\delta_H)^2 + \frac{1}{2}(b_S + \gamma_S)^2 - \phi_0 - (1-\theta)(\delta_0 - \delta_B e_B^* - \delta_H e_H^{ii*} + \widetilde{\varepsilon}_H) - \frac{1}{2}e_B^{*2} - \frac{1}{2}\rho\sigma_H^2(1-\theta)^2] = b_0 - (\delta_0 + \gamma_0 + \phi_0) + \frac{1}{2}(b_S + \gamma_S)^2 + \frac{1}{2}(b_H + \delta_H)^2 + \frac{1}{2}(1-\theta)[2b_B\delta_B + (1+\theta)\delta_B^2 - (1-\theta)\delta_H^2] - \frac{1}{2}(1-\theta)^2 \rho\sigma_H^2$, which is the formula displayed in the above text.

# Appendix C: Private Finance Initiative

In this appendix, we detail the analysis of PFI structure. We begin with the second stage's structure and payoff of the SPV and then determine the net benefit for the FT.

## Second stage with all in-house facility management: case (k,l)=(i,i).

Insourcing yields the following program for the SPV: $V^i = \max_{e_B, e_H, e_S} \mathrm{E}[u(\alpha + (1-\beta)(\tilde{C}_B + \theta\widetilde{C}_H + \widetilde{C}_S) - \tilde{C}_B - \frac{e_B^2}{2} - \theta\widetilde{C}_H - \frac{e_H^2}{2} - \widetilde{C}_S - \frac{e_S^2}{2})]$. Replacing the cost function and take the certainty equivalent of the risk averse SPV's payoff, this gives $\max_{e_B, e_H, e_S} u[\alpha - \beta(\gamma_0 + \delta_0 + \phi_0 - \delta_B e_B - \delta_H e_H - \gamma_S e_S) - \frac{e_B^2}{2} - \frac{e_H^2}{2} - \frac{e_S^2}{2} - \frac{1}{2}\rho\beta^2(\sigma_H^2 + \sigma_S^2)]$. This gives the SPV's optimal effort levels: $e_B^{**} = \beta\delta_B$, $e_H^{**} = \beta\delta_H$ and $e_S^{**} = \beta\gamma_S$.In this case, the utility of the SPV is

$$V^{i**} = u\left[\alpha - \beta(\gamma_0 + \delta_0 + \phi_0) + \frac{1}{2}\beta^2\delta_B^2 + \frac{1}{2}\beta^2\delta_H^2 + \frac{1}{2}\beta^2\gamma_S^2 - \frac{1}{2}\rho\beta^2\left(\sigma_H^2 + \sigma_S^2\right)\right].$$

## Second stage with mixed outsourcing: case (k,l)=(i,o).

In this case, the SPV outsources the soft FM services. The outsourcing firm's manager has a utility defined by $U_S = \mathrm{E}\left[\max_{e_S(\cdot)} u(t_S(\widetilde{C}_S) - \widetilde{C}_S - \frac{e_S^2}{2})\right]$. Taking into account his risk aversion, this yields the equivalent utility $U_S = \max_{e_S} u(\alpha_S - \beta_S(\gamma_0 - \gamma_S e_S) - \frac{1}{2}e_S^2 - \frac{1}{2}\rho\beta_S^2\sigma_S^2)$. Therefore, his optimal effort level is equal to $e_S^{**} = \beta_S\gamma_S$. Her optimal utility is

$$U_S^{**} = u(\alpha_S - \beta_S\left(\gamma_0 - \beta_S\gamma_S^2\right) - \frac{1}{2}\beta_S^2\gamma_S^2 - \frac{1}{2}\rho\beta_S^2\sigma_S^2). \tag{10}$$

The SPV has the following program: $V^o = \max_{e_B, e_H, \alpha_S, \beta_S} E[u(\alpha + (1-\beta)(\tilde{C}_B + \theta\tilde{C}_H + \widetilde{C}_S) - \tilde{C}_B - \frac{e_B^2}{2} - \theta\widetilde{C}_H - \frac{e_H^2}{2} - \alpha_S - (1-\beta_S)\widetilde{C}_S)]$. The SPV diminishes the compensation $\alpha_S$ until the participation constraint $U_S^{**} = u(0)$ binds. After substitution of costs, the SPV then has the program $\max_{e_B, e_H, \beta_S} u[\alpha - \frac{1}{2}\beta_S^2\gamma_S^2 - \frac{1}{2}\rho\beta_S^2\sigma_S^2 - \beta(\delta_0 + \gamma_0 + \phi_0 - \delta_B e_B - \delta_H e_H - \beta_S\gamma_S^2) - \frac{e_B^2}{2} - \frac{e_H^2}{2} - \frac{1}{2}\rho\beta^2\sigma_H^2 - \frac{1}{2}\rho\sigma_S^2(\beta_S - \beta)^2]$. This gives the SPV manager's optimal efforts $e_H^{**} = \beta\delta_H$

and $e_B^{**} = \beta\delta_B$. After plugging those values, the payoff in this utility function is concave in $\beta_S$ and yields a maximum at

$$\beta_S^{**} = \beta\frac{\gamma_S^2 + \rho\sigma_S^2}{\gamma_S^2 + 2\rho\sigma_S^2}.$$

Then, after simplification, the SPV's utility is given by

$$\begin{aligned} V^{o**} = u[\alpha - \beta(\delta_0 + \gamma_0 + \phi_0) + \frac{1}{2}\beta^2\delta_B^2 + \frac{1}{2}\beta^2\delta_H^2 + \frac{1}{2}\beta^2\gamma_S^2 \\ + \frac{1}{2}\rho\beta^2(\sigma_H^2 + \sigma_S^2) + \frac{1}{2}\beta^2\rho\sigma_S^2\frac{\rho\sigma_S}{\gamma_S^2 + 2\rho\sigma_S^2}]. \end{aligned} \tag{11}$$

## First stage with outsourced soft FM

The expected net benefit for FT is given by $\mathrm{E}W^{**} = \mathrm{E}[b_0 + b_B e_B^{**} + b_H e_H^{**} + b_S e_S^{**} - T(\widetilde{C}_B, \widetilde{C}_H, \widetilde{C}_S)]$, where the effort levels are determined above and depend on $\beta$. Plugging the transfer, this gives $\mathrm{E}W^{**} = \mathrm{E}[b_0 + b_B e_B^{**} + b_H e_H^{**} + b_S e_S^{**} - \alpha - (1-\beta)(\phi_0 - \theta\delta_0 - \delta_B e_B^{**} - \delta_H e_H^{**} + \gamma_0 - \gamma_S e_S^{**})]$ where the two shocks can be cancelled because they have zero expectations. The FT reduces the compensation $\alpha$ until the SPV's participation constraint binds; i.e. $V^{o**} = u(0)$. Inserting this value in the FT's net benefit gives

$$\mathrm{E}W^{**} = \begin{bmatrix} b_0 - (\delta_0 + \gamma_0 + \phi_0) \\ +(b_B + \delta_B)e_B^{**} + (b_H + \delta_H)\, e_H^{**} + (b_S + \gamma_S)\, e_S^{**} \\ -\frac{e_B^{**2}}{2} - \frac{e_H^{**2}}{2} - \frac{e_S^{**2}}{2} \\ -\frac{1}{2}\rho\sigma_H^2\beta^2 - \frac{1}{2}\rho\beta_S^2\sigma_S^2 - \frac{1}{2}\rho\sigma_S^2\,(\beta_S - \beta)^2 \end{bmatrix}.$$

The first three lines of this expression correspond to the FT's expected profits in the first-best. The last line expresses the distortion due to moral hazard and risk. It can be shown that this expression is a quadratic function of $\beta$.

Let

$$I_S^{**} = \frac{\gamma_S^2 + \rho\sigma_S^2}{\gamma_S^2 + 2\rho\sigma_S^2} \in [0,1],$$

so that $\beta_S^{**} = \beta I_S^{**}$. It can be shown that $\mathrm{E}W^{**}$ has the quadratic form $C + B\beta - A\beta^2$ where $A = [\delta_B^2 + \delta_H^2 + \gamma_S^2 I_S^{**} + \rho\sigma_H^2 + \rho\sigma_S^2\,(1 - I_S^{**})]/2 > 0$, $B = (b_B + \delta_B)\delta_B + (b_H + \delta_H)\,\delta_H + (b_S + \gamma_S)\, I_S^{**}\gamma_S$ and $C = b_0 - (\delta_0 + \gamma_0 + \phi_0)$. Then, the optimal $\beta$ is given by

$$\beta^{**} = \frac{B}{2A} = \frac{(b_B + \delta_B)\delta_B + (b_H + \delta_H)\,\delta_H + (b_S + \gamma_S)\, I_S^{**}\gamma_S}{\delta_B^2 + \delta_H^2 + \gamma_S^2 I_S^{**} + \rho\sigma_H^2 + \rho\sigma_S^2\,(1 - I_S^{**})}$$

and $\mathrm{E}W^{**} = C + 2A\,(\beta^{**})^2 = C + B^2/\,(4A)$, which yields

$$\begin{aligned} \mathrm{E}W^{**} = b_0 - (\delta_0 + \gamma_0 + \phi_0) + \frac{1}{2}\,(\beta^{**}\delta_B)^2 + \frac{1}{2}\,(\beta^{**}\delta_H)^2 + \frac{1}{2}\,(\beta^{**}\gamma_S I_S)^2 \\ + \frac{1}{2}\rho\sigma_H^2(\beta^{**})^2 + (\beta^{**})^2\frac{1}{2}\rho\sigma_S^2\left[I_S^2 + (I_S^2 - 2I_S + 1)\right], \end{aligned}$$

which simplifies to the value in the text.

# Appendix D: Optimal structure

## Proof of Proposition 4

We here characterize the expression (9). For $\theta = 1$, the second line of this expression is a convex function of $\sigma_H^2$ that decreases from 0 to $-1/2$ when hard FM risk $\sigma_H^2$ goes from zero to infinity. For $\theta \in (0,1)$, this line is also a convex function of $\sigma_H^2$ that first decreases below zero as $\sigma_H^2$ rises above zero, and reaches a minimum value $(\delta_B^2 + \delta_H^2 + \gamma_S^2)\,\theta^2$ at $\sigma_H^2 = (\delta_B^2 + \delta_H^2 + \gamma_S^2)\,\theta/\left[(1-\theta)\,\rho\right]$, then increases, crosses the zero axis and rises to positive infinity. For $\theta = 0$, this line is positive and rises to infinity as $\sigma_H^2$ increases.

This implies that, for $\theta = 1$, the above expression is always larger than zero if $\delta_B > 1$ so that PFI is always preferred. Otherwise, if $\delta_B < 1$, there exists as level of risk aversion or hard FM risk variance above which that the traditional procurement is preferred. For $\theta \in (0,1)$, PFI is always preferred if $\delta_B^2\theta^2 + \delta_H^2(1-\theta)^2 > (\delta_B^2 + \delta_H^2 + \gamma_S^2)\,\theta^2$; that is, if $(1-\theta)^2/\theta^2 > (\delta_H^2 + \gamma_S^2)/\delta_H^2$ or equivalently, $\theta < \overline{\theta}$, where

$$\overline{\theta} \equiv 1/\left(1 + \sqrt{1 + \gamma_S^2/\delta_H^2}\right).$$

Otherwise, there exist two thresholds for $\sigma_H^2$ such that traditional procurement is preferred for $\sigma_H^2$ lying within those thresholds and PFI is preferred for $\sigma_H^2$ lying outside those thresholds. Finally, if $\theta = 0$, the PFI is always preferred.

## Proof of Proposition 4

We want to prove: *Suppose no hard FM risk. Then, the FT prefers the PFI for sufficiently low soft FM risk and traditional procurement for higher soft FM risk.*

Towards this aim, we using $A = \rho\sigma_S^2$, $B = \gamma_S^2$ and $C = \delta_B^2 + \delta_H^2$ and can write

$$F = \frac{BA^3 + (B+A)\,A\,(C\,(B+2A) + B\,(B+A))}{(B+2A)\,(A^2 + C\,(B+2A) + B\,(B+A))}.$$

Then, we get

$$\frac{dF}{dA} = \frac{(AB + 2AC + BC + B^2)\begin{pmatrix} 3AB^3 + 2A^3B + 4A^3C + B^3C \\ +6A^2B^2 + B^4 + 4AB^2C + 6A^2BC \end{pmatrix}}{(2A+B)^2\,(AB + 2AC + BC + A^2 + B^2)^2} > 0.$$

Therefore $F$ increases with $\rho\sigma_S^2$. Also

$$\lim_{\rho\sigma_S^2 \to \infty} F = \lim_{A \to \infty} F = B + C = \gamma_S^2 + \delta_B^2 + \delta_H^2.$$

Hence,

$$\lim_{\rho\sigma_S^2\to\infty} \mathrm{E}W^{**} - \mathrm{E}W^{*} = -\frac{1}{2}\delta_B^2\left(1-\theta^2\right) - \frac{1}{2}\delta_H^2\left(1-(1-\theta)^2\right) - \frac{1}{2}\gamma_S^2 < 0.$$

To sum up, as $\rho\sigma_S^2$ falls from 0 to $\infty$, $\mathrm{E}W^{**} - \mathrm{E}W^{*}$ monotonically falls from positive to negative values. QED.

# Appendix E

In the calibration, we make the following assumptions:

$$\begin{aligned}
\sigma_H &= \frac{5}{100}\mathrm{E}C_H^* = \frac{5}{100}\,\text{(annual hard FM cost of a hospital)}\\
\sigma_S &= \frac{5}{100}\mathrm{E}C_S^* = \frac{5}{100}\,\text{(annual soft FM cost of a hospital)}\\
\gamma_S e_S^* &= \frac{5}{100}\,\text{(annual soft FM cost of a hospital)}\\
\delta_B e_B^* &= \frac{1}{2}\frac{5}{100}\,\text{(annual hard FM cost of a hospital)}\\
\delta_H e_H^* &= \frac{1}{2}\frac{5}{100}\,\text{(annual hard FM cost of a hospital)}\\
e_H^{ii*} &= b_H + \theta\delta_H\\
e_S^{ii*} &= b_S + \gamma_S.\\
e_B^* &= (1-\theta)\delta_B\\
\theta &= 0.9\\
b_H &= b_S = b_B = 0
\end{aligned}$$

We consider a constant absolute risk aversion coefficient of $\rho = 0.18$, which constitutes a lower bound for high income individuals and risky asset (see Eisenhauer and Ventura, 2003). Alternatively, we could assume that the risk premium for the hard FM is about $x\%$ of the standard deviations of hard FM cost. That is,

$$\frac{1}{2}\rho\sigma_H^2 = \frac{x}{100} * \sigma_H$$

This gives $\rho = \frac{1}{\sigma_H}\frac{2x}{100} = \frac{2x}{5*(\text{annual hard FM cost of a hospital})} = \frac{2}{35}x$. To match the value in the literature, $\rho = 0.18$, we should impose $x = 3.1$. This means that hard FM and soft FM would accept a risk premium that is equal to 3.1% of the standard deviation, which is reasonable but small.

This gives

$$\begin{aligned}
\sigma_H &= \frac{5}{100} EC_H^* = \frac{5}{100} (\text{annual hard FM cost of a hospital}) = \frac{5}{100} * 7 = 0.35 \\
\sigma_S &= \frac{5}{100} EC_S^* = \frac{5}{100} (\text{annual soft FM cost of a hospital}) = \frac{5}{100} * 4.3 = 0.21 \\
\gamma_S^{\text{cal}} &= \sqrt{\frac{5}{100} (\text{annual soft FM cost of a hospital})} = \sqrt{\frac{5}{100} * 4.3} = 0.46 \\
\delta_B^{\text{cal}} &= \sqrt{\frac{1}{0.1} \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital})} = \sqrt{\frac{1}{0.1} \frac{1}{2} \frac{5}{100} * 7} = 1.32 \\
\delta_H^{\text{cal}} &= \sqrt{\frac{1}{0.9} \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital})} = \sqrt{\frac{1}{0.9} \frac{1}{2} \frac{5}{100} * 7} = 0.44
\end{aligned}$$

We also add benefits from quality enhancing that are of the same order as the cost reduction achieved in the hard FM of above calibration set-up. That is,

$$\begin{aligned}
b_B e_B^* &= \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital}) \\
b_H e_H^* &= \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital}) \\
b_S e_S^* &= \frac{5}{100} (\text{annual soft FM cost of a hospital})
\end{aligned}$$

when $e_B^* = (1-\theta)\delta_B$, $e_H^* = b_H + \theta\delta_H$ and $e_S^* = b_S + \gamma_S$ where $\delta_B$, $\delta_H$ and $\gamma_S$ take the previously calibrated values. This gives

$$\begin{aligned}
b_B (1-\theta) \delta_B^{\text{cal}} &= \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital}) \\
b_H \left( b_H + \theta \delta_H^{\text{cal}} \right) &= \frac{1}{2} \frac{5}{100} (\text{annual hard FM cost of a hospital}) \\
b_S \left( b_S + \gamma_S^{\text{cal}} \right) &= \frac{5}{100} (\text{annual soft FM cost of a hospital})
\end{aligned}$$

This gives

$$\begin{aligned}
b_B * 0.1 * 1.32 &= \frac{1}{2} \frac{5}{100} 7.0 \Longrightarrow b_B = 1.32 \\
b_H (b_H + 0.9 * 0.44) &= \frac{1}{2} \frac{5}{100} 7.0 \Longrightarrow b_H = 0.26 \\
b_S (b_S + 0.46) &= \frac{5}{100} 4.3 \Longrightarrow b_S = 0.287
\end{aligned}$$

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