The Value of Group Purchasing: Evidence from the U.S. Hospital Industry*

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Abstract

Group purchasing organizations, or GPOs, are pervasive in many settings, but the actual value of GPOs remains a constant topic of debate. We offer one of the first studies examining the effect of GPOs on supply expenses in the U.S. hospital setting. We find that a one-standard-deviation increase in GPO scale (GPO market share weighted by member hospitals' bed capacity) decreases an average hospital's supply expenses by 2.7%, translating into an annual savings of more than half a million dollars. Our supplemental analyses help to foster a causal interpretation of our main findings, and our study of the heterogeneous effect sheds light on collective bargaining and product standardization as the underlying mechanisms. We find no evidence that GPOs reduce supply expenses at the cost of the quality of patient care, nor by means of changing the patient composition. Instead, we find some of the cost savings are passed to consumers in terms of lowered hospital prices, although only in highly competitive hospital markets. Our results contribute directly to the ongoing debates over the value of GPOs and more broadly to the literature on countervailing buyer power and intermediaries.

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1 Introduction

Group purchasing organizations, or GPOs, are intermediary organizations that aggregate demands for capital goods, materials, and services for member-buyers, and negotiate acquisition prices from suppliers, such as manufacturers and distributors. GPOs exist in many markets, including healthcare, retail, hospitality, and education.[1] As Grennan (2013) put it, the actual value provided by GPOs is a constant topic of debate. Whether GPOs add value to their member–buyers through lowered acquisition costs has not only generated interest from academics but also attracted intense policy discussion. While proponents argue that GPOs could lead to cost savings due to its bargaining power (Hu and Schwarz, 2011; O'Brien et al., 2017), various counterarguments suggest that GPOs could hurt member–buyers through direct competition among asymmetric members (Chen and Roma, 2011), limited benefit of demand aggregation due to the potential of custom contracting (Saha et al., 2019), misaligned incentives resulting from the vendor funding model (Litan et al., 2011), and competitive disadvantages due to aggregating demand with asymmetric preferences (Grennan, 2013).

Mirroring the controversy in the theoretical literature, existing empirical evidence has likewise offered limited and largely mixed findings. Existing empirical work on the effectiveness of GPOs has mainly looked at retailing and healthcare, where group purchasing is most influential. For example, Geyskens et al. (2015) studies GPOs among European grocery retailers and finds preliminary evidence that GPOs deliver cost savings.[2] Molina (2021) builds a structural model around the vertical relationship between bottled water manufacturers and retailers, and estimates that buyer alliances are able to bargain a lower wholesale price with enhanced countervailing power. Evidence from healthcare settings, however, is more divided. Studies that have claimed cost-saving benefits are largely de-

[1] Synonyms include: "co-op, aggregation group, purchasing alliance, buying group, leveraged buying organization, leveraged procurement group, coalition or cooperative business group" (Moore and Gray, 2011).

[2] Geyskens et al. (2015) mainly focus on studying how GPO affects sales instead of costs, and they consider their results regarding costs as indicative rather than definitive, due to data limitations.

scriptive and based on surveys of hospital executives (Burns and Lee, 2008; Schneller, 2009; Burns and Yovovich, 2014; Dobson et al., 2019). On the contrary, a couple of studies that do utilize detailed hospital purchase data (GAO, 2002) and aftermarket transaction data (Litan et al., 2011) actually find that GPOs have failed to secure the best prices for their members. Indeed, a 2010 report by the U.S. Senate Finance Committee — provocatively titled "*Empirical Data Lacking to Support Claims of Savings with Group Purchasing Organizations*" — has highlighted the limitations of the existing evidence being "based on estimates and perceptions, rather than hard data" (Grassley, 2010).

This paper offers one of the first studies examining the effect of GPOs on supply expenses in the U.S. hospital setting. The rationale for our choice of setting is primarily two-fold. First, GPOs play a pivotal role in hospital supply acquisitions. Surveying U.S. hospitals, Burns and Lee (2008) and O'Brien et al. (2017) have estimated that 90% of them use a GPO. It is also estimated that GPO contracts account for about 70% of a hospital's non-labor purchases (Schneller, 2009; Burns and Yovovich, 2014). Added to this, the hospital sector has witnessed a large amount of GPO entries and exits during our study period, which provides a considerable amount of variation to facilitate our identification.

The second — and more important — reason, however, is that the hospital setting is critical in containing healthcare costs. According to the American Medical Association, healthcare spending in the U.S. has been increasing at an annual rate higher than 4% over the past decade.[3] Decomposing the dramatic increase, Cooper et al. (2019) find that hospital prices grew substantially faster than physician prices from 2007 to 2014. Moreover, hospital care takes up over 30% of the total healthcare spending. And among all costs incurred by hospitals, *supply expenses* — the primary outcome in our study — rank the second most important component.[4] Hence, rising expenditure from the supply chain

[3]See `https://www.ama-assn.org/system/files/2021-05/prp-annual-spending-2019.pdf`. The national health expenditure was $3.8 trillion or $11,582 per capita in 2019, accounting for 17.7% of GDP.

[4]Abdulsalam and Schneller (2017) finds that the ratio of supply expenses over operating costs ranges from 15% to 40% across different studies, depending on what is included in the denominator. Bai and Zare (2020) uses hospital cost reports, and they estimate that the non-capital-non-labor costs of a hospital, which they argue mostly comprise of medical supply expenses, account for 54.9% of the total operating costs.

is not only a problem to healthcare providers but also concerns federal and state policy makers, as higher healthcare spending provokes higher government spending through public insurance, subsidies to consumers under the ACA, and tax exclusion for employer-sponsored plans.

Our data cover the universe of medical and surgical hospitals in the U.S., spanning from 2010 to 2019. To quantify GPOs' effect, for each hospital we construct the *scale* of the GPO that the hospital is using, which is calculated as the GPO's market share weighted by hospital beds (i.e., the ratio of the total number of beds available across a GPO's member hospitals to the total number of beds available nationwide). A hospital's supply cost is measured as the ratio of the dollar value of supply expenses to the number of adjusted discharges. Our baseline model suggests that, a one-standard-deviation increase (i.e., 0.108) in the scale of a hospital's GPO decreases the hospital's supply expenses per discharge by 2.7%. More specifically, these results suggest that, switching from a GPO in the 25th percentile of scale to a GPO in the 75th percentile leads to a reduction of supply expenses per discharge by 4.8%, which amounts to a total annual savings of $981,749 for an average hospital in the data.

The identification of our baseline model exploits within-hospital variation in GPO scales, which could be driven by hospitals' choices of GPO, as well as by GPOs' market dominance changing over time. To foster a more causal interpretation of our findings, we then offer three sets of additional analyses to address any remaining endogeneity concerns about hospital–GPO selection.

First, we adopt a specification where the identification only utilizes variation in GPO scales within a hospital–GPO pair. This specification allows us to rule out the possibility that our main results are driven by the focal hospital switching in/out a GPO, or switching among different GPOs, which might be endogenous. We also adopt a specification to

According to a report by the AHA, non-labor expenses have increased 16.6% on a per patient basis since 2019 due to the major disruption caused by the COVID-19 pandemic and inflation. (https://www.aha.org/costsofcaring, accessed on 05/03/2023).

specifically deal with the complications due to hospital mergers and acquisitions, which could lead to simultaneous changes in GPOs and supply expenses. Second, we restrict our sample to system-affiliated hospitals whose choices of GPO are most likely determined at the system level and therefore arguably exogenous to any individual hospital's unobservables. Lastly, we conduct an event study to identify the effect of increased GPO scales by taking advantage of a merger event involving two national GPOs. All these analyses produce qualitatively consistent results.

To explore the underlying mechanisms, we study the heterogeneous effect of GPO scales along several dimensions, which empirically supports the mechanisms of collective bargaining and product standardization. We next offer evidence that GPOs do not reduce supply expenses at the cost of the quality of patient care, nor by means of changing patient composition. We then explore whether hospitals pass through their cost savings to final consumers in terms of lower hospital prices. We find some supporting evidence, but only in relatively competitive hospital markets. Lastly, we show that our results are robust to alternative measures of hospital supply efficiency and GPO scales.

Our study contributes directly to the existing debate over whether GPOs lead to supply cost savings in the hospital setting; it offers the first comprehensive study on the impact of GPOs at a national scale. With respect to the dimension of supply expenses, our paper adds to the small-but-growing literature on hospital supply procurement as well, a literature that has thus far emphasized the role of bargaining ability (Grennan, 2013, 2014), information (Grennan and Swanson, 2020), buyer competence (Bucciol et al., 2020), and supplier substitutability (Toulemon, 2018). Due to the lack of product-level transaction data in our study, we are unable to disentangle a specific mechanism. However, our analyses offer direct evidence and policy implications regarding the role of GPOs and their effects on hospital supply expenses.

Furthermore, our study adds to the existing economics literature on hospital operating costs, which has focused on, for instance, hospital mergers (Burns et al., 2015; Schmitt, 2017; Craig et al., 2021; Gaynor et al., 2021; Prager and Schmitt, 2021) and the adoption of health information technology (Borzekowski, 2009; Dranove et al., 2014), among others. We contribute to this strand of the literature by identifying and examining the role of GPOs as an intermediary in reducing supply expenses, the largest component of non-labor related operating costs (Abdulsalam and Schneller, 2017; Bai and Zare, 2020).

More broadly, our paper is also related to the growing theoretical and empirical literature on countervailing buyer power. The notion of countervailing power stems from Galbraith (1952), who asserted that an increase in buyer concentration led to greater bargaining power against sellers, which contributed to the U.S.'s economic success in the mid-twentieth century. Since Galbraith's study, both the theoretical and the empirical literature have identified conditions under which buyers can realize cost savings through countervailing power. These conditions include the size of a buyer or buyer group (Chipty, 1995; Snyder, 1996; Chipty and Snyder, 1999; Inderst and Wey, 2007; Inderst and Montez, 2019), exclusive purchasing (Sorensen, 2003; Inderst and Wey, 2007; Ellison and Snyder, 2010; Dana, 2012), nonlinear pricing (O'Brien and Shaffer, 1997; Marvel and Yang, 2008; Hu et al., 2012), and supplier competition (Ellison and Snyder, 2010; Dubois et al., 2021). In this vein, our study in the U.S. hospital setting is centered specifically around the size of a buyer group (i.e., GPO scales), and we also offer supportive evidence for exclusive purchasing (i.e., product standardization).

More interestingly, in the existing literature, buyers size up and harvest larger buyer power, mainly through horizontal consolidation (Gaynor and Town, 2011; Craig et al., 2021) or self-organized alliances (Geyskens et al., 2015; Colen et al., 2020; Molina, 2021), whereas GPOs are mostly third-party *intermediaries*.[5] Most similar to ours are Pharmacy Benefit Managers (Conti et al., 2021; Brot-Goldberg et al., 2022; Ho and Lee, 2022) in the

[5]Another type of intermediaries, such as wholesalers described in Spulber (1996, 1999) and systematically studied in Donna et al. (2022), locates vertically between manufacturers and consumers. Different from them, GPOs do not directly purchase from but only negotiate with upstream suppliers. As a consequence, the common concern of double marginalization with respect to supply chain intermediaries does not apply to GPOs.

setting of negotiation between insurers and pharmaceutical manufacturers, and marketing agencies in the context of online ad bidding (Decarolis and Rovigatti, 2021). Our paper sheds light on the effectiveness of intermediaries as a market-based counterforce to upstream concentration and increasing input prices.

The remainder of the paper proceeds as follows. Section 2 provides the industry background, and Section 3 discusses the data. We present our empirical strategy in Section 4 and the main results in Section 5. In Section 6, we examine heterogeneity and the underlying mechanisms. We then offer additional analyses in Section 7 and conclude in Section 8.

2 Industry Background

According to the Healthcare Supply Chain Association (HSCA), a group purchasing organization (GPO) is an entity that helps healthcare providers realize savings and efficiency by aggregating purchasing volume and using that leverage to negotiate discounts with manufacturers, distributors, and other vendors.[6] This definition points toward the most important function of a GPO — collective bargaining and bulk purchasing. A GPO's pooled purchasing commitment across member hospitals creates more bargaining leverage than any single hospital could wield, which generates cost savings.[7] In achieving these functions, a GPO effectively serves as an intermediary, linking the medical suppliers upstream with the healthcare providers downstream.

Members of GPOs include hospitals, nursing homes, and other healthcare providers, who procure a variety of inputs from their respective GPO's menu, ranging from consumable supplies (e.g., needles, cotton balls), to pharmaceuticals and food, and to more durable medical devices and physician preference items (e.g., MRI machines, cardiac

[6] See `https://supplychainassociation.org/about-us/what-is-gpo/`. The HSCA itself is a representation of the nation's 13 leading GPOs (HSCA, 2019).

[7] Cost savings can also come from reduced transaction costs because hospitals need no longer bargain with each individual supplier, resorting to a GPO's comprehensive menu instead.

stents). GPO contracts account for about 70% of the non-labor purchases for an average hospital (Schneller, 2009; Burns and Yovovich, 2014). In addition to offering group purchasing, many GPOs also offer a spectrum of value-added services, including but not limited to revenue management, clinical evaluation and standardization, benchmarking data, patient safety control, technology assessment, and equipment repair (GAO, 2010; HSCA, 2019).

Most GPOs predominantly rely on the administrative fees collected from suppliers as their major source of revenue. As an industry norm, these administrative fees are almost always based on a fixed percentage (usually 2%–3%) of the contract value (i.e., the transaction amount between the supplier and the hospital). GPOs can also charge membership fees to their members, although these membership fees vary across GPOs and constitute a small proportion of GPO revenues. For example, GAO (2015) surveyed the five largest GPOs of the time and reported that, on average, administrative fees and membership fees account for 92% and 3% of a GPO's revenue, respectively.[8] This vendor-funded model is shared by group purchasing alliances in many other industries in the U.S., including food services, hospitality, charity, and some government procurements.[9]

The first healthcare GPO was established by the Hospital Bureau of New York in 1910. However, the industry had not experienced much growth until 1986, when the U.S. Congress passed legislation that granted a statutory safe harbor for GPOs under the Federal Anti-Kickback Statute. This safe harbor allows GPOs to collect fees from manufacturers/distributors without violating anti-trust and anti-kickback laws. Since then, GPOs have quickly gained popularity and have become an indispensable part of the healthcare supply chain. It has been previously estimated that over 90% of U.S. hospitals belong to a GPO (Burns and Lee, 2008; O'Brien et al., 2017), although this estimate is based on surveys of large-system hospitals. Using our data, which represent the universe of the

[8]Other sources of revenue, such as investment income and licensing fees, take up even smaller proportions and do not always apply to all GPOs.

[9]See https://www.supplychainassociation.org/wp-content/uploads/2018/05/GPO_Fee_Model_Overview.pdf

U.S. hospitals, we find during our sample frame (2010 to 2019) that, 60%–68% of all U.S. hospitals reported using a GPO. This proportion is even larger among the general medical and surgical hospitals (68%–76%) which we focus on in our study. More detailed time trends regarding the pervasiveness of GPOs can be found in Figure 1. Moreover, a typical contract between a hospital and a GPO spans multiple years. For example, GAO (2003) reports that a GPO usually awards contracts of 3 to 5 years in length; we find a similar statistic in our data.[10]

The GPO market has witnessed a wave of consolidation over the past decade. There were more than 100 GPOs nationwide in the early years of the 2010s. This number, however, gradually decreased and fell by half by 2019, the last year of our sample period. During the same timeframe, the GPO market has become more concentrated, with a majority of market shares taken by a handful of large players. Averaged over 2010-2019, the top 5 (and 10) GPOs account for 88% (and 93%) of all the hospitals nationwide. In Figure 1, we also calculate the Herfindahl-Hirschman Index (HHI) of the GPO market, where market share of a GPO is measured by its member hospitals as a percentage of all the hospitals in the country.[11] The increase in GPO concentration is relatively modest in most of the years, which indicates that the decrease in the number of GPOs over this timeframe is mainly due to exits by small players. However, the HHI jumped from about 1,700 to 2,500 in 2015, resulting in a concentrated market, based on the Horizontal Merger Guidelines of the Department of Justice and the Federal Trade Commission. Specifically, this change in the HHI was primarily driven by a merger between two national GPOs, Vizient and MedAssets, which we will utilize as a quasi-experiment for our identification in Section 5.2.3.

[Insert Figure 1 here]

[10] We find an average contract length of about 4.34 years. Note that our measure of GPO–hospital tenure is based on the hospitals' reporting of their GPO identities, which could be left- or right-truncated for some observations. In this sense, the actual contract length can be even larger.

[11] Throughout this study, we assume that the GPO market is national in scope. We offer our rationale in Section 3.

3 Data

3.1 Data source and construction of variables

We draw data from various sources, including the annual survey by the American Hospital Association (AHA), the CMS Healthcare Cost Report Information System (HCRIS), and the U.S. Census Bureau. Our main outcome variable, supply expense, is from the AHA data. Supply expense measures the hospital's annual expenditure on tangible commodities, including pharmacies and excluding labor-related costs.[12] Previous research has shown that respondents to the AHA annual survey have a sound understanding of the components of their supply expenses and submit accurate values (Abdulsalam and Schneller, 2017; Abdulsalam et al., 2018); as such, the accuracy of this measure can be trusted.

To measure cost efficiency, we construct supply expense per discharge, which is calculated as the ratio of total supply expenses in dollars to total number of adjusted discharges for a given hospital.[13] Similar measures have been used in other studies, such as Schmitt (2017), Craig et al. (2021), and Gaynor et al. (2021). We also show that our main results remain consistent even if using alternative measures for supply-cost efficiency, such as supply expense (in raw values), as well as the ratio of supply expense to operating cost.

The data on GPO affiliation also come from the AHA. Beginning in year 2003, the AHA reports the following GPO-related information for each hospital: a dummy indicator for whether or not a hospital is using a GPO, and if yes, the GPO's name along with the city and state in which it is headquartered. In some of the years, detailed contact information for the GPO is also provided. To identify a GPO, we used its name, city and state.

[12] The AHA annual survey defines supply expenses as "the net cost of all tangible items that are expensed including freight, standard distribution cost, and sales and use tax minus rebates. This would exclude labor, labor-related expenses, and services as well as some tangible items that are frequently provided as part of labor costs."

[13] Total adjusted discharge was calculated from the HCRIS as the summation of inpatient discharge and outpatient discharge where the outpatient discharge is calculated as total inpatient discharge scaled by the ratio of outpatient revenue to inpatient revenue.

Although a hospital can report multiple GPOs, multi-homing is rare (less than 0.5%) in the AHA data. Moreover, hospitals tend to make most of their purchases through a single GPO (Burns and Lee, 2008; Burns and Yovovich, 2014). Given this, when a hospital reports multiple GPOs, we treat the biggest one (in terms of GPO market share) as its main and sole GPO for the purposes of this study.[14]

GPOs can differ significantly in terms of market dominance. Therefore, instead of using a dummy variable to capture whether a hospital uses a GPO, we measure a GPO by its *scale*, defined as the market share of a given GPO.[15] More specifically, GPO scale is calculated by the ratio of the number of beds summed across a GPO's member hospitals to the total number of beds available nationwide.[16] This calculation implicitly assumes a national market boundary for GPOs. We believe that this is a valid assumption because most GPOs operate across multiple states. Moreover, when negotiating with suppliers and manufacturers, a GPO's total number of member hospitals, regardless of their locations, constitutes a key determinant of its leverage. This argument is not only advocated in GPO-sponsored studies and industry reports (Goldenberg and King, 2009; O'Brien et al., 2017), but also highlighted by empirical work in either healthcare or retail settings (Grennan, 2013; Geyskens et al., 2015). For hospitals that are not using a GPO, their GPO *scale* is set to be 0.[17]

Also from the AHA and the HCRIS, we draw a series of hospital characteristics, including the number of beds available, the percentages of patients discharged through Medicare and Medicaid, and dummies for whether or not the hospital is a private not-

[14]Hospitals could utilize a secondary alliance only for specific contracts in limited supply areas (Burns and Lee, 2008). Our results are similar if we drop these multi-homing hospitals.

[15]Note that since most of the hospitals used GPOs, a study using a GPO dummy would be moot and would result in a limited amount of variation for identification.

[16]That is, $scale_g = \frac{\sum_{i \in \mathbb{I}_g} bed_i}{\sum_{\forall i} bed_i}$. Alternatively, (1) we try to use the number of patient admissions instead of the number of beds as weight; (2) we try to calculate a simple fraction of market share (i.e., the number of hospitals using GPO g divided by the total number of hospitals in the country). Both of them yield similar results.

[17]We also test if our results are sensitive to an alternative definition of GPO scale for non-GPO-using hospitals. That is, to be consistent with the GPO-using hospitals, we view a non-GPO-using hospital as its own GPO and use its own bed size as the numerator in calculating its GPO scale.

for-profit or a teaching hospital. We then merge this hospital×year–level panel with county×year–level socioeconomic conditions, including total population, percentage of adult population, percentage of non-white population, unemployment rate, and the Herfindah–Hirschman Index (HHI) of the local hospital market, which is calculated using the hospital's market share in terms of bed share. These hospital and local market characteristics help to control for time-varying unobservables that might be driving hospitals' supply expenses.

We also include two variables that aim to capture the relationship between the member hospital and its GPO. Our first variable is the length of the relationship between the hospital and its GPO, measured by the number of consecutive years that a hospital has been using its current GPO. When a hospital doesn't use a GPO, this value is assigned to be 0.[18] We expect that the longer a GPO has been working with a hospital, the more it knows about the hospital's cost structure and needs, and the more it can help the hospital save costs. Our second measure attempts to capture the geographic distance from the hospital to the GPO. Specifically, for each GPO, we first calculate its mean center, using the geographic coordinates of all member hospitals in its network.[19] We then calculate the distance (in 100 miles) between this center and each of its member hospitals. We hypothesize the mean center as where the GPO most likely bases its sales team or representatives, and it is easier for the GPO to gather information from a hospital that is more geographically proximate. When a hospital does not use a GPO, this distance is set to be 0.[20]

[18]As mentioned before, this variable is measured with truncation for some observations; but our results do not change if we drop those observations.

[19]Mean center is a basic statistic in centrography. Mathematically, suppose (x_i^g, y_i^g) denotes the latitude and longitude for one of N member hospitals of GPO g. The mean center of GPO g is simply given by $(\frac{\sum_i^N x_i^g}{N}, \frac{\sum_i^N y_i^g}{N})$. Alternatively, we try to calculate the distance between a hospital to the Euclidean median center of its GPO which is just a point minimizing the total distance to every member hospital. The results remain unchanged.

[20]It is debatable whether these two variables (i.e., relationship length and geographic distance) should be set to 0 for non-GPO-using hospitals. We note, however, our main empirical specification also controls for the GPO fixed effect where non-GPO-using hospitals are classified as a distinct GPO, and our results are robust when dropping these two variables.

3.2 Descriptive statistics

Our final sample consists of a total of 35,511 observations at the hospital$\times$year level, covering a total of 4,068 unique hospitals and 162 distinct GPOs from 2010 to 2019. Our sample starts in 2010 because that was the year when supply expenses first became available in the AHA data. We end in 2019 to avoid any confounding effects that might be due to the outbreak of the COVID-19 pandemic.

Table 1 reports the summary statistics for the key variables. Within our sample, an average hospital discharges 15,028 patients per year and incurs about $10.2 million in supply expenses. Correspondingly, our main outcome variable, log(supply expenses/adjusted discharges), has a mean and standard deviation of 7.22 and 0.74, respectively. On average, the supply expenses account for 14.3% of a hospital's total operating costs, a finding consistent with the estimate in Abdulsalam and Schneller (2017).

[Insert Table 1 here]

Within our analytical sample, about 60% of the hospitals keep using GPOs throughout the period of 2010 to 2019, although they could have switched GPOs during the years. Throughout our study period, only 0.6% of the hospitals do not use any GPO in any year. The remaining hospitals have experienced a transition from using to not using a GPO, or vice versa. In Appendix Table A1, we compare GPO-using and non-GPO-using hospitals in our sample, along with their observed characteristics. GPO users are generally larger in size, more likely to be private non-profit, teaching hospitals and system-affiliated, and tend to discharge fewer Medicaid patients.

4 Empirical Strategy

To study the effect of GPO scale on the efficiency of hospitals' supply expenses, we begin with the following baseline specification,

$$y_{igh(c)t} = \beta scale_{gt-1} + \delta^X X_{it} + \delta^W W_{ct} + \delta^V V_{igt-1} + \mu_i + \eta_{ht} + \phi_g + \varepsilon_{igh(c)t} \tag{1}$$

where the subscripts i, g, $h(c)$, t denote *hospital*, *GPO*, *HRR (county)*, and *year*, respectively. $y_{igh(c)t}$ is the outcome of interest; it captures supply expenses per discharge. Specifically, we scale the raw supply expenses by adjusted discharges and then take logarithms. $scale_{gt-1}$ captures the focal hospital's GPO scale, measured using the (national) market share of a GPO in terms of the bed share of its member hospitals. Note that $scale_{gt-1}$ is one-year lagged, taking into account the fact that contracts with suppliers are negotiated by GPOs before hospitals start procuring. A larger *scale* indicates that a GPO has a larger pool of member hospitals, which could suggest stronger bargaining leverage and lower prices. In this case, we expect the estimate of β to be negative.

X_{it} denotes a vector of hospital characteristics. Consistent with Schmitt (2017) and other studies on hospital costs, X_{it} includes (logged) bed capacity, a dummy for teaching hospital status, two ratios of inpatient discharges accounted for by Medicare and Medicaid respectively, a dummy for the hospital being private not-for-profit, and a dummy for being a teaching hospital. We also control for a series of economic conditions in the local market (i.e., county), W_{ct}, with the list reported in Table 1. Lastly, we include two control variables that are meant to capture the relationship between the hospital and its GPO, V_{igt-1}, including the length of contract in cumulative years and the distance between the hospital and the center of the GPO.

In the baseline specification, we also include fixed effects at the hospital, GPO, and HRR×year level. The inclusion of the hospital fixed effect allows the identification coming from variation in GPO scales over time within a given hospital, which helps to address the endogeneity due to time-invariant heterogeneity that might be correlated with a hospital's GPO choice and supply expense efficiency. To be more specific, the variation in GPO scale derives from : a) a focal hospital's switching of GPOs over time, and b) a GPO's change in its market dominance over time. Meanwhile, the inclusion of the HRR×year fixed effects helps to control for any time-varying unobserved heterogeneity at the aggregated market level that could potentially affect a hospital's supply expenses and its choice of GPOs. We further address the remaining concerns related to our identification in Section 5.2 after we present our main results.

5 GPO Scale and Hospital Supply Efficiency

In what follows, we first present our baseline results based on Equation 1. We then proceed by discussing how we address the remaining endogeneity concerns, through three supplementary analyses.

5.1 Baseline results

Table 2 shows the baseline results that are based on Equation 1. Column (1) is the most naive model, wherein we only control for hospital and HRR×year fixed effects. The result suggests that a larger GPO scale is associated with lower supply expenses per discharge. In Columns (2) and (3), we progressively add time-varying controls and GPO fixed effects, and the results remain similar. Take Column (3), our preferred specification, as an example. We find that a one-standard-deviation increase in GPO scale (0.108) leads to a 2.7% decrease in a hospital's supply expenses per discharge. Stated alternatively, we find that supply expenses per discharge decrease by 4.8% (0.19×0.251) if a hospital switches from a GPO in the 25th percentile of the scale to a GPO in the 75th percentile, which amounts to a total annual savings of $981,749 for an average hospital in the data.[21]

[21] Specifically, an average (median) hospital incurs a per-adjusted-discharge supply expenses of $1,361 ($1,411) and discharges 15,028 (9,408) patients. The savings are therefore $981,749 (4.8% × $1,361 × 15,028)

Taken together, these estimates offer evidence that cost savings are larger when a hospital adopts a GPO with a larger scale. These results are also consistent with the hypothesis that collective bargaining is a major mechanism by which GPOs help hospitals lower their supply expenses.

[Insert Table 2 here]

5.2 Addressing the endogeneity of GPO scale

Our preferred specification (Table 2 Column (3)) has included controls for hospital and GPO fixed effects. However, there might exist some time-varying unobservables within a hospital that could contaminate our identification. One possible scenario arises when a manager is striving to lower operating expenses by internally adjusting their supply acquisition, and at the same time, directs the hospital to a large-scale GPO for the purpose of cost savings and other benefits. Another possible scenario arises when a standalone hospital or a hospital system is acquired by a more cost-effective system while at the same time inherits the acquirer's default GPO. In these cases, it is hard to disentangle the effect of joining a GPO from other confounding drivers unobserved at the hospital level (e.g., manager behaviors) or at the system level (e.g., system-wise cost-saving practice).

To correct for any remaining endogeneity concerns, we thus provide three sets of supplemental analyses. First, we offer results for two extended specifications where we additionally control for hospital$\times$GPO and system$\times$year fixed effects on the basis of our baseline specification. Next, we focus on system-affiliated hospitals whose choices of GPO are likely determined at the system level and, therefore, arguably more exogenous to any individual hospital's unobservables. Lastly, we take advantage of a merger event between two national GPOs and perform an event study to identify the effect of increased GPO scales.

and \$637,185 (4.8% $\times$ \$1,411 $\times$ 9,408) for an average and a median hospital, respectively.

5.2.1 Extended specifications

Our main specification (Equation 1) has controlled for GPO and hospital fixed effects. Here we first consider an extended specification where we additionally include hospital$\times$GPO fixed effects. This specification allows us to utilize variation in GPO scale within a hospital–GPO pair, which is indeed driven by GPO membership decisions made outside of the focal hospital and, therefore, arguably exogenous to the focal hospital's unobservables. Put differently, the inclusion of hospital$\times$GPO fixed effects rules out the possibility that our results are driven by the focal hospital switching between using and not using a GPO, or switching among different GPOs, which might be an endogenous decision. Table 3 Column (1) reports the results, which stay similar to our main findings.

In the same vein, we also consider another extended specification where system$\times$year fixed effects are included.[22] This specification is useful to deal with the concern when hospital mergers and acquisitions lead to changes in GPO scales and hospital performance at the same time. This specification ends up using a lower amount of variation for identification, as compared to our baseline model. However, we find that our results stay largely consistent. To sum up, both results suggest that our main findings are not likely contaminated by "GPO shopping" within a hospital or endogenous hospital mergers and acquisitions.

5.2.2 System-affiliated hospitals

To further address the potential endogeneity concern, we now focus on system-affiliated hospitals whose choices of GPOs are arguably more exogenous. We posit that for hospital systems, the decision of joining a particular GPO largely follows a top-down approach and is likely made at the parent-system level. Member hospitals within a given system are likely to adopt the system-wide default GPO due to managerial convenience and cost savings associated with contracting with the same GPO within a system (Burns and Lee,

[22] We consider a standalone hospital to be its own system.

2008).[23] Indeed, we find that within-system choices of GPO are highly correlated and that about two-thirds of system hospitals follow the default choice of GPO (i.e., the most popular GPO within the system), regardless of the system's size.[24] Studying system-affiliated hospitals can therefore help alleviate the endogeneity concerns related to GPO choice.

Column (3) of Table 3 presents the results for the sample of system-affiliated hospitals, where we find that the results remain similar to our main findings. From Column (4) to Column (6), we progressively restrict the sample to a smaller subset, with the choice of GPO becoming less and less likely to be determined by an individual hospital's unobservables. In Column (4), we restrict our sample to large hospital systems, namely, those systems with a total number of member hospitals no smaller than 5. In our sample, these large systems account for more than 67% of all the system-affiliated hospitals, although they represent only 26% of the total number of systems. Column (5) focuses on the "small-fish" hospitals within those large systems. To qualify as a "small fish," a hospital must own no more than 20% of the within-system bed share (i.e., the hospital is "systematically unimportant"). Per our definition, "small fishes" are fringe members within a system. We therefore suspect that their choices of GPO are more likely to be driven by "large fishes" who have a pivotal vote in deciding which GPO for most hospitals to use within a system.[25] Lastly, in Column (6), we include only the conforming "small fishes" who use the system's default GPO.[26] We find that these results are overall consistent with our expectations and the magnitudes of the effects become larger as we further restricted our sample. More specifically, we find that a one-standard-deviation increase of GPO scale results in a 3.3%–6.2% reduction of supply expenses across these subsamples.

[23] Assad et al. (2020) argue that individual German gas stations are more likely to adopt algorithmic pricing when their headquarters do so, which is similar to our idea here.

[24] As is shown in Appendix Table A2, even for the largest systems (with over 70 members), they do not use more than three different GPOs on average.

[25] We experiment with different cutoffs for large system and "small fish", and find consistent results.

[26] A system's default GPO is the only GPO that it uses or the GPO with the largest within-system market share if there is more than one.

[Insert Table 3 here]

5.2.3 Event study

Lastly, we take advantage of an acquisition event that occurred in 2015 between two competing "mega" GPOs: MedAssets and Vizient. MedAssets, the fourth largest GPO with 13% of market shares nationwide in 2014, decided to exit the GPO market and sold its business line to the UHC-VHA alliance (renamed as Vizient after the merger), which was already the largest player in the market at the time.[27]

The acquisition led to a large increase in GPO scale for the merging GPOs who each and combined has thousands of member hospitals nationwide. We argue that the merger itself is not likely to be driven by unobserved heterogeneity at the individual hospital level. This creates an opportunity to identify the causal effect of increased GPO scales. To proceed, we adopt an event study approach.

In our preferred specification, we define the treated hospitals as those who used either MedAssets or Vizient in 2014 (the year just prior to the acquisition) and used Vizient throughout all post-merger years (i.e., 2015–2018).[28] The control hospitals are those that used neither MedAssets nor Vizient in 2014, and did not use Vizient throughout all the post-merger years either. As is shown in Table 2, compared to the control group, the treated group experienced a sharp increase in their GPO scale due to the acquisition: the jump in GPO scale right after the merger for treated hospitals compared to control hospitals reaches 0.15.

[27]The UHC-VHA alliance operated through Novation which was their brand of GPO business but then renamed itself "Vizient" in Jan 2016. To be consistent throughout the paper, we always use "Vizient" to refer to the UHC-VHA alliance (even in pre–merger years). The merger between Vizient and MedAssets was announced in 2015, and the transaction was claimed to be finished by 2016. In the raw AHA data, we see that almost all the hospitals who used MedAssets in 2014 and previous years switched to Vizient in 2015. Therefore, we take year 2015 as the event year (i.e., t_0 in the event study parlance). See https://newsroom.vizientinc.com/en-US/releases/vizient-inc.-completes-acquisition-medassets-spend-and-clinical-resource-management-scm-and-sg2-businesses and https://www.modernhealthcare.com/article/20151102/NEWS/151109998/2-7-billion-medassets-sale-shakes-up-healthcare-group-purchasing-market for more details.

[28]Note that our data end at year 2019, which corresponds to year 2018 for GPO scale, since it is measured using a 1-year lag.

We estimate the following event study specification,

$$y_{igh(c)t} = \sum_{\substack{2010 \leq t \leq 2019 \\ t \neq 2015}} \gamma_t \times Treated_{ig} \cdot I_{\{year=t\}} + \delta^X X_{it} + \delta^W W_{ct} + \delta^V V_{igt-1} + \mu_i + \eta_{ht} + \phi_g + \varepsilon_{igh(c)t} \tag{2}$$

We use the same set of controls and fixed effects as in Equation 1. The series of $\hat{\gamma}_t$ capture the dynamic effect of increased GPO scale on the treated hospitals as opposed to the control hospitals. Figure 3(a) visualizes the estimated coefficients, along with the 95% confidence intervals. All the coefficients are compared to the baseline year of 2015. More detailed results can be found in Column (1) of Table 4.

[Insert Table 4 here]

We find that the treated and control group trend similarly before the acquisition event, suggesting that the treated hospitals are comparable to the control hospitals whose GPOs did not experience an acquisition. Moreover, we find that the treated group experienced a significant decline in supply expenses immediately after the acquisition, and such costs savings persisted to the end of our sample period. To put the coefficient estimate into perspective, take $\widehat{\gamma}_{2016} = -0.125^{***}$ as an example. This means that the treated hospitals, on average, save 12.5% more on supply expenses per discharge as opposed to the control hospitals. We also conduct a variety of alternative analyses. For example, we have also defined the treated and control groups using pre-merger GPO information only. That is, we define the treated group as hospitals that used MedAssets or Vizient in 2014, and the control group as hospitals that used neither MedAssets nor Vizient in 2014. In addition, we have also allowed MedAssets (pre-merger) and Vizient (pre-merger) hospitals to exhibit differential treatment effects. These results are largely consistent and shown in Figures 3(b) to 3(d) and Columns (2) to (4) of Table 4.

Given that the GPO scale of the treated hospitals increases by 0.15 on average compared to that of control hospitals (Figure 2), our event study suggests larger cost savings as compared to our baseline results. However, it is worth noting that the cost-saving effect of GPOs is actually concentrated among large GPOs. By allowing for differential effects based on GPO scale (Appendix Table A3), we find strong evidence for increasing returns to GPO scales, and the estimated effect becomes closer to what our event study has suggested. Besides, we believe that the event study might also capture other merger-specific savings in addition to the effect of increased GPO scales. For example, it has been argued in their merger disclosure that MedAssets has "real strength in capital equipment and purchased services", which is considered to be complementary to the offering of Vizient. Such complementarity between MedAssets and Vizient could help secure additional savings.[29]

[Insert Figure 3 here]

6 Heterogeneity and Mechanisms

We have established in the previous section that a larger GPO scale contributes to lowered hospital supply expenses. Below, we discuss two possible pathways through which cost savings is realized, and examine heterogeneity in the effect of GPO along these pathways in order to explore the underlying mechanisms.

6.1 Collective bargaining

One possible mechanism through which GPOs could lead to cost savings is collective bargaining. The primary functionality of GPOs as an intermediary is to consolidate demand/purchase commitment and negotiate discounts with upstream suppliers. The bargaining power mechanism has been examined in the existing literature related to buyer

[29]See https://www.modernhealthcare.com/article/20151102/NEWS/151109998/2-7-billion-medassets-sale-shakes-up-healthcare-group-purchasing-market.

power.[30]

Indeed, our main analysis – identifying the effect of GPO scale – has offered suggestive evidence on the mechanism of collective bargaining. To offer additional evidence, we now study whether the effect of GPO scale differs by hospitals' underlying bargaining leverage. Were collective bargaining a mechanism, we should expect hospitals that lack bargaining leverage to benefit more from using a large GPO (Belavina and Girotra, 2012).

We first examine heterogeneity of the GPO effect by hospital size. We posit that small hospitals lack resources and bargaining leverage, so they might be at a disadvantage when negotiating with suppliers on their own. As a result, small hospitals would benefit from GPOs more than large hospitals should collective bargaining be one of the underlying mechanisms. Note that there exists a counterargument that larger hospitals might benefit more because they might better steer GPOs to serve their own interests.

We therefore divide our sample by the median of hospital size, measured using the number of hospital beds available in 2009.[31] We then run regressions separately for small and large hospitals. Results are reported in Table 5. Column (1) replicates our main result in Column (3) of Table 2. Columns (2) and (3) show that the cost-saving effect of GPO scale is larger in magnitude for small hospitals than for large ones. To the extent that a GPO's bargaining leverage compensates more for small hospitals, this set of results offers support to collective bargaining as one of the underlying mechanisms through which GPOs help hospitals to lower their supply expenses.

As an alternative test, we also divide the whole sample into rural and urban hospitals.[32] We suspect that rural hospitals, on average, lack bargaining leverage compared to

[30] An interesting study by Inderst and Montez (2019) argues that buyer size and bargaining power are complements. They find that size is not always an advantage in bilateral negotiation because it could be more expensive for a large buyer to relocate its demand to other sellers. When such buyer dependency dominates, a larger buyer could actually pay a higher per-unit price when the sellers have sufficiently high bargaining power.

[31] The cutoff is measured in 2009 to avoid changes in hospital size due to hospitals' GPO decisions. However, our results stay largely similar if we use time-varying or HRR-specific cutoffs to divide the sample.

[32] We follow the NCHS Urban-Rural Classification Scheme (2013) and categorize hospitals into one of the following six groups based on whether the counties they are located are in metropolitan statistical areas, and the county population size: (1) large central metro, (2) large fringe metro, (3) medium metro, (4) small

their urban counterparts, for at least two reasons. First, rural areas have a lower population density and therefore lower demand for healthcare. Second, hospitals in rural areas face more limited access to suppliers because suppliers might prefer entering in/selling to urban markets with a larger number of hospitals and a stronger demand from patients. Similar to the analysis by hospital size, we run subsample regressions for rural and urban hospitals separately. The results are reported in Columns (4) and (5). Overall, we find larger cost savings for rural hospitals as opposed to their urban counterparts, therefore lending additional support to the hypothesis that collective bargaining is one main mechanism by which GPOs lower supply expenses.

[Insert Table 5 here]

6.2 Product standardization

Another possible mechanism through which GPOs help reduce hospital supply expenses is product standardization (HSCA, 2019). Product standardization arises when GPOs exercise exclusive dealing through limiting product options within each product category. Such exclusivity would incentivize suppliers to compete more aggressively to be included in the GPO contract and therefore induce larger price discounts (O'Brien and Shaffer, 1997).[33] Commitment to exclusive purchasing, or product standardization in our setting, has been identified in the existing literature as an important source of buyer power (Sorensen, 2003; Inderst and Wey, 2007; Ellison and Snyder, 2010; Dana, 2012).

Were product standardization an underlying mechanism, we would expect GPOs to have a larger impact on hospitals that can better adopt the product standardization model. However, there is no straightforward way to measure product standardization

metro, (5) micropolitan, and (6) noncore (ranked from the most urban to the most rural). We define counties in metropolitan categories (1 to 4) as urban counties and counties in nonmetropolitan categories (5 and 6) as rural counties. See `https://www.cdc.gov/nchs/data_access/urban_rural.htm` for more details.

[33] Moreover, product standardization might help hospitals save on logistics-associated supply acquisition and inventory management (Noether and May, 2017), although our data does not allow us to directly test these savings directly.

for a given hospital. Further, even if such a measure were available, it might be influenced by the hospital's choice of GPOs, biasing the causal identification. Therefore, we propose proxies for the likelihood of product standardization at the aggregate market level and interact these measures with GPO scale to test our hypothesis. We expect that hospitals in a market environment that is more amenable to product standardization are likely to save more on their supply expenses. We consider heterogeneity across markets from the following two perspectives: open payment and vertical integration.

6.2.1 Open payment

Our first proxy for product standardization is the number of unique medical device manufacturers that have made payments to hospitals/physicians in the local market (i.e., county). We source data from the CMS *Open Payments*, which is a national transparency program that collects and publishes information about financial relationships between drug and medical device companies and healthcare providers. Purposes of these payments include but are not limited to research, meals, travel, honoraria, and speaking fees. These payments are considered to influence providers' choice of medical devices (Carey et al., 2021; Bergman et al., 2021; Grennan et al., 2022). We suspect that product standardization is more difficult to achieve in a market where a large number of manufacturers compete and make those payments.

To address the complication that those payments might be endogenous to hospitals' choices of GPO and their likelihood to standardize products, we measure our proxies at the baseline–year level of 2013, when the Open Payments data were first made available. We restrict our analytical sample to the years 2013 to 2019 accordingly. These results are reported in Column (1) of Table 6, where we find a higher number of medical device firms that had a financial relationship with hospitals/physicians in a local market leads to a smaller cost savings. More specifically, we find that a one-standard-deviation increase in GPO scale leads to 0.5% less in cost savings, when comparing a county at the 25th percentile (in terms of the number of medical device manufactures – i.e., 4) to one at the 75th percentile (i.e., 52). These results suggest a strong heterogeneous effect, since a one-standard-deviation increase in GPO scales leads to an average cost savings of 2.7%.

In addition to the count measure of medical device firms making those payments, we also calculate an HHI-type concentration measure of payments. The results seem to suggest a coherent story, although we lack statistical power to draw a definitive conclusion. We also extend our analysis by considering payments made by drug companies and find largely similar patterns of results (Columns (3)-(4) of Table 6).

6.2.2 Hospital–physician integration

Our second proxy for product standardization is the extent of hospital–physician integration in a local market (i.e., county). We construct this proxy by first calculating, for each hospital, the share of physicians who are integrated with the hospital to provide medical services for primary care and specialty care. The AHA data divide physicians into nine types based on their affiliation with a hospital and report the number of physicians by type for each hospital. We consider the physicians of Integrated Salary Model (ISM), Management Service Organization (MSO), and Closed Physicians–Hospital Organization (CPHO) as relatively more integrated than the rest.[34] We then define three continuous types of integration measures: Ratio 1 as the number of ISM physicians to total physicians; Ratios 2 and 3 progressively add MSO and CPHO physicians in the numerator. Finally, we aggregate each hospital-level ratio up to market level, using a hospital's full-time equivalent as the weight. We expect that a higher level of hospital–physician integration grants greater discretion for hospitals to decide which medical supplies to procure and therefore achieve a higher level of product standardization. Were product standardization an underlying mechanism, we expect the effect of GPO scale to vary by the extent of integration in the local market.

[34] The raw data have many missing values. We therefore impute a missing value with the nearest non-missing value and end up dropping about 10% of the hospitals due to missing values.

Similar to our proxies based on Open Payments, these integration measures are measured at the baseline–year (i.e., 2009) level. These results are reported in Columns (5)–(7) of Table 6. Column (5) measures integration by using the ratio of ISM physicians. We find that a higher level of integration is associated with more cost savings. In particular, we find that the effect of a one-standard-deviation increase of GPO scale is 0.7% larger (in absolute magnitude) in a county at the 75th-percentile level of integration (i.e., 0.06) than in a county at the 25th level of integration (i.e., 0.01). The size of the effect is large, given that our baseline effect for a one-standard-deviation increase in GPO scale amounts to a cost savings of 2.7%. Columns (6) and (7) progressively add MSO and CPHO physicians into our measure of integration. We find the results stay similar, although the magnitude of the effect shrinks, consistent with the prior finding that MSO and CPHO physicians are less integrated and less likely to accommodate product standardization as compared to ISM physicians.

6.2.3 Summary

To sum up, we find evidence that when the local market is more amenable to product standardization (i.e., with a smaller number of medical device/drug companies having a financial relationship with hospitals/physicians, or with a higher level of physician–hospital vertical integration), the estimated cost-savings effect is larger. We think that these results are consistent with product standardization as an important mechanism through which GPOs help to lower supply expenses, in addition to the impact of collective bargaining. However, we cannot disentangle these two underlying mechanisms, because product standardization could also enhance collective bargaining.[35] It would be especially interesting to gather available data on detailed contract information offered by

[35]For example, imagine a hospital has 10 surgeons, each with a different preferred supplier for total joint replacement (TJR). The GPO would have little bargaining power if it had to negotiate with 10 different suppliers. However, if the GPO can persuade these surgeons to standardize their preferred TJRs (to one particular supplier), its bargaining leverage and price discount are expected to be larger, as the purchasing volume is larger. This rationale also applies when a GPO persuades multiple member hospitals to converge on the same product.

GPOs and examine whether a higher level of product standardization at the GPO contract level translates into more savings.

[Insert Table 6 here]

7 Additional Analyses

In this section, we first extend our analysis to examining the effect of GPO scale on hospitals' quality of care and their patient composition. We then study whether and to what extent these cost reductions in supply expenses have been passed to patients in terms of lowered prices. We last consider several robustness checks dealing with alternative measures of supply-cost efficiency and GPO scale.

7.1 Quality of patient care and case-mix

We find GPOs lead to lowered supply expenses per discharge. However, from a patient welfare perspective, it is critical to examine whether lowered supply expenses hurt patient care. We offer analyses that directly study the effect of GPO scale on quality of care. For this purpose, we rely on the publicly available measures of hospital quality data from the CMS. Specifically, we consider Medicare's 30-day mortality and readmission rates for three specific conditions: heart attack, heart failure, and pneumonia. Both the mortality and readmission rates have been risk-adjusted to remove confoundings due to patient selection. These quality measures are available on the CMS Hospital Compare website and directly affect Medicare reimbursement as part of the Hospital Value-Based Purchasing Program and the Hospital Readmission Reduction Program. Previous studies, such as Doyle et al. (2019), have suggested that those quality measures are reliable and valid indicators of hospital quality.

Note that both the 30-day mortality and readmission rates are based on claims from a pooled 3-year rolling sample of fee-for-service Medicare and Veterans Health Administration patients prior to the focal year.[36] To take into consideration such a reporting lag, we use the lagged-three-period GPO scale as the main explanatory variable of interest, and follow the same specification as in Equation (1). The results are summarized in Table 7. Columns (1)–(3) present estimates of the effect of GPO scale on 30-day mortality rate, and Columns (4)–(6) present analogous results for 30-day readmission rate.

In all cases, we find no evidence of meaningful changes in mortality or readmissions. In fact, all the estimates are very small in magnitude relative to a mean mortality (readmission) rate of around 11%–15% (16%–22%). These results suggest that GPOs do not seem to increase cost efficiency at the expense of quality of patient care, at least for the specific quality measures that we consider here.

We last study whether GPOs lead to changes in patient composition using the CMS case-mix index reported under the Inpatient Prospective Payment Systems. We find no evidence that hospitals serve a different patient case-mix when using a larger GPO, which suggests that the reduced supply expense per discharge is not likely driven by hospitals attracting less severely sick patients.

[Insert Table 7 here]

7.2 Hospital prices

So far, we have shown that GPOs are able to generate sizeable cost savings for member hospitals and those cost savings do not compromise the quality of patient care. However, it remains an open question whether consumers would benefit from those cost reductions in terms of lowered hospital prices. To better evaluate the welfare implications for these cost savings, we also examine the effect of GPO scales on hospital prices.

Following Dafny (2009), we utilize the CMS Healthcare Cost Report Information System (HCRIS) and measure hospital prices by calculating the average net revenue for non-

[36] For example, year t's measures, updated in July, are calculated using data from year t–3 Q3 to year t Q2.

Medicare inpatient discharges. This same measure has been used in other studies examining hospital prices, including Dranove et al. (2017), Schmitt (2018), Dafny et al. (2019), and Lin et al. (2021).

We first follow our main specification as in Equation (1) and regress the logged hospital prices on GPO scales. The results are reported in Column (1) of Table 8. Overall, we find average hospital prices decrease as GPO scale increases, although the coefficient is small and imprecisely estimated. We then explore heterogenous effects based on hospital market competitiveness. We suspect that, in highly concentrated hospital markets, hospitals might be reluctant to pass through their cost savings to downstream consumers. However, in more competitive markets, hospitals could be propelled to share the reduced costs with their consumers through lower prices. In Columns (2) to (4) of Table 8, we restrict our sample to hospitals located in relatively competitive markets (i.e., HRRs with hospital HHI smaller than the 75th, 50th, and 25th percentiles). We find consistent evidence that hospital prices are significantly lower in more competitive markets. At the bottom of Table 8, we replicate our cost-saving results for each sample (i.e., using logged supply expense per discharge as the dependent variable), which allows us to back out the pass-through elasticity (i.e., the ratio of percentage changes in price to percentage changes in cost). For example, in the most competitive hospital market where hospital HHI is below the 25th percentile, we find a pass-through elasticity of 55%. These numbers should be interpreted with caution though since our measure of supply expense ignores other savings related to GPOs, such as transaction costs.

Overall, we offer some preliminary evidence regarding how GPOs could affect hospital prices for final consumers. Our results suggest that some of the cost savings are passed through in terms of lowered hospital prices, although only in competitive hospital markets. These results also suggest evaluating the social benefit of GPOs needs to take into consideration differences in market conditions such as hospital market structures.

[Insert Table 8 here]

7.3 Alternative measures of outcome and GPO scale

Our main analysis used logged supply expenses per discharge as the measure for supply-cost efficiency. We consider two alternative outcome measures here: (1) logged supply expenses, and (2) the ratio of supply expenses to total operating costs. The results are reported in Columns (1) and (2) of Table 9. The results for logged supply expenses are largely similar to our main results. In addition, we find that GPO scale is associated with a lowered supply expense ratio, which suggests improved supply-cost efficiency.

Our preferred measure of GPO scale is calculated as GPO market share weighted by each individual member hospital's bed share as a member hospital with a larger bed capacity should add more bargaining leverage to a GPO. As a robustness check, we also consider an unweighted measure for GPO scale. That is, the market share of a GPO is calculated as the number of its member hospitals divided by the total number of hospitals nationwide. The results are reported in Column (3) in Table 9. In addition, our main analysis assigns GPO scale to be zero for non-GPO hospitals. An alternative approach is to consider non-GPO hospitals as their own GPOs, and calculate their GPO scale as the ratio of the focal hospital's bed capacity to total bed capacity nationwide. The results, shown in Column (4), are very similar to our main findings.

[Insert Table 9 here]

8 Conclusion

We offer one of the first empirical studies to examine the impact of GPOs in the hospital setting by utilizing a national-scope observational dataset. We find that GPO scale is associated with hospital supply-cost efficiency. Our calculation suggests that an average hospital can save close to $1 million on their supply expenses annually when they switch from a GPO at the 25th percentile of scale to one at the 75th percentile. We note that this is likely a lower bound for the realized savings, since GPOs could also help lower transaction costs and labor-related procurement costs, which are not taken into account in our analysis. Also, note that we have focused here on the role of GPOs as intermediaries for aggregating demand and for achieving product standardization. However, GPOs have increasingly shifted their attention to non-price related services, such as technology assessment, clinical and safety improvement initiatives, and consulting services (HSCA, 2019; Burns and Briggs, 2020). Our results are silent with respect to whether those services add value to members of a GPO.

We also find that smaller or rural hospitals benefit more from using a larger GPO, thereby supporting collective bargaining as one of the underlying mechanisms for realized cost savings that GPOs appear to facilitate. In addition, we find suggestive evidence for the mechanism of product standardization as cost savings are larger in markets that are considered to be more amenable to product standardization.

In an attempt to evaluate the potential impact on consumers, we first eliminate the possibility that cost-savings are achieved at the expense of lower care quality and selective patient admission. We then check if hospitals are able to pass through some of the reduced costs to their consumers in terms of lower hospital prices. We find some supporting evidence but only in markets where hospitals do not possess massive market power. These results are consistent with the prior that market power might disincentivize hospitals to pass through cost savings to consumers.

We highlight several avenues for future research. It has been pointed out that GPOs could hurt manufacturers' incentives to innovate (Inderst and Wey, 2007; Hu and Schwarz, 2011), create barriers to market entry of suppliers (Nollet and Beaulieu, 2005), lead to members' dependence on fewer supply chains (Bruhn et al., 2018), and cause poor information sharing (Cachon and Lariviere, 2005). These upstream externalities could offer a more comprehensive perspective on welfare analyses and remain important areas for future work.

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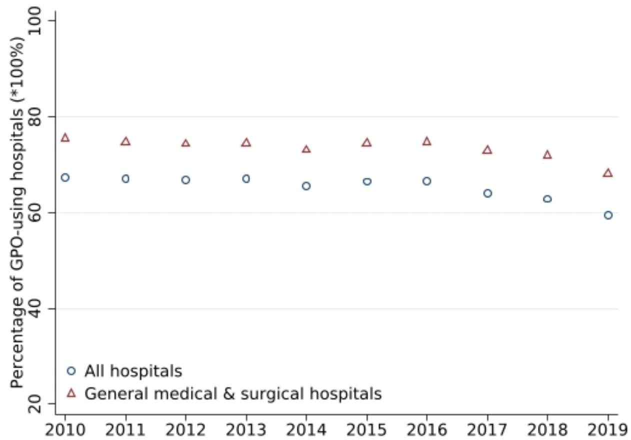
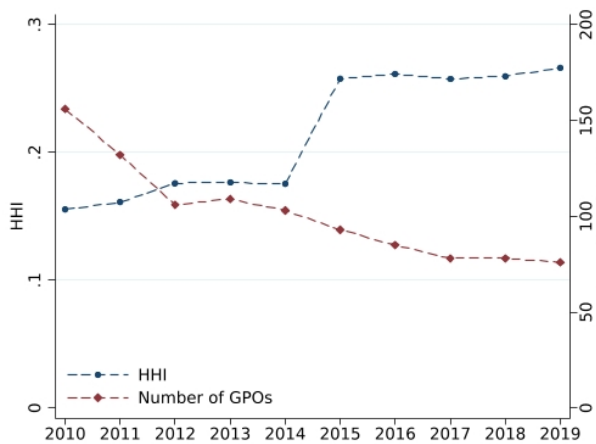
Figures

Figure 1: GPO market



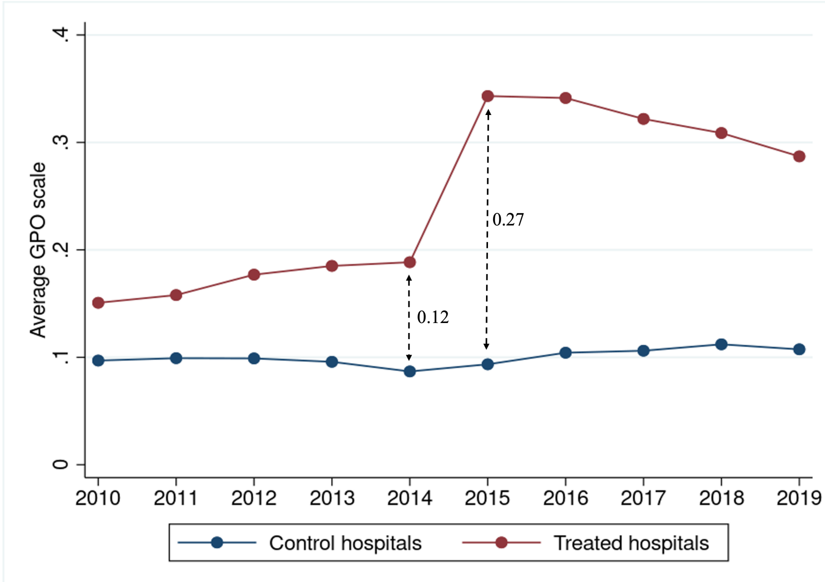
(a)



(b)

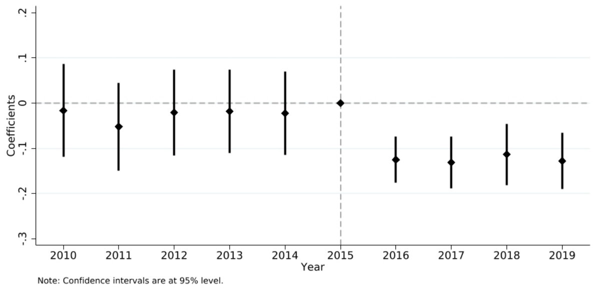
Note: Figure (a) shows the fraction of all hospitals (and general medical/surgical hospitals) that use GPOs. Figure (b) shows the number of GPOs and the Herfindahl–Hirschman Index (HHI), where the market share of a GPO is calculated in terms of the number of its member hospitals as a percentage of all hospitals nationwide. Both figures are based on the AHA data.

Figure 2: GPO scale (treated vs. control)

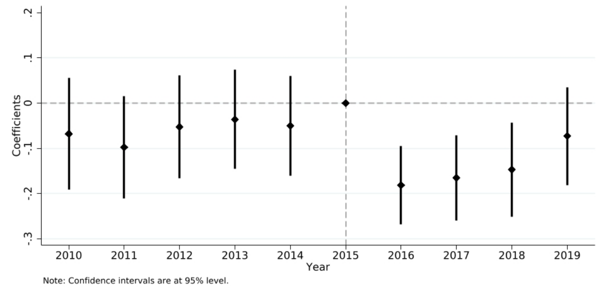


Note: This figure shows the average GPO scale for treated and control hospitals used in the event study, respectively. Treated hospitals are defined as those who used either MedAssets or Vizient in 2014 (the year just prior to the acquisition) and used Vizient throughout all the post–merger years (i.e., 2015–2018). The control hospitals are defined as those who used neither MedAssets nor Vizient in 2014 and did not use Vizient throughout all the post–merger years. The jump in GPO scale following the merger is calculated as $(\overline{scale}_{2015}^{treated} - \overline{scale}_{2015}^{control}) - (\overline{scale}_{2014}^{treated} - \overline{scale}_{2014}^{control}) = 0.27 – 0.12 = 0.15$.

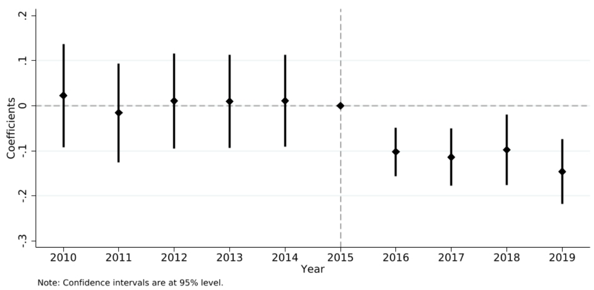
Figure 3: Coefficient plots of event study



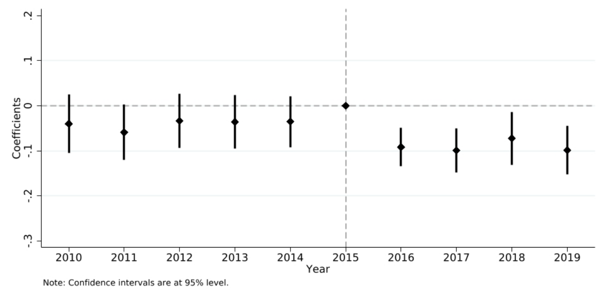
(a)



(b)



(c)



(d)

Note: These figures are based on event study results in Section 5.2.3. Figures (a) to (d) correspond to Columns (1) to (4) in Table 4. Figure (a) reports the preferred results, where the treated hospitals are defined as those who used either MedAssets or Vizient in 2014 (the year just prior to the acquisition) and used Vizient throughout all the post-merger years (i.e., 2015–2018). The control hospitals are defined as those who used neither MedAssets nor Vizient in 2014, and did not use Vizient throughout all the post–merger years. Figures (b) and (c) only includes MedAssets's or Vizient's hospitals in the treated group while keeping the control group unchanged. Figure (d) defines the treated and control hospitals based on ex-ante GPO status (i.e., year 2014). Red bins represent the confidence intervals at 95% level.

Tables

Table 1: Summary statistics

Variable	Mean	SD	p5	p25	p50	p75	p95
Outcome variables							
log(supply expenses/adjusted discharges)	7.216	0.737	5.958	6.773	7.252	7.685	8.354
log(supply expenses)	16.135	1.667	13.317	14.837	16.275	17.470	18.653
Supply expenses/operating costs	0.143	0.077	0.045	0.089	0.130	0.180	0.290
GPO scales							
Weighted GPO scale (0–1)	0.137	0.108	0.000	0.017	0.130	0.207	0.341
Unweighted GPO scale (0–1)	0.115	0.084	0.000	0.027	0.125	0.153	0.276
GPO×hospital–level control variables							
Relationship length (in years)	4.924	4.162	0.000	1.000	4.000	8.000	12.000
Geographic distance (in 100 miles)	5.445	4.788	0.000	1.782	4.753	7.859	14.830
Hospital×year–level control variables							
log(beds)	4.404	1.176	2.773	3.219	4.466	5.371	6.258
Medicare discharge ratio (%)	41.540	16.316	17.998	30.451	39.737	50.490	72.430
Medicaid discharge ratio (%)	10.342	9.924	0.000	2.985	7.095	15.295	30.022
Private non-profit (0/1)	0.654	0.476	0.000	0.000	1.000	1.000	1.000
Teaching hospital (0/1)	0.263	0.440	0.000	0.000	0.000	1.000	1.000
County×year–level control variables							
log(median household income)	10.838	0.255	10.457	10.663	10.822	10.984	11.316
log(population)	11.635	1.884	8.779	10.201	11.473	13.148	14.763
Adult population (%)	65.871	9.424	58.568	62.637	65.127	67.142	71.106
Non-white population (%)	17.436	15.199	2.508	5.535	12.380	25.788	49.906
Unemployment rate (%)	6.160	2.745	2.800	4.100	5.600	7.800	11.300
Hospital market HHI (0-1)	0.564	0.358	0.060	0.227	0.509	1.000	1.000

Note: This table is based on the main analytical sample of 35,511 hospital×year observations.

Table 2: Baseline results

Dependent variable:	log(supply expenses/adjusted discharges)		
	(1)	(2)	(3)
GPO scale	–0.190***	–0.212***	–0.251***
	(0.053)	(0.067)	(0.068)
Observation	35511	35511	35511
Within R2	0.001	0.029	0.028
Time-varying controls		X	X
HRR × Year FE	X	X	X
Hospital FE	X	X	X
GPO FE			X

Note: This table reports the estimation results based on Equation 1. The dependent variable is logged per-discharge supply expenses. GPO scale is measured using the weighted national market share of a GPO in terms of the bed size of its member hospitals and lagged one year. All columns except for Column (1) include the following time-varying controls: GPO–hospital pair relationships, hospital–level characteristics, and county–level socioeconomic conditions. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3: Addressing endogeneity

Dependent variable:	log(supply expenses/adjusted discharges)					
	Extended specifications		Hospital-affiliated hospitals			
	(1)	(2)	(3)	(4)	(5)	(6)
GPO scale	–0.263***	–0.246**	–0.307***	–0.401**	–0.567***	–0.571***
	(0.069)	(0.124)	(0.094)	(0.162)	(0.165)	(0.186)
Observation	35511	35511	22061	13632	12025	10615
Within R2	0.027	0.026	0.027	0.028	0.032	0.028
Time-varying controls	X	X	X	X	X	X
HRR × Year FE	X	X	X	X	X	X
Hospital FE		X	X	X	X	X
GPO FE		X	X	X	X	X
Hospital × GPO FE	X					
System × Year FE		X				

Note: This table reports the estimation results of sections 5.2.1 and 5.2.2. The dependent variable is logged per-discharge supply expenses. GPO scale is measured using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals and lagged one year. All columns include the following time-varying controls: GPO–hospital pair relationships, hospital–level characteristics, and county–level socioeconomic conditions, and control for HRR×year, hospital, and GPO fixed effects. Column (1) includes all the hospitals and additionally controls for hospital×GPO fixed effects. Columns (2) to (5) follow the baseline set of controls. Column (2) includes all the system-affiliated hospitals. Column (3) includes hospitals affiliated with large hospital systems whose total numbers of member hospitals are no smaller than 5. Column (4) focuses on the so-called "small-fish" hospitals within the large systems defined in Column (3). "Small-fish" hospitals are those with within-system bed share no larger than 20%. Column (5) further restricts the sample to the conforming "small-fish" hospitals who use the system-default choice of GPO. The system–default GPO is the GPO that most hospitals use within a system. Large systems, "small-fish" hospitals and default GPOs are all measured at the time of 2009. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4: Event study

Dependent variable:	log(supply expenses/adjusted discharges)			
	(1)	(2)	(3)	(4)
Treated × Year 2010	–0.016	–0.068	0.023	–0.040
	(0.052)	(0.063)	(0.058)	(0.033)
Treated × Year 2011	–0.052	–0.098*	–0.016	–0.059*
	(0.049)	(0.058)	(0.056)	(0.031)
Treated × Year 2012	–0.021	–0.053	0.011	–0.034
	(0.049)	(0.058)	(0.054)	(0.031)
Treated × Year 2013	–0.018	–0.036	0.010	–0.036
	(0.047)	(0.056)	(0.053)	(0.030)
Treated × Year 2014	–0.023	–0.050	0.011	–0.035
	(0.047)	(0.056)	(0.052)	(0.029)
Treated × Year 2016	–0.125***	–0.182***	–0.102***	–0.092***
	(0.026)	(0.044)	(0.027)	(0.022)
Treated × Year 2017	–0.131***	–0.165***	–0.114***	–0.099***
	(0.029)	(0.048)	(0.032)	(0.025)
Treated × Year 2018	–0.114***	–0.147***	–0.098**	–0.072**
	(0.035)	(0.053)	(0.040)	(0.030)
Treated × Year 2019	–0.128***	–0.073	–0.146***	–0.099***
	(0.032)	(0.055)	(0.037)	(0.028)
Observation	30892	25225	28430	35511
Within R2	0.029	0.029	0.028	0.028
Time-varying controls	X	X	X	X
HRR × Year FE	X	X	X	X
Hospital FE	X	X	X	X
GPO FE	X	X	X	X

Note: This table reports the results for Equation 5.2.3. The dependent variable is logged per-discharge supply expenses. All columns control the same set of time-varying covariates and fixed effects as in the main result. Year 2015 is omitted as the benchmark year. Column (1) reports the preferred results, where the treated hospitals are defined as those who used either MedAssets or Vizient in 2014 (the year just prior to the acquisition) and used Vizient throughout all the post-merger years (i.e., 2015–2018). The control hospitals are defined as those who used neither MedAssets nor Vizient in 2014, and did not use Vizient throughout all the post-merge years. Columns (2) and (3) only includes MedAssets's or Vizient's hospitals in the treated group only while keeping the control group unchanged. Column (4) defines the treated and control hospitals only based on ex-ante GPO status (i.e., year 2014). Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5: Heterogeneity in hospital bargaining power

Dependent variable:	log(supply expenses/adjusted discharges)				
	All	Small	Large	Rural	Urban
	(1)	(2)	(3)	(4)	(5)
GPO scale	–0.251***	–0.280**	–0.198***	–0.291**	–0.249***
	(0.068)	(0.114)	(0.073)	(0.120)	(0.069)
Observation	35511	17138	18373	14891	20620
Within R2	0.028	0.031	0.031	0.035	0.023
Time-varying controls	X	X	X	X	X
HRR $\times$ Year FE	X	X	X	X	X
Hospital FE	X	X	X	X	X
GPO FE	X	X	X	X	X

Note: This table reports the results discussed in Section 6.1. The dependent variable is logged per-discharge supply expenses. GPO scale is measured using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals and lagged one year. All columns control the same set of time-varying covariates and fixed effects as in the main result. Column (1) replicates the baseline result as in Table 2 Column (3) where all the hospitals are included. Columns (2) to (5) only includes small, large, rural and urban hospitals, respectively. Small (large) hospitals are those with sizes below (above) the median which is measured using the number of hospital beds available for 2009. Rural and urban hospitals are defined using the NCHS Urban-Rural Classification Scheme (2013) based on the county where a hospital is located. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 6: Heterogeneity in product standardization

Dependent variable:	log(supply expenses/adjusted discharges)						
Measure of product standardization	Device		Drug		Physician–hospital integration		
	Count	HHI	Count	HHI	Ratio 1	Ratio 2	Ratio 3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GPO scale	–0.336***	–0.166*	–0.382***	–0.242***	–0.191**	–0.199***	–0.189**
	(0.085)	(0.085)	(0.102)	(0.080)	(0.075)	(0.076)	(0.078)
GPO scale × product standardization	0.001**	–0.285	0.001**	–0.097	–1.326**	–1.002*	–0.834*
	(0.000)	(0.187)	(0.001)	(0.279)	(0.616)	(0.551)	(0.448)
Observation	21916	21916	21916	21916	33769	33769	33769
Within R2	0.027	0.027	0.027	0.026	0.029	0.029	0.029
Time-varying controls	X	X	X	X	X	X	X
HRR × Year FE	X	X	X	X	X	X	X
Hospital FE	X	X	X	X	X	X	X
GPO FE	X	X	X	X	X	X	X

Note: This table reports the impact of product standardization on GPOs' effectiveness. The dependent variable is logged per-discharge supply expenses. GPO scale is measured using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals and lagged one year. All columns control the same set of time-varying covariates and fixed effects as in the main result. Columns (1) and (3) measure product standardization using the numbers of drug and medical device manufacturers, respectively, in the CMS Open Payment data. Columns (2) and (4) measure product standardization using the HHI of drug and medical device markets, respectively, where the market shares in the HHI are calculated in terms of payment dollars. The CMS's Open Payment data only start from 2013. For Columns (1) to (4), the sample spans from 2013 to 2019 and the Open Payment measures are fixed at the baseline year (i.e., 2013). Columns (5) to (7) measure product standardization using three ratios of physician–hospital integration. We consider the three most integrated models as defined in the AHA data: the physicians of Integrated Salary Model (ISM), Management Service Organization (MSO) and Closed Physicians–Hospital Organization (CPHO). Ratio 1 is the ratio of ISM physicians to total physicians; Ratios 2 and 3 progressively add MSO and CPHO physicians. We then aggregate each hospital–level ratio up to market level using a hospital's full time equivalent as the weight. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7: The effect on health care quality and patient composition

Dependent variable:	Mortality Rate			Readmission Rate			Case Mix Index	
	AMI (1)	HF (2)	PN (3)	AMI (4)	HF (5)	PN (6)	CMI (7)	log(CMI) (8)
GPO scale	–0.010	–0.162	0.239	0.148	–0.011	–0.234	0.018	0.007
	(0.223)	(0.203)	(0.247)	(0.215)	(0.240)	(0.160)	(0.018)	(0.012)
Observation	17751	26606	29918	16184	27084	29943	32051	32051
Within R2	0.001	0.002	0.002	0.004	0.001	0.002	0.005	0.002
Time-varying controls	X	X	X	X	X	X	X	X
HRR $\times$ Year FE	X	X	X	X	X	X	X	X
Hospital FE	X	X	X	X	X	X	X	X
GPO FE	X	X	X	X	X	X	X	X

Note: This table reports the effect of GPO on hospital quality and patient composition. GPO scale is measured using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals and lagged 1 year. All columns control the same set of time-varying covariates and fixed effects as in the main result. Columns (1) to (3) use mortality rates of heart attack (AMI), heart failure (HF) and pneumonia (PN) patients, respectively, as the dependent variables. Columns (4) to (6) use the corresponding readmission rates. Both mortality rates and readmission rates are lagged three years to account for reporting lags. Columns (7) and (8) use raw and logged case mix index as the dependent variables. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 8: The effect on hospital prices

Dependent variable:	log(price)			
	All	Competitive markets		
		HHI < p75	HHI < p50	HHI < p25
	(1)	(2)	(3)	(4)
GPO scale	–0.061	–0.080	–0.126**	–0.214**
	(0.044)	(0.049)	(0.059)	(0.090)
Observation	35005	25968	17489	9005
Within R2	0.274	0.282	0.288	0.311
HRR × Year FE	X	X	X	X
Hospital FE	X	X	X	X
GPO FE	X	X	X	X
Coefficient in cost regression	–0.251***	–0.306***	–0.312***	–0.385***
	(0.068)	(0.075)	(0.092)	(0.129)
Implied pass-through elasticity	24.30%	26.14%	40.38%	55.58%

Note: This table reports the effect of GPO on hospital prices. GPO scale is measured using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals and lagged 1 year. All columns control the same set of time-varying covariates and fixed effects as in the main result. Column (1) reports the result for the full sample with all hospitals. Columns (2) to (4) restrict to subsamples with hospitals located in relatively more competitive markets (i.e., HRRs with HHI smaller than 75th, 50th, and 25th percentiles). The corresponding coefficients estimated from cost regressions and the implied pass-through elasticity (i.e., $\frac{\triangle p/p}{\triangle c/c}$) are reported at the bottom of the table. standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 9: Alternative measures

Dependent variable:	Alternative dependent variables		Alternative independent variables	
	(1)	(2)	(3)	(4)
(Weighted) GPO scale	–0.217***	–0.034***		
	(0.059)	(0.007)		
Unweighted GPO scale			–0.330***	
			(0.087)	
Strictly positive GPO scale				–0.251***
				(0.068)
Observation	35511	35510	35511	35511
Within R2	0.017	0.004	0.028	0.028
Time-varying controls	X	X	X	X
HRR $\times$ Year FE	X	X	X	X
Hospital FE	X	X	X	X
GPO FE	X	X	X	X

Note: This tables reports the results using alternative measures of the dependent and independent variables. All columns control the same set of time-varying covariates and fixed effects as in the main result. Columns (1) and (2) measure GPO scale using the weighted national market share of a GPO in terms of the bed sizes of its member hospitals as in the main results, and use logged supply expenses and the ratio of supply expenses to operating costs as the dependent variables, respectively. Columns (3) and (4) use the logged per-discharge supply expenses as in the main results, and use unweighted GPO scale and strictly positive GPO scale, respectively. Unweighted GPO scale measures a GPO's national market share in terms of the number of its member hospitals. Strictly positive GPO scale takes each non-GPO hospital as its own GPO and calculate the scale as the ratio of the focal hospital's bed size to national bed size. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendices

Table A1: Comparison between GPO-using and non-GPO-using hospitals

	(1): Use GPO	(2): Do not use GPO	(1) – (2) Diff	Significance
Sample: all the general medical and surgical hospitals in the AHA data.				
log(beds)	4.436	4.088	0.348	***
log(adjusted discharges)	8.962	8.327	0.635	***
Medicare discharge ratio	0.410	0.411	–0.001	
Medicaid discharge ratio	0.102	0.113	–0.011	***
Private non-profit	0.668	0.433	0.234	***
Teaching hospital	0.276	0.172	0.104	***
System-affiliated	0.625	0.570	0.055	***
Sample: analytical sample (35,511 obs)				
log(beds)	4.446	4.171	0.275	***
log(adjusted discharges)	9.116	8.660	0.456	***
Medicare discharge ratio	0.413	0.430	–0.018	***
Medicaid discharge ratio	0.103	0.108	–0.006	***
Private non-profit	0.676	0.533	0.144	***
Teaching hospital	0.276	0.194	0.082	***
System-affiliated	0.627	0.589	0.038	***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2: Within–system choice of GPO

System size (Number of hospitals within the system)	Number of hospital systems falling in this size category	Average number of GPOs within the system	Percentage of member hospitals using the system-dominant (default) GPO
2–9	428	1.24	81.73
10–19	44	1.63	73.65
20–29	11	2.08	64.74
30–39	8	2.36	62.05
40–49	3	2.49	73.59
50–59	1	1.5	56.51
60–69	4	2.93	58.5
≥ 70	5	2.27	63.08

Note: This table reports the within-system choices of GPO by different system sizes. System affiliation and GPO membership are from AHA data.

Table A3: Nonlinear effect of GPO scale

Dependent variable:	log(supply expenses/adjusted discharges)		
	(1)	(2)	(3)
GPO scale	0.057		
	(0.183)		
GPO scale ^{2}	–0.933*		
	(0.492)		
1{0<GPO scale<0.1}		–0.025	
		(0.021)	
1{0.1≤GPO scale<0.2}		–0.051**	
		(0.021)	
1{GPO scale≥0.2}		–0.060**	
		(0.024)	
1{Out of top 10 but scale > 0}			–0.007
			(0.025)
1{Top 6–10}			–0.039
			(0.025)
1{Top 5}			–0.062***
			(0.022)
Observations	35511	35511	35511
Within-R2	0.028	0.028	0.028
Time-varying controls	X	X	X
HRR × Year FE	X	X	X
Hospital FE	X	X	X
GPO FE	X	X	X

Note: This table reports the nonlinear effect of GPO scale. The dependent variable is logged per-discharge supply expenses. Column (1) adds a quadratic term of GPO scale. Columns (2) and (3) discretize the GPO scale and take non-GPO-using hospitals as the omitted benchmark. All columns include the following time-varying controls: GPO–hospital pair relationships, hospital–level characteristics, and county–level socioeconomic conditions. Standard errors are clustered at the hospital system level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.