Getting the Price Right? The Impact of Competitive Bidding in the Medicare Program

Hui Ding, Mark Duggan, and Amanda Starc*

August 13, 2022

Abstract

We study Medicare's competitive bidding program (CBP) for durable medical equipment (DME). We use Medicare claims data to examine the effect on prices and utilization, focusing on continuous positive airway pressure (CPAP) devices for sleep apnea. We find that spending falls by 47.2% percent after a highly imperfect bidding mechanism is introduced. This is almost entirely driven by a 44.8% price reduction, though quantities also fall by 4.3%. To disentangle supply and demand, we leverage differential cost sharing across Medicare recipients. We measure a demand elasticity of -0.272 and find that quantity reductions are concentrated among less clinically appropriate groups.

JEL classification: I11

*Ding: Center for Health and Wellbeing, Princeton University, 219 Julis Romo Rabinowitz Building, Princeton, NJ 08540 (e-mail: hd5220@princeton.edu); Duggan: Department of Economics, Stanford University, 579 Serra Mall, Stanford, CA 94305, and NBER (e-mail: mgduggan@stanford.edu); Starc: The Kellogg School of Management, Northwestern University, 2211 Campus Drive Evanston, IL 60208, and NBER (e-mail: amanda.starc@kellogg.northwestern.edu). We thank seminar participants at the City University of New York, the Federal Trade Commission, Stanford and the ASSA meetings, especially Zack Cooper and David Dranove, for helpful comments. The views expressed in this paper are solely those of the authors and do not necessarily represent the views of the institutions or other individuals mentioned above, nor of the National Bureau of Economic Research. All errors are our own.

1 Introduction

Prices convey information about consumer willingness to pay for a good or service and about its cost of production. Yet in many healthcare markets, the information aggregation properties of prices are distorted. Most insured consumers do not face market prices and reimbursements are often set administratively. Prices may be substantially different from a competitive price and can be influenced by medical specialty societies, potentially leading to regulatory capture (Chan and Dickstein, 2019). Market price-setting mechanisms may also be imperfect. For example, in healthcare, there is an implicit reliance on administered prices (Clemens and Gottlieb, 2017; Clemens et al., 2017) and firms can exert substantial market power (Cooper et al., 2019). Perhaps as a result, high prices are a key feature of relatively high healthcare costs in the United States (Anderson et al., 2003). In this paper, we examine how market institutions can control health care costs; specifically, we measure the impact of a shift from administered prices to a more market-based mechanism.

The Medicare program provided health insurance coverage to 62.8 million U.S. residents in 2020 at an annual cost of more than $800 billion (CMS, 2020a). For most Medicare recipients, the federal government directly reimburses hospitals, physicians, and other health care providers for the services delivered to patients. Prices for each service are determined by a complex set of regulations that vary by service type.[1] In part due to concerns about inefficiency in its price-setting process, Medicare has recently tried to inject market forces for certain health care services. One example of this is durable medical equipment (DME), which includes wheelchairs, oxygen concentrators, and dozens of other health care products.

In July of 2010, the Centers for Medicare and Medicaid Services (CMS) piloted a competitive bidding program (CBP) in nine areas around the country for a subset of DME products. Suppliers were asked to submit price bids for each product and CMS selected the lowest bids, subject to the constraint that the winning suppliers could meet the total demand in these regions. In 2013,

[1] For example, prices for physician services are determined by the resource-based relative value scale (RBRVS). These prices are updated annually for more than 10,000 different procedures and vary with the estimated costs to provide each service.

100 regions were added and the process was replicated for an expanded set of products. Before the CBP, Medicare set prices using a fee schedule based on supplier charges to Medicare during the 1980s and increased these amounts annually. These prices were adjusted by state, reflecting geographic price differences that were subject to national floor and ceiling price limits.[2] There is evidence suggesting that these prices paid by Medicare were often higher than market rates for various DME items and lowered to rates comparable to the prices paid by commercial insurers after the CBP (GAO, 2016; Newman et al., 2017).

CMS selected metropolitan areas with a large population and high DME costs to roll out CBP. In 2010 about 55 percent of Medicare recipients resided in an area where competitive bidding would apply by 2013. CMS selected high-cost and high-volume products to include in the competitive bidding process: the products included in competitive bidding in 2011 or 2013 accounted for more than half of DME expenditures in 2010. We leverage variation across geographic areas and across products in the use of competitive bidding. Medicare's competitive bidding process dramatically reduced spending, and most of the reduction was due to lower prices. Our findings reveal that spending on DME products included in competitive bidding fell by 47.2 percent and that this effect persisted over time.[3]

To better understand how the program affected consumers and suppliers, we next focus on a specific DME product – Continuous Positive Airway Pressure (CPAP) machines. The machine is the gold standard of treatment for obstructive sleep apnea (OSA).[4] Conditional on symptoms, a patient may decide to visit his or her doctor. The doctor may diagnose the patient as having one or

[2]Price limits on a per claim basis were derived from the state-level fee-for-service payment. The price ceiling was set at the median of the state-level fee schedule amounts. The price floor was set as 85 percent of the median of the state-level fee schedule amounts. In 2016, CMS started to adjust these fee schedule to incorporate single payment amount from the CBP in non-competitive bidding areas.

[3]We also find evidence for some substitution across DME products, with utilization actually increasing for those DME products not included in competitive bidding. When we account for this substitution, our estimated effects are slightly attenuated, with a 38.2 percent price reduction and a 7.8 percent decline in utilization.

[4]According to the American Academy of Sleep Medicine (AASM), positive airway pressure (PAP) is recommended or strongly recommended in nearly all cases for OSA (Patil et al., 2019). These include CPAP, auto-adjusting PAP (billed using the same product code as CPAP), and bi-level PAP (also included in the CBP but less commonly used – quantity was a fourth of CPAP in 2010). Other treatment options for OSA include weight management, oral appliances, and surgery (reviewed in Morgenthaler et al. (2006)).

more forms of sleep apnea.[5] Conditional on a sleep apnea diagnosis, the patient may be prescribed a CPAP machine. After the prescription, patients can rent a CPAP from suppliers.

CPAP machines are a particularly good market to study. First, sleep apnea diagnoses are linked to enrollees in the data. Second, a single product is included in the sample (E0601-RR), so a reduction in quantity demanded cannot be attributed to a rise in substitute products. Third, sleep apnea is a highly prevalent condition, especially among males and the elderly (Senaratna et al., 2017). Sleep apnea is associated with multiple health consequences such as cardiovascular disease and traffic accidents (Marin et al., 2005). In particular, there is growing evidence of a link between sleep apnea and higher risk for depression, anxiety, and suicidal ideation (Choi et al., 2015; Kaufmann et al., 2017; McCall et al., 2019). Given increasing suicide rates in the US and the disparities by gender and age (Duggan and Scimeca, 2018), proper assessment and treatment for Medicare beneficiaries is increasingly important. Finally, CPAP is relatively large in terms of total Medicare spending (ranked 6th among DME products in 2010). Finally, cost sharing is a substantial burden: 20% of the rental fee amounts to approximately $80 per month over our sample period.

Prior to competitive bidding, Medicare was spending nearly $200 million annually on CPAP machines, with rental payments making up most of this amount. Once CMS has made 13 monthly rental payments for a CPAP machine, the Medicare recipient effectively owns it. Our results reveal that competitive bidding reduced the average rental price by 45% and utilization of this product by 4.3%. This effect was driven by a decline on both the extensive margin and the intensive margin.

Given the reduction in quantity, the overall impact of the policy change is unclear. We ask two key questions. First, to what extent are reductions in utilization due to reduced supply? Second, did the program ration care appropriately? To answer the first question, we explore whether the magnitude of the change in utilization differed for Medicare recipients who are dually eligible for the Medicaid program, as this group does not contribute to the cost of their medical care. Theoretically, one would expect a larger quantity reduction for this group since there would be no offsetting demand response. Consistent with this prediction, we estimate a significantly larger

[5]For example, in obstructive sleep apnea, the upper airways become blocked during sleep.

reduction in utilization among "dual eligibles." Combining the differential change in duals' out-of-pocket costs with the differential change in their utilization, we estimate a demand elasticity of approximately -0.27. This is very similar to the oft-cited estimate from the RAND Health Insurance Experiment (Manning et al., 1987).

Overall quantity falls despite downward-sloping demand, implying supply-side changes. A supply reduction could lead to shortages. Patients may have unfilled prescriptions conditional on diagnosis or delays in treatment. The combination of lower prices and reduced utilization suggests a potential tradeoff between cost and access. To explore this trade-off, we first show that diagnosis rates were unchanged post-CBP. We next demonstrate that the quantity reductions were concentrated among consumers without a sleep apnea diagnosis. We then construct a measure of clinical appropriateness, similar in spirit to Chandra and Staiger (2007). Once again, our findings suggest that the quantity reductions mostly came from patients with clinical appropriateness below average, and marginal consumers affected by the CBP are those with lower CPAP propensity.

While we focus on DME, our findings highlight the potential inefficiencies in the Medicare program's current methodology for setting prices. Public insurers often use regulated prices, reimbursing providers based on expected costs. Our results highlight that such an approach can lead to inefficiently high spending. Nevertheless, the CBP has some undesirable features, including non-binding bids and the median pricing rule. Even with an imperfect bidding process, Medicare's prices for DME products fell by more than 40 percent. In our setting, the savings from introducing competitive bidding were substantial. However, simply setting lower prices is not without trade-offs: quantities also fell. The data indicates that the drop in quantities is due to supplier behavior and is partially offset by a demand response. Yet because the quantity reduction was concentrated in less clinically appropriate patients,[6] a cost-benefit analysis shows that the savings exceed the costs of reduced access. Future work should examine whether better auction mechanisms, such as a simultaneous descending clock auction, can improve outcomes.

[6]This finding is consistent with the survey result from OIG (2017) that beneficiaries were unlikely to experience disruptions in access to CPAP supplies and their hypothesis that the CBP may have reduced provision of unnecessary supplies.

In concurrent and independent work, Ji (2019) finds similar reductions in price and quantity following the introduction of the CBP. She models bidding and argues the observed prices are 6% too low. We estimate a demand elasticity that allows us to quantify the heterogeneous impact of changing prices. Our results indicate that the optimal, higher prices would dampen any negative distributional impact of the program. Higher prices would increase consumption among dual-eligible beneficiaries in particular. In combination with our results, this suggests that market forces could be a powerful instrument to reduce the high cost of health care in the general U.S. market and in the Medicare program specifically. Yet market reforms may have important distributional consequences. Our results add to a literature documenting the role of prices in driving healthcare spending (Anderson et al., 2003; Cooper et al., 2019). They also add to growing evidence on the important role of institutions and mechanisms for purchasing health care goods and services. Chandra et al. (2016) argue that the healthcare sector is similar to other industries and subject to standard market forces. Yet while a number of studies contrast public and private provision of insurance in Medicare (Town and Liu, 2003; Curto et al., 2019), less attention has been paid to the mechanisms used to procure health care services within public insurance. The price reductions we measure are more dramatic than those found in earlier studies examining markets for prescription drugs (Duggan and Scott Morton, 2006, 2010; Dranove et al., 2021). In the meantime, competitive bidding was unsuccessfully implemented for physician-administered drugs (Martin and Sharp, 2018). More broadly, both Medicare and Medicaid use competitive bidding and market mechanisms to pay private drug and medical insurers, which have been more extensively studied in the previous literature (MACPAC, 2011; Decarolis, 2015; Dranove et al., 2021; Curto et al., 2021). Internationally, firms compete in competitive bidding systems in both drug and device markets (Decarolis and Giorgiantonio, 2015; Cao et al., 2021). Grennan and Swanson (2020) show that transparency can lead to saving in hospitals' purchases of medical devices, but the effect is limited in the business-to-business setting.

The paper is organized as follows. Section 2 describes the institutional setting and data. Section 3 measures the impact of the CBP on prices and quantities. Section 4 measures demand elasticities

and describes the marginal consumer. Section 5 presents a cost-benefit analysis, and Section 6 concludes and suggests avenues for future work.

2 Setting and Data

Medicare is a social insurance program that provides health insurance to 62 million elderly and disabled individuals in the U.S. (CMS, 2020a). There are three primary categories of Medicare spending for fee-for-service (FFS) recipients.[7] Part A covers inpatient care that is provided in hospitals or in skilled nursing facilities along with hospice care (typically provided in one's home). Part B covers outpatient care, physician services, home health care, and durable medical equipment (DME).[8] The majority of FFS recipients obtain private insurance coverage for prescription drug costs through Medicare Part D, which was created by the 2003 Medicare Prescription Drug, Improvement, and Modernization Act.

We utilize Medicare FFS claims data in each year for a random 20 percent sample of the Medicare FFS population. In our main analysis, we restrict attention in each quarter to Medicare beneficiaries who were enrolled in FFS Medicare Part B for all three months in the quarter.[9] Appendix Table A1 describes Medicare spending for FFS recipients in both 2010 and 2015.[10] In 2010,

[7] In recent years approximately one-third of Medicare recipients have enrolled in private Medicare Advantage (MA) plans for their coverage. The remaining recipients are enrolled in traditional fee-for-service (FFS) Medicare, through which the government directly reimburses hospitals, physicians, and other health care providers for services delivered to or products obtained by Medicare recipients.

[8] While the vast majority of FFS recipients have one or more Part B claims each year, only about one-in-five have a Part A claim.

[9] When predicting beneficiaries' propensity to use a CPAP device, we require people to be enrolled in FFS Medicare Part B for the full three months in current and previous three quarters so that we can observe all their claims related to sleep apnea.

[10] For each year, the first column displays the number of individuals with one or more claims for a service. The second and third columns list Medicare and patient spending for that service in the year. The fourth column lists total payment per capita, which is calculated as the sum of Medicare and patient spending, divided by the number of patients. For this table, we multiply both the number of patients and total spending in our data by 5 to estimate national totals. The top row of Appendix Table A1 shows that Medicare Part A and B spending (normalized to 2015 dollars using the Consumer Price Index) for those enrolled in FFS Medicare increased from $342.1 billion to $350.4 billion from 2010 to 2015; the number of Medicare recipients with one or more Part A and/or Part B FFS claims rose from 32.9 million to 34.5 million over this period. Part D was the fastest growing component of spending for Medicare FFS recipients during this period. Total Medicare spending was approximately one-third to one-half higher during this period than implied by our table due to Medicare Advantage, through which an increasing fraction of Medicare recipients obtained their coverage.

Medicare DME spending was $11.3 billion and more than 11 million Medicare recipients had one or more DME claims. There are hundreds of DME products, including but not limited to diabetic testing supplies, CPAP devices, oxygen equipment, nebulizers, walkers, wheelchairs, and scooters. Appendix Table A2 lists the top 20 (by 2010 spending) DME products.[11] CPAP machines, which are the focus of our study, accounted for $209.9 million in 2010 Medicare expenditures.

In addition to creating Medicare Part D, the 2003 Medicare Prescription Drug, Improvement, and Modernization Act established the framework for competitive bidding for certain DME products. The program officially started in January 2011 (with a bidding process in 2009) in nine Round 1 competitive bidding areas (CBAs) and was then expanded to another 100 CBAs in Round 2 in July 2013.[12] Each round lasted for three years, and so there was a "Round 1 Recompete" that started in January 2014 in the same nine Round 1 CBAs. CBAs were selected by CMS mainly based on core based statistical areas (CBSAs) with larger populations, Medicare DME spending (per recipient), and suppliers per recipient.[13]

Table 1 provides summary statistics for Round 1 CBAs, Round 2 CBAs, and the remaining 860 CBSAs. The most notable difference is that the Round 1 and Round 2 CBAs on average had substantially more Medicare recipients than in other CBSAs. As a result, more than 60 percent of Medicare FFS recipients (based on 2010 enrollment and residence) lived in an area that had competitive bidding in effect by July 2013. Additionally, average spending per recipient was significantly higher in 2010 in the geographic areas that were selected for competitive bidding, yet average spending for DME products and the share of recipients with DME claims (included in the CBP) did not differ much between CBAs and other CBSAs.

[11] As the table shows, oxygen concentrators accounted for more spending than any other DME product, with $1.98 billion in 2010 Medicare expenditures and reimbursement per claim of $189 in that same year (all 2010 prices and payments are adjusted to 2015 dollar value as in Appendix Table A1). The per-claim costs include coinsurance payments by Medicare recipients (or by their secondary insurer).

[12] Before the official start of the CBP in 2011, CMS implemented Competitive Bidding Demonstration for DME, prosthetics, orthotics, and supplies, during 1999-2002 in Polk County, Florida and San Antonio, Texas. Three rounds of bidding in the two sites showed price reduction but little impact on utilization. More detailed evaluation is reported in (Hoerger et al., 2003). Then in 2007, CMS conducted the Round 1 CBP and awarded contracts effective July 1, 2008, to suppliers. The Medicare Improvements for Patients and Providers Act (MIPPA) of 2008, however, terminated the Round 1 contracts on July 15, 2008, and required CMS to repeat the competition in 2009 (GAO, 2016).

[13] Beyond CBAs we follow similar steps as CMS, grouping zipcodes into core based statistical areas (CBSAs).

Table 1: Summary Statistics Across Geographic Areas

	Non-CBA (N=860)	**R1 CBA (N=9)**	**R2 CBA (N=100)**
# MCR FFS Population	2,979	58,460	36,552
Age	70.7	71.1	71.1
Male	0.45	0.45	0.45
SSDI	0.20	0.18	0.18
Dual Eligible	0.18	0.20	0.19
Average MCR Payment	7,558	9,465	8,717
Average MCR DME Payment	285.6	302.0	255.1
Has DME Claim	0.29	0.28	0.26
Has CBP DME Claim	0.18	0.18	0.16

Notes: This table presents summary statistics from Medicare 20% FFS data in 2010. Geographic area is defined as core based statistical areas (CBSAs), which are the basis for defining CBAs. For a few cases that are not perfectly matched, we keep CBSAs that consists the majority of each CBA, and drop small areas that are left outside CBAs. Medicare FFS population counts beneficiaries that had no HMO coverage over the 12 months. Average Medicare payment per beneficiary includes only Medicare payment in Part A and B, but not deductible, coinsurance, etc. All summary statistics except average population are weighted by Medicare FFS population.

Across different rounds of the CBP, CMS divided DME into 14 categories. Within each product category, there is one lead item assigned by CMS based on the highest total allowed charges nationwide together with its related accessories.[14] For example, rental payments for oxygen concentrators (HCPCS code E1390-RR) accounted for 83.2% of the payment in 2010 in the category of oxygen equipment, while other types of oxygen system equipment (i.e. portable, stationary, liquid, gaseous oxygen systems) and contents accounted for the remainder. As for the CPAP category, rental payments for the device (HCPCS code E0601-RR) accounted for 24.0% of category payments in 2010, while its accessories such as nasal interface, full face mask, and exhalation port accounted for 13.2% to less than 1%. For the other categories, the lead item accounted for between 27.6% and 91.5% of the total payment within the category in 2010.

The fourth column of Appendix Table A2 shows, for each of the top-selling DME products,

[14]External infusion pumps will not be included in 2021 and therefore do not have a lead item selected. To be consistent with other categories, we also select the top item by 2010 Medicare payment, the external ambulatory infusion pump for insulin (HCPCS code E0784-RR), as the lead item of this product category.

whether it was included in Round 1 (R1), Round 2 (R2), Round 1 Recompete (R1RC), or National Mail Order (NMO). The next three columns list the average 2010 FFS price, the average 2015 FFS price, and the average 2015 price in CBAs. With just one exception (diabetic test strips, which experienced a significant price drop), the 2015 FFS price is only slightly lower than the 2010 FFS price.[15] For products included in competitive bidding, the 2015 FFS price represented the average price that prevailed outside of the 109 CBAs (an average across 53 state FFS prices published by CMS), while the next column lists the average price in competitive bidding areas in 2015. In almost every case, the average price in competitive bidding areas is substantially lower than the FFS price in that same year. For CPAP devices, the average price in competitive bidding areas was 54 percent lower ($47.0 vs. $102.4).[16] Our study will exploit variation over time and across space to explore the extent to which changes in prices and quantities were driven by the CBP.

In our empirical analysis, we initially consider the lead item in each of the 12 DME categories when estimating the effect of competitive bidding on the price and total quantity of each product along with the market structure (e.g. the number of suppliers or the HHI). We next focus on the effect of competitive bidding on just CPAP devices. These devices are used to treat obstructive sleep apnea, which is a potentially serious sleep disorder in which breathing repeatedly stops and starts during sleep. The American Academy of Sleep Medicine (AASM) recommends CPAP as both the first-line and the gold-standard treatment for obstructive sleep apnea (Ramar et al., 2015). Medicare beneficiaries rent CPAP devices for 13 months, after which the patients own the device.[17]

A primary goal of the CBP was to induce market-based prices that would replace the current fee-for-service prices for home medical equipment. At the same time, Congress passed legislation creating the Medicare Part D program. That program successfully leveraged market mechanisms

[15] Most DME products were excluded from competitive bidding, though the products that CMS selected tended to have significantly higher spending and volume. CMS revised fee schedule for non-mail order diabetic testing supplies to be equal to mail orders in 2012 (https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/DMEPOSFeeSched)

[16] The price reduction led to total spending in CBAs dropping from $102.2 million in 2010 to $63.9 million in 2015, while during the same period, total payment in non-CBAs increased from $107.7 to $138.3 million.

[17] CPAP is listed within CMS's "capped rental DME" category. In this setting, Medicare pays a monthly rental fee that is capped at 13 consecutive months. Within the 13 months, months 1-3 are paid at the published fee schedule rental rate, and months 4-13 are paid at 75% of the published rate.

to reduce pharmaceutical prices (Duggan and Scott Morton, 2010). A natural question is whether similar mechanisms can have a similar impact for other goods and services purchased by the Medicare program.[18] Yet there are important design issues even for DME products within the CBP.

Previous research has criticized two key features of the CBP: the median price auction and non-binding bids. Under the approach used by CMS, a supplier does not have a financial incentive to truthfully bid its reservation price (Merlob et al., 2012; Cramton et al., 2015). If suppliers did bid their costs, the median price would then be set below some winning bidders' costs: the median-price auction is not ex-post individually rational. Furthermore, "winning" the auction does not guarantee that a firm becomes a Medicare supplier. While winning the auction earns a firm the option of signing a supply contract, bids are not binding. Cramton et al. (2015) points out that this feature generates the incentive for "suicide" (low) bids to preserve that option. In practice, this means that CMS could choose a price that is just high enough so that the market does not collapse.

Finally, the competitive bidding mechanism could affect market structure and prices in future periods. In the CPAP market we study, there are three major manufacturers (ResMed, Philips Respironics, and Fisher & Paykel) capturing more than 80% of the total market share. Suppliers of the renting services are DME distributors, mostly regional and local providers together with a few national providers such as Lincare and Apria.[19]

Both the sign and the magnitude of the effect of Medicare's CBP on quantity are theoretically ambiguous. On the one hand, the lower price for DME products along with the termination of some supplier contracts could reduce the total quantity supplied. On the other hand, since most Medicare recipients pay some share of their medical care cost out-of-pocket, the lower price could increase the total quantity demanded. Therefore, the equilibrium impact of competitive bidding on total quantity is ultimately an empirical question.

[18] For example, it may be difficult to auction off health care services such as medical procedures that may be of differing quality across providers.

[19] Lincare is owned by a multinational chemical company. Apria is privately held and managed by affiliates of the Blackstone Group.

3 The Impact of Competitive Bidding on Prices and Quantities

3.1 All Product Categories

In this section, we evaluate the impact of Medicare's CBP on prices, quantities, and Medicare spending. We initially focus on the twelve lead items, excluding two categories of DME products, diabetic testing supplies and wheelchairs.[20] As denoted with an asterisk in Appendix Table A2, the lead items vary substantially in price and total payment. For example, the top product – oxygen concentrators – accounted for $1.98 billion in Medicare spending in 2010 with a monthly rental price that year of $189.0. TENS supplies, however, only cost $32.8 and had just $26.9 million in total spending that year.

We leverage variation with respect to time, product, and geographic area in the use of competitive bidding. We include R1 CBAs where the CBP started in 2011Q1, R2 CBAs where the CBP started in 2013Q3, and geographic areas that have never been included in the CBP as controls. We consider the period from the first quarter of 2009 through the fourth quarter of 2015, which gives us at least two full years before competitive bidding was launched in any CBA and at least two full years after launch in each area. To study the timing of the effect, we plot the estimated coefficients on indicators for the number of quarters since the CBP. More precisely, let E_{ps} be the quarter in which product p in geographic area s enters the CBP. Let $D^{l}_{pst} = 1(t - E_{ps} = l)$ be an indicator that is equal to one if and only if product p in geographic area s is l quarters from the start of the CBP at time t.[21] Then our event study specification is:

[20] We exclude diabetic testing supplies from the analysis sample because only mail-ordered diabetic testing supplies were included in the CBP. This might cause substitution between mail- and non-mail-ordered items that confound the analysis. Moreover, mail-order diabetic testing bidding was first included in Round 1 but then became nationwide in 2013. We exclude wheelchairs from the sample because CMS eliminated the purchasing option for the power wheelchair in 2011 (same time as Round 1 bidding) in non-CBAs, while keeping both purchasing and rental options in CBAs. See https://www.cms.gov/Regulations-and-Guidance/Guidance/Transmittals/Downloads/R848OTN.pdf for more details.

[21] We allow for 20 lags and 9 leads, excluding periods that are 9 quarters after the CBP (when there is only Round 1 CBAs in the sample which entered into Round 1 Recompete and experienced further changes in price and quantity). Furthermore, we set $\beta^{-1} = 0$.

$$Y_{pst} = \sum_{l=-20}^{9} \beta^l D^l_{pst} + \phi_{pt} + \sigma_{st} + \theta_{ps} + \varepsilon_{pst}, \quad (1)$$

in which we include product by year-quarter fixed effects (ϕ_{pt}), CBSA by year-quarter fixed effects (σ_{st}), and product by CBSA fixed effects (θ_{ps}).[22] We plot the β^l coefficients for all time periods. We weight each observation by the number of claims in that geographic area for that product in 2010, and cluster standard errors by geographic area.

Figure 1 Panel (a) plots the coefficients on the lag and lead indicators of competitive bidding for key outcome variables of interest: prices, quantities (total number of product/service counts per 1000 Medicare FFS recipients[23]), and spending (total Medicare allowed amount per 1000 Medicare FFS recipients). We estimate specifications in logs to account for the considerable differences in baseline prices, quantity, and spending across the 12 products.[24] The top row of Figure 1 shows that prices fall dramatically in the post-period. Appendix Table A3 shows that post-CBP, prices fall by an average of 41.8%.[25] Similarly, the middle row of Figure 1 shows that quantity is flat before competitive bidding, falls immediately when competitive bidding is introduced, declines slightly further over time, and on average dropped 9.3% after the CBP as shown in Appendix Table A3. Finally, the bottom row of Figure 1 presents the net effect of competitive bidding on spending per enrollee. The fall in total spending is visually (and economically) substantial. Appendix Table A3 shows that spending falls by an average of 47.2% after the CBP. For both Figure 1 Panel (a) and Appendix Table A3, we use the number of claims in that geographic area for that product in 2010 to put more weight on larger geographic areas and products with more patients. As a robustness

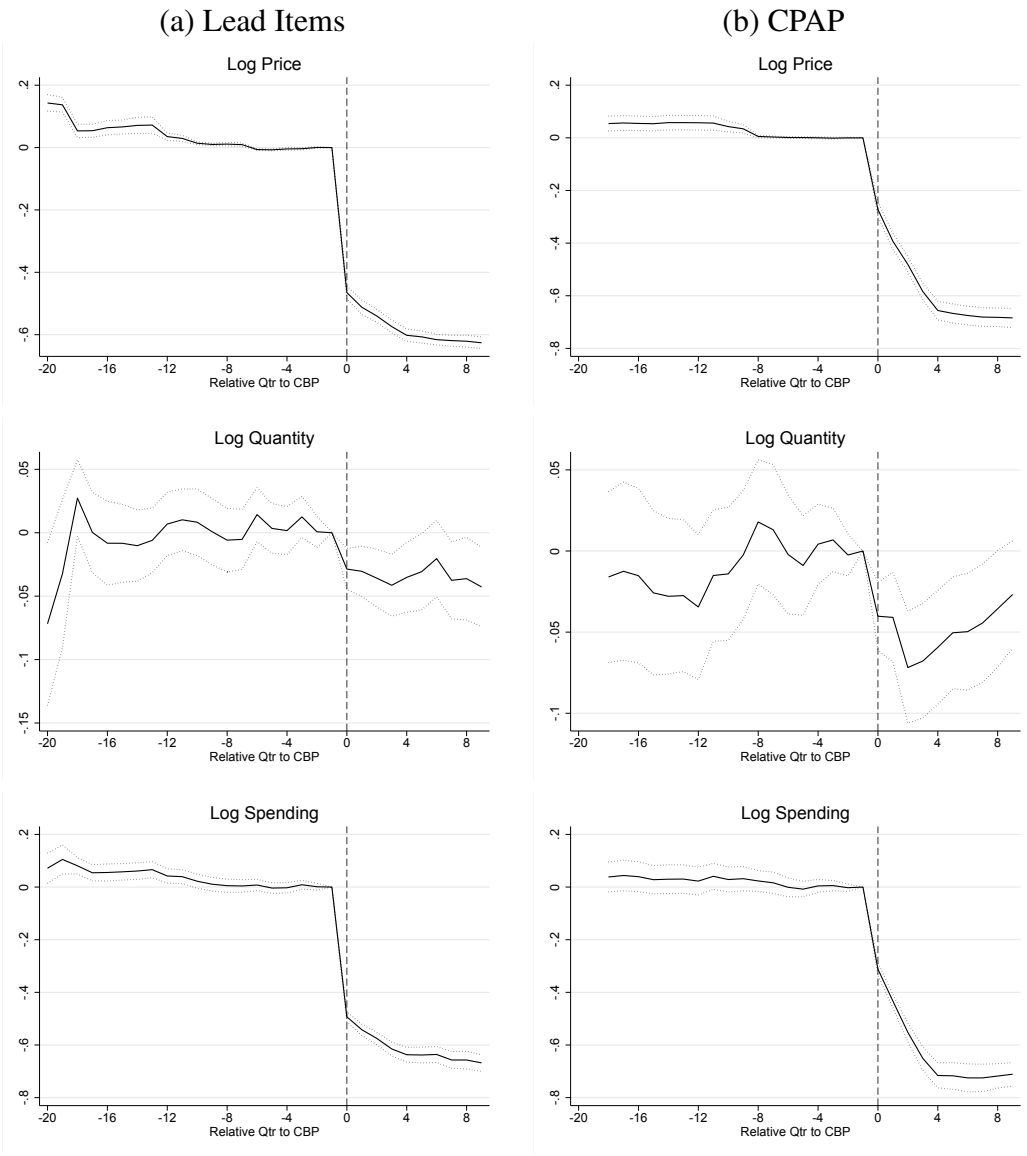
[22] We can do this because different products are added in the CBP at different time.

[23] Since DME is covered by Medicare Part B, we restrict our sample to Medicare recipients who had full FFS Part B coverage in each quarter. We aggregate quantity and payment for DME among these beneficiaries and use this population as denominator.

[24] A minority of product by geographic area by quarter cells (21%) have zero claims and therefore are missing log price, log quantity and log payment. This is mostly driven by small geographic areas not included in the CBP. Given that we weight by the number of claims in each area for each product in the pre-CBP period, this has a relatively small impact. In a series of robustness checks, we exclude areas that are not in the CBP from the analysis sample. The results are very similar.

[25] The -0.46 coefficient in the initial quarter implies a 37% ($e^{-0.46} - 1 = -0.37$) decrease in price, which drops further to 45% four quarters after the CBP. The gradual decline in price could be due to a grandfather clause that enabled some patients to continue rental services from their old DME suppliers at the original price.

Figure 1: The Impact of Competitive Bidding on Lead Item Prices and Quantities



Notes: These figures plot the effect of competitive bidding for 12 lead items (Panel (a)) and specifically for CPAP (Panel (b)). The observation is at product by CBSA by year-quarter level in (a) and CBSA by year-quarter level in (b). Outcome variables include price, quantity (total number of product counts per 1000 Medicare FFS recipients), and spending (total Medicare allowed amount per 1000 Medicare FFS recipients), all in log terms. The solid line is point estimates for the effect of quarter pre/post-CBP and the dotted lines are the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. Regressions in (a) include product fixed effects, CBSA fixed effects, year-quarter fixed effects, and their double interaction, weighted by the number of claims in each CBSA for each product in 2010. Regressions in (b) include CBSA fixed effects and year-quarter fixed effects, weighted by Medicare FFS population in 2010.

check, Appendix Table A4 weights observations by the number of Medicare FFS recipients in 2010 in each geographic area and presents almost identical results. In the subsequent analyses when we

focus on CPAP or other specific products separately, we will use population weight for simplicity and consistency.

In Appendix Table A5, we present several robustness checks. Columns 1 and 2 restrict the sample to only the 9 round 1 and 100 round 2 competitive bidding areas; the results are similar. Columns 3 and 4 restrict the sample to large non-CBAs (>9000 Medicare FFS population in 2010) along with round 1 and 2 competitive bidding areas. Again, the results are very similar. Columns 5 and 6 add a state-by-post-CBP indicator, which turns on when any area in the state has been included in the CBP to control for the effects of changes over time in state-level policies, including Medicaid. Again, the results are similar. Columns 7 and 8 restrict attention to Medicare FFS recipients who are enrolled in the program during our entire sample period; the results are once again quite consistent with our baseline results.

Appendix Table A6 reports the results for different rounds. The sample used for Columns 1 and 2 includes Round 1 items in Round 1 CBAs and non-CBAs. The sample used for Columns 3 and 4 includes the same products and geographic regions, but restrict the time period to 2009Q1 - 2013Q4 (before Round 1 CBAs were recompeted). The sample used for Columns 5 and 6 includes Round 2 items in Round 2 CBAs and non-CBAs. The sample used for Columns 7 and 8 includes Round 1 Recompete items in Round 1 CBAs and non-CBAs. Whether we truncate the sample before the recompete or not, we get a slightly smaller price drop in Round 1 than Round 2. Within Round 1 CBAs and Round 1 items, excluding year-quarters after the recompete yields estimates of a smaller decrease in price, which indicates that there is a further price drop in the recompete. The quantity difference is largest among Round 1 Recompete items and smallest among Round 2 items. This is consistent with results from separate specifications for each of the lead items within each category, as reported in Appendix Table A7. The range of the average price drop is 12% to 51%. Average quantity falls for all 12 items (and this is statistically significant among nine), and the reductions range from 2% to 90%. In the next section we look more closely at this results, focusing exclusively on CPAP machines.

Appendix Table A3 Panel B estimates the same specifications at the category (rather than prod-

uct) level.[26] These specifications allow for substitution across products within a category. As expected, the impact is slightly attenuated: prices fall by 38.2%, while quantities fall by 7.8% once we allow for within-category substitution. The program, viewed from this level, still substantially lowers program expenditures: Medicare reimbursement falls by an average of 43.0%.

3.2 CPAP Machines

Figure 1 Panel (b) restricts attention to CPAP machines.[27] Similar to the aggregate analysis, both the average price of CPAP machines and spending on these products fall significantly upon the introduction of competitive bidding. As this figure shows, average quantities also decline.

In Table 2, we estimate the relative magnitudes of the impact of competitive bidding in a difference-in-difference specification. The estimating equation is given by:

$$Y_{st} = \beta_1 \cdot CBP_{st} + \sigma_s + \theta_t + \varepsilon_{st},$$

where the dependent variables are (the log of) price, quantity, the number of (new) beneficiaries with one or more CPAP claims, and Medicare reimbursement (all denominated by 1000 Medicare FFS recipients except price) for CPAP in geographic area s during year-quarter t. The main variable of interest is the treatment indicator CBP_{st} which is set equal to 1 when CPAP is included in the CBP in geographic area s during year-quarter t and otherwise equal to 0. In all regressions, we include geographic σ_S and quarter-by-year θ_t fixed effects. We weight all regressions by the Medicare FFS population in each geographic area in 2010, and cluster standard errors by geographic area.

Table 2 presents the results. Because we are looking at a single product, we do not need to distinguish between the lead item and the rest-of-category demand. Again, the patterns in the

[26] We aggregate total payment and quantity (the number of items or services provided) within each category and calculate the average price per item.

[27] Price, quantity (per 1000 Medicare FFS recipients) and spending (per 1000 Medicare FFS recipients) are still in log terms to show changes in percentages. Only 1.4% of the geographic by quarter cells have zero claims for CPAP and thus have missing price, log quantity and payments. We also weighted geographic area by it size, measured as Medicare FFS population in 2010 (based FFS Part B months and counting people with 6-month coverage as 0.5).

Table 2: The Impact of Competitive Bidding on CPAP Prices and Quantities

	(1) Log Price	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries	(5) Log Spending
1(Competitive Bidding)	-0.594***	-0.0442***	-0.0439***	-0.0437***	-0.638***
	(0.0150)	(0.0163)	(0.0151)	(0.0126)	(0.0193)
Mean	71.33	20.45	8.300	2.326	1466
N	26,762	26,762	26,762	25,120	26,762
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
CBSA FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the results of regression analysis for the effect of the CBP on price and quantity of CPAP. The observation is at CBSA by year-quarter level. Outcome variables include price, quantity, number of (new) beneficiaries, and total spending, all denominated by one thousand Medicare FFS beneficiaries except price, and all in log terms (the mean of dependant variable shown is in level terms). All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

results are striking. Competitive bidding leads to a 44.8% ($e^{-0.594} - 1 = -0.448$) reduction in the average price of the rental. Given a pre-competitive bidding mean of \$79/month in 2010, this represents a \$35/month price reduction (or \$7 in OOPC to consumers facing 20 percent cost sharing per claim). Again, quantities also fall by an average of about 4.3% ($e^{-0.0442} - 1 = 0.0432$), regardless of the measure of quantity; the quantity reductions are due to both new beneficiaries and existing consumers. On net, average Medicare spending for CPAP devices falls by 47.2% ($e^{-0.638} - 1 = -0.472$) following the introduction of competitive bidding.

Appendix Figure A1 shows that market concentration grew post-CBP: the HHI increased by 0.05 (or 500) points in the average CBA. This is primarily due to two factors: small local firms exiting the market and large national players growing. A natural concern is that the CBP could lead to increased consolidation and higher prices in the future.[28]

Comparing across waves, Appendix Table A8 shows that CPAP also had smaller price drop and

[28]However, we note that the reduction in suppliers is a policy choice: only about one-third of the bidding suppliers were awarded CBP contracts (GAO, 2012). Despite rental services, suppliers also provide and get paid for the replacement of related supplies under frequency restrictions that are set by CMS. With the start of the CBP, new Medicare patients could only get CPAP from suppliers with a DME contract. Suppliers not awarded contracts could elect to become grandfather suppliers to continue providing CPAP for their existing patients (e.g. those who were 4 months into the 13 months needed to own) but could not provide DME products to new patients.

larger quantity decrease in Round 1 than Round 2. This is consistent with suppliers learning how to adapt to competitive bidding over time. Within Round 1 areas, excluding year-quarters after R1RC also shows smaller decreases in price and larger decreases in quantity, but the differences are not as big as the comparison between Round 1 and 2. Appendix Table A9 further shows that Round 1 led to slightly smaller increase in HHI and larger reduction in the number of suppliers.[29] However, given the standard errors, we do not want to overinterpret this result. Furthermore, the slightly heterogeneous effects across waves may lead to the concern that our two-way fixed effect estimation is biased in the overall treatment effect. To address this concern, Appendix Figure A2 replicates our main results using alternative estimators that address potential issues with two-way fixed effects. The patterns are qualitatively similar across estimators. For example, our baseline estimate for the price reduction in the fourth quarter after CBP are -0.584, while the new estimates range from -0.416 to -0.615. For quantity, all estimators suggest an about -5.8% ($e^{-0.06} - 1 = -0.058$) decrease.

The supply side changes in CBAs could have spillover effect to the neighboring non-CBAs, for example, the program could reduce the number of suppliers serving an untreated CBA adjacent to a treated CBA. From the demand side, the spillover effect could be limited since the reimbursement is based on the enrolleeâs address instead of the location of the providers. Appendix Table A11 reports the results estimated using only non-adjacent non-CBAs (Panel A) or only adjacent non-CBAs as controls (Panel B), which produces qualitatively similar results to our preferred estimates. Panel C reports the placebo effect using adjacent non-CBAs as treated and non-adjacent non-CBAs as controls. Despite a slight decrease in price (0.3% of the main effect), we find no effects on quantity and market structure.[30]

Appendix Table A13 documents other potential margins of adjustment. One potential concern is that the reduction in utilization is partly reflecting a deferral of necessary care among Medicare recipients. Column 1 shows that the incidence of obstructive sleep apnea (or OSA, as measured

[29] Appendix Table A10 replicates the impact of CBP on market structure by wave for lead items and categories. The increases in HHI and decreases in the number of suppliers are both largest in Round 2.

[30] Appendix Table A12 presents similar findings for lead items and categories.

by number of patients newly diagnosed with OSA per 1k Medicare population) actually goes up slightly after the introduction of competitive bidding, suggesting that if anything more patients are receiving in-person care for this diagnosis. Appendix Figure A3 shows similar result in event study format. The result is similar if we include all types of sleep apnea (SA) beyond OSA. Column 2 shows that total Medicare FFS spending (not including DME) for patients with an OSA diagnosis falls by 3.4% post-CBP along with a 29.5% ($e^{-0.349} - 1 = -0.295$) reduction in DME spending in Column 3, suggesting that there is no substitution to other types of care or deterioration of people's health.

One specific substitute for a CPAP machine that we observe in the data is the oral device/appliance used to reduce upper airway collapsibility (HCPCS code E0486). Appendix Table A14 reports the impact of CBP on the price and quanitity of this oral device. We find no effect on price, some evidence of an increase on the intensive margin (excluding the prevalent zeros), but no movement in overall quantity.[31] Under the same spirit, we also check the impact of CBP on the complements of CPAP. While most of the accessories of CPAP are added together in the same round, one particular type of mask (combination oral/nasal mask, HCPCS code A7027) was not included in Round 1. As shown in Appendix Table A15, the direct impacts of Round 2 and the Round 1 Recompete on mask prices and quantities are similar to our main results. However, there was no effect on both price and quantity in Round 1. Note here, this includes not only complement effect but also substitute effect, since other types of masks are included together with CPAP in Round 1.

Taken together, the results in this section demonstrate that the introduction of competitive bidding led to a sharp reduction in the price of DME products and a reduction in the utilization of these products as well. The effects were similar when considering all lead items in the 12 DME categories or when focusing exclusively on CPAP devices. In both cases, we estimate that competitive bidding substantially lowered Medicare spending. In the next section, we investigate the mechanisms driving these changes and explore heterogeneity in both the price and utilization ef-

[31] Based on the imprecise estimation in Column 3, the number of oral device claims per thousand Medicare population increased by 0.00669. Meantime, number of patients using CPAP is decreased by -0.484 per thousand Medicare population (in levels, not log, which is not included in the main table). That means only 1.38% of the decrease in CPAP patients switched to the oral device.

fects.

4 Mechanisms and Heterogeneity

4.1 Heterogeneity

In this section, we focus on CPAP machines to (a) decompose the contribution of supply and demand to the changes summarized above and (b) measure allocative efficiency given the change in utilization. We do this by (a) focusing on heterogeneity by dual status and (b) clinical appropriateness. Figure 2 plots the differences in our event study framework between those Medicare recipients who are dually eligible for the Medicaid program, and all other Medicaid recipients. The figure also shows the trajectory of prices and utilization before and after the introduction of the CBP for beneficiaries with and without a sleep apnea diagnosis.

Theoretically, we expect a different quantity effect for dual eligibles. Duals were fully insulated from any price changes before and after the policy change due to their secondary coverage from Medicaid. In contrast, there was a reduction in out-of-pocket price for non-duals as a result of the CBP, as the allowed amounts for Medicare declined. All else equal, this would lead to an increase in their utilization of CPAP machines.

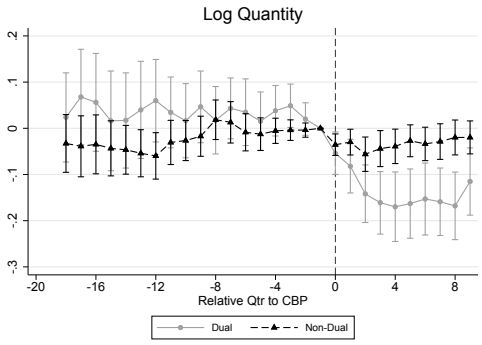
Appendix Figure A4 shows, the reduction in the total price is essentially identical for duals and non-duals. However, in Figure 2, we observe a substantial reduction in utilization among duals (who had no offsetting effect of a lower out-of-pocket price) while the utilization remains relatively constant for non-duals. This strongly suggests that the differential changes in out-of-pocket prices were responsible for the relative decrease in quantity among those dually eligible for Medicaid. Perhaps not surprisingly, quantity declines more for those Medicare recipients without a sleep apnea diagnosis, suggesting that the patients with more severe sleep apnea continued to use CPAP devices.

Table 3 presents treatment effect estimates for different groups of consumers categorized by demographics and health status. The results in Table 3 are quite consistent with the differences

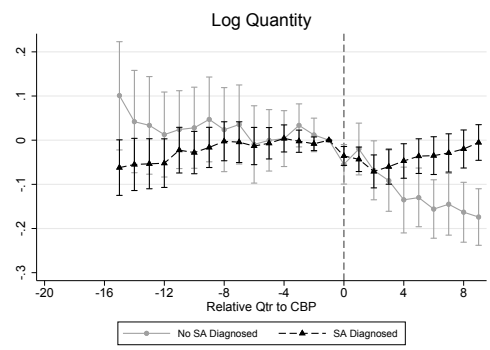
implied by Figure 2. Quantities fell by significantly more among dual eligibles and among those without a sleep apnea diagnosis.[32] The point estimates also suggest a larger reduction among men than among women, though the difference is not statistically significant. We explore these differences further in the next section, along with the allocative efficiency of the changes in utilization.

Figure 2: The Impact of Competitive Bidding on CPAP Quantities by Subgroups

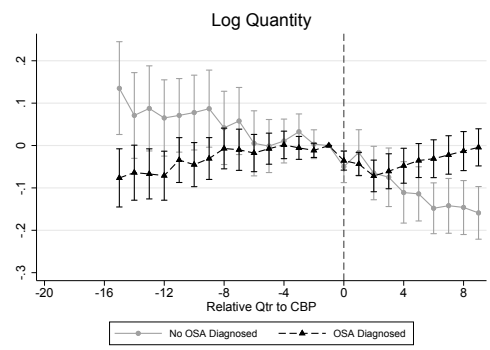
(a) By Dual Status



(b) By Sleep Apnea (SA)



(c) By Obstructive Sleep Apnea (OSA)



Notes: These figures plot event study coefficients of relative years interacting with group dummies. The observation is at CBSA by year-quarter by subgroup level. Panel A groups sample to duals vs nonduals. Panel B and C define subgroups as those diagnosed with either SA (primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in an inpatient, outpatient, or physician carrier table) or OSA (primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) in the previous year, restricting to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis (sample period starts from 2009Q4). Outcome variable is the total quantity of product per one thousand Medicare FFS recipients, in log terms. The blue solid lines show point estimates for the effect of the CBP for duals / No SA / No OSA diagnosis and the red dashed lines show point estimates for the effect of the CBP for nonduals / SA / OSA diagnosed. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010.

[32] Appendix Table A16 reports larger drop for people without sleep apnea diagnosis among only dual eligible as well.

Table 3: The Impact of Competitive Bidding on CPAP Quantities by Subgroups

	(1) Dual vs. Non-Dual	(2) Female vs. Male	(3) No SA vs. SA	(4) No OSA vs. OSA	(5) Below vs. Above Median Propensity
1(Competitive Bidding) * Group 1	-0.165***	-0.0625***	-0.123***	-0.132***	-0.125**
	(0.0308)	(0.0222)	(0.0350)	(0.0355)	(0.0516)
1(Competitive Bidding) * Group 2	-0.0182	-0.0293	-0.0242	-0.0164	-0.0197
	(0.0185)	(0.0210)	(0.0187)	(0.0180)	(0.0205)
Mean of Dep Var (Group 1)	19.34	16.75	4.253	5.504	3.103
Mean of Dep Var (Group 2)	20.86	25.32	162.2	157.1	39.05
Coef Diff (Group 1 - 2)	-0.147	-0.0332	-00983	-0.116	-0.106
p-value	[<0.0001]	[0.0148]	[0.00108]	[0.000287]	[0.0160]
N	50,477	52,486	45,270	45,949	32,456

Notes: This table presents the results of regression analysis for the effect of the CBP on quantity in different subgroups. The observation is at CBSA by year-quarter by subgroups level. Subgroups are defined as duals vs nonduals, male vs female, whether diagnosed with sleep apnea (or SA, primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in an inpatient, outpatient, or physician carrier table) or Obstructive Sleep Apnea (or OSA, primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) in the previous year, and CPAP propensity above vs below median. OSA/SA diagnosis and CPAP propensity samples are restricted to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis (sample period starts from 2009Q4). CPAP propensity is estimated using OSA/SA diagnosis and demographic variables in 2010 (details in Section 4.3). Main variables of interests are the CBP indicator interacting with group dummies (group 1 and 2 corresponding to the order in column title). All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

4.2 Separating Supply and Demand

We observe very different utilization patterns between those Medicare recipients with and without Medicaid coverage (duals and non-duals, respectively). We will use this heterogeneity to separate the impact of the CBP into its supply-side and demand-side components.

How does a change in the administrative price affect equilibrium outcomes? First, due to the rules of the Medicare program, a price drop reduces out-of-pocket costs to consumers (by 20% of the change in price). The price reduction is passed on to non-duals in the form of lower cost sharing, which could increase in the quantity demanded. Second, a price reduction could also lead to a reduction in supply. This could occur along two margins: a reduction in the number of firms in the market and/or a reduction in the number of claims per firm. To answer the key policy questions of interest, we use variation driven by dual-eligible status to separate the effects of changes in supply from the effects of changes in demand.

The policy environment suggests a natural difference-in-differences specification: we can com-

pare outcomes for dual eligibles and non-dual eligibles before and after the introduction of the CBP. These two groups face the same suppliers in both periods in each geographic market. Although they may be demographically different, we can test for the existence of differential trends in the period leading up to the introduction of the CBP. Critically, because duals and non-duals face different changes in their out-of-pocket prices, we can separate supply from demand.

Left-hand panel in Appendix Figure A4 depicts the impact on the average price and how this varies over time, while Appendix Figure A5 shows the changes in the out-of-pocket cost (OOPC) faced by the two groups.[33] The total price falls for both groups but the OOPC diverges. OOPC for duals (solid blue line) remains fixed and very close to zero, while the OOPC for non-duals (dashed red line) falls in line with total prices. Despite this, we again see in the right-hand panel of Appendix Figure A4 that the spending reduction is more pronounced among the duals. As described above, quantities for duals fall, while quantities for non-duals actually rise slightly.

Both the direction and magnitude of these results are consistent with large supply side changes. Absent OOPC changes, quantities supplied fall because of the reduction in price. A differential demand response among non-duals mitigates this quantity reduction since consumers actually face a lower price after the CBP. Given elasticity estimates, we can predict counterfactual quantities under alternative policies. To measure the demand elasticity, we leverage the differences in cost sharing rules across "dual" and "non-dual" beneficiaries directly. Formally, let G be a dummy variable that takes on a value of 1 for non-duals. We can calculate the total quantity D in market m at time t for group g in G or $1-G$: D_{gmt}. We know that for non-duals ($G=1$), $OOPC_{gmt} = 0.2 * P_{gmt}$; for duals, $OOPC_{gmt} = 0$. The elasticity (which we can evaluate at the average $OOPC$) can be written as:

$$\varepsilon = \frac{\partial D}{\partial OOPC}\frac{OOPC}{D} = \frac{\partial log(D)}{\partial OOPC}OOPC.$$

OLS estimates of $\partial log(D)/\partial OOPC$ may be biased by omitted variables or reverse causality. For example, places with high demand of CPAP might generate higher price in the bidding while

[33] OOPC is calculated as 20% of the price for non-dual eligibles and 0 for dual eligibles. This number can be different from the actual out-of-pocket payment if the beneficiary has Medigap coverage, which will bias us against finding any difference across the two groups. We explore this issue below.

still have more claims than places with low demand. To address this, we estimate the elasticity using the interaction of competitive bidding and non-dual status as the instrumental variable for OOPC. Intuitively, we are using exactly the variation depicted in Appendix Figure A5, comparing duals and non-duals before and after competitive bidding. The previous figures effectively plot the first-stage and reduced form using this variation, which we describe in Table 4.

Table 4: The Impact of Competitive Bidding on CPAP Demand

	(1) OOPC	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries
Panel A: OLS				
1(Competitive Bidding)*Nondual	-7.183***	0.124***	0.115***	0.110***
	(0.174)	(0.0219)	(0.0207)	(0.0229)
1(Competitive Bidding)	0	-0.149***	-0.139***	-0.139***
		(0.0258)	(0.0240)	(0.0221)
Panel B: IV				
OOPC		-0.0173***	-0.0160***	-0.0153***
		(0.00310)	(0.00292)	(0.00309)
1(Competitive Bidding)		-0.149***	-0.139***	-0.139***
		(0.0258)	(0.0240)	(0.0221)
Elasticity		-0.272	-0.251	-0.242
Mean of OOPC (Nondual)	15.76	15.76	15.76	15.77
F-Stats		1,707	1,707	1,671
N	50,477	50,477	50,477	41,656

Notes: This table presents the results of regression analysis for the effect of the CBP on price and quantity of CPAP separately among duals and non-duals. The observation is at CBSA by year-quarter by dual/nondual level. Outcome variables include out-of-pocket cost (OOPC, defined as 20% of price for non-dual and 0 for dual), quantity and number of (new) beneficiaries, all denominated by one thousand Medicare FFS beneficiaries, and all in log terms except OOPC. Panel A shows the OLS result, while Panel B shows the IV result using 1(Competitive Bidding)*Nondual as the instrument for OOPC. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for dual eligible status. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. F-statistics is estimated using Kleibergen-Paap rk Wald F test. Significance levels: *10%, **5%, ***1%.

The first column in Panel A describes the relationship between competitive bidding and OOPC. Columns 2-4 in Panel B estimate the corresponding 2SLS regressions in which we include group fixed effects, time fixed effects, market fixed effects, and a "post" dummy in both stages of the regression. The excluded instrument is a "post" dummy interacted with G, the indicator for non-

duals. This serves as the instrumental variable of OOPC since the competitive bidding only decrease the OOPC for non-duals, as confirmed in the first column of Panel A. The exclusion restriction assumes there is no channel that the competitive bidding affects duals and non-duals differently other than through the change in OOPC. We scale the coefficient to obtain a demand elasticity. The coefficient in column 2 of Panel B (-0.0173) corresponds to the coefficient in column 2 of Panel A (0.124) divided by the coefficient in column 1 (-7.183). The coefficient represents the average treatment effect among compliers, who here are always non-dual beneficiaries. This number allows us to calculate a demand elasticity for non-duals only.[34] The estimate suggests that a one dollar reduction in out-of-pocket cost, which represents a 6.34 percent reduction at the mean of 15.76 (among non-duals in 2010), leads to an increase of 1.73 percent in the quantity demanded. Taking the ratio of these two changes, we estimate a demand elasticity of -0.272. The estimate is very similar across specifications (using different dependent variables) and is close to the elasticity estimate of 0.2 for overall health care utilization in the well-known RAND health insurance experiment (Manning et al., 1987).

Our results indicate that demand is indeed downward sloping. Despite this, quantities fall post-competitive bidding, consistent with a large supply-side response to the policy-induced reduction in price. A natural question is how much demand would have increased absent these supply side changes. Given the supply side changes, quantity falls. Quantity would have fallen by less than observed if not for the price drop leading to a countervailing increase in quantity demanded. If we applied the same demand elasticity to non-duals, we would expect only a 2.8% decrease in quantity $(0.149 - (-0.272) * (0.2 * (-35)/15.76))$. This indicates that a demand response insulated non-duals from much of the negative quantity impact of the policy change, which is consistent with the event study plots in Figure 2 and OLS results for subgroups in Table 3.

Our demand elasticity estimation leverages different OOPC changes among duals and non-duals assuming that non-duals pay 20% coinsurance and therefore faced a OOPC reduction after the CBP. This might be attenuated if non-duals have supplemental insurance insulating them from

[34] It seems plausible that duals would be more price sensitive than non-duals given lower income and assets.

cost-sharing. In fact, Medicare Supplement (Medigap) insurance would cover the 20% Part B copay associated with CPAP machines. We do not observe supplemental coverage at the individual level. However, we know how prevalent coverage is at the market level. To explore the impact of supplemental coverage on our elasticity estimates, we split the sample into above and below median Medigap coverage markets (average Medigap share is 37.6% and 25.5% respectively). Theoretically, one would expect a smaller quantity differential between duals and non-duals in high-Medigap states given that non-duals are more likely to be insulated from the effects of any price changes in high-Medigap states. Consistent with this, the results displayed in Appendix Table A17 show that quantity effect for non-duals is smaller in the below-median markets; the negative impact for duals is almost completely offset. The interaction term is smaller in markets where Medigap coverage is more prevalent; the quantity reduction for duals is more like non-duals. The "naive" elasticity estimates are also larger in magnitude: -0.341 in below-median markets versus -0.211 in above-median markets. While the range of elasticity estimates is non-trivial, the elasticity estimate is below -0.5 in all subsamples.[35] Additional sub-samples by terciles or isolating the top quartile show a consistent pattern: the "naive" elasticity estimate ranges from approximate -0.19 in markets where Medigap is especially prevalent to -0.41 in markets where Medigap coverage is rare. Our approach allows us to isolate the impact of consumer behavior and provide policy-relevant elasticities that account for market institutions.

There are two potential concerns when comparing dual eligible patients with non-duals, both related to Medicaid payment policy. First, Medicaid reimbursement could change at the same time that the CBP takes effect. We test this assumption using robustness checks with state-by-post-CBP indicators and state-by-dual-by-post-CBP indicators, which turn on when any place in the state has been included in the CBP and allows it to differ across dual and non-dual population. For both main effects (Table 2) and dual analysis (Table 4), we find similar results as in Appendix Table A18 and A19 after controlling for changes in (dual or non-dual specific) state-level policies that coincide with the CBP. Second, if Medicaid does not pay the full out-of-pocket cost after Medicare

[35] We also estimate demand elasticity in different subgroups of Medigap share areas using the pooled sample of 12 lead items and see a similar pattern: -0.108 in below-median markets versus -0.0444 in above-median markets.

pays for the crossover claims, lowering the price in Medicare would cause different changes in the payment that suppliers receive for dual and non-dual patients.[36] As a robustness check, we restrict the sample for dual analysis to be states that 1) set Medicaid price the same as Medicare price for DME items (AL, AK, DE, IN, IA, MN, MT, NV, NM, NC, WV, WY), or 2) have full crossover payment for Part B services (AR, HI, IA, ME, MS, MO, NE, OH, OK, SD, VT, WY).[37] Results are presented in Appendix Table A20 and yield a similar estimate for the demand elasticity. Finally, we also replicate the dual analysis using the pooled sample of 12 lead items in Appendix Table A21. The elasticities are similar to the CPAP estimates for new consumers but smaller for existing consumers. This is consistent with more within-category substitution in other DME product categories.

The quantity reduction among duals suggests a supply-side response to reduced reimbursement, consistent with provider responses in other healthcare markets (Clemens and Gottlieb, 2014). To use the data to construct a supply elasticity or measure firm costs, we would also need an assumption on firm conduct. This is an important direction for future work. From a normative perspective, it is not clear whether the reduction in quantity along with the fall in Medicare spending is "good" or "bad," because we have not specified the socially optimal level of CPAP consumption. Furthermore, it is difficult to determine whether the CBP led to a reduction in consumption among consumers for whom CPAP machines are clinically appropriate.

4.3 Clinical Appropriateness

To investigate the impact of the changes described above, we note that we observe very different utilization patterns for consumers with and without a sleep apnea diagnosis. We will use this het-

[36] A crossover claim is a claim for a recipient who is eligible for both Medicare and Medicaid, where Medicare pays a portion of the claim and Medicaid is billed for any remaining deductible and/or coinsurance.

[37] Information from MACPAC States' Medicaid Fee-for-Service Durable Medical Equipment Payment Policies, https://www.macpac.gov/publication/states-medicaid-fee-for-service-durable-medical-equipment-payment-policies/. Information from MACPAC State Medicaid Payment Policies for Medicare Cost Sharing, https://www.macpac.gov/wp-content/uploads/2015/01/State-Medicare-Cost-Sharing-2015.xlsx Note that there is no specific summary for payment policy on DME items, therefore we refer to policy on physician services which is also paid under Medicare Part B

erogeneity to explore the allocative efficiency of the CBP. Following Chandra and Staiger (2007), we define the clinical appropriateness for treatment using pre-period data on diagnoses and demographics. We then explore the extent to which the CBP reduced "appropriate" CPAP use given the clinical literature.

Given that only CPAP prices (and not for example physician reimbursement) are affected by the CBP, we do not expect a change in upstream diagnoses unless consumer and/or physician behavior changes. Previous results summarized above in Appendix Table A13 and Appendix Figure A3 demonstrated that overall diagnosis rates did not change much as a result of the CBP. Furthermore, there is no difference in trends between duals and nonduals in terms of the diagnosis rate of sleep apnea. The left-hand panel of Appendix Figure A6 shows the impact of the CBP on the probability of having any sleep apnea (SA) diagnosis in the past year (current quarter + previous 3 quarters, and the right-hand panel shows the probability of having obstructive sleep apnea (OSA) diagnosis in the past year (current quarter + previous 3 quarters). In both cases, the diagnosis rate increased by around 0.001 percentage points among each group (with non-duals slightly higher), which is relatively small compared to the mean of 2.9% for OSA and 3.3% for SA.

To model the utilization of CPAP devices conditional on demographic and clinical data, let ζ be a vector of consumer characteristics, including clinical appropriateness for CPAP treatment, Z. We define the population by a joint distribution $G(\zeta)$. We write a consumer i of type ζ's utility from CPAP consumption as $v(\zeta_i, OOPC)$, where $OOPC$ is the price faced by the consumer. We can then define the price at which a consumer is indifferent to owning a CPAP machine as $\sigma(\zeta_i) = max(OOPC : v(\zeta_i, OOPC) > 0)$. We note that, given the inconvenience and treatment costs, this quantity could be negative. We can then write aggregate demand as:

$$D(OOPC) = \int 1(\sigma(\zeta_i) \geq OOPC)\, dG(\zeta) = Pr(\sigma(\zeta_i) \geq OOPC).$$

Now let the clinical appropriateness for treatment Z_i be one component of the vector ζ. The

average clinical appropriateness in a market can be written as:

$$\bar{Z}(OOPC) = \frac{1}{D(OOPC)} \int Z_i 1(\sigma(\zeta_i) \geq OOPC) dG(\zeta) = E(Z_i | \sigma(\zeta_i) \geq OOPC).$$

We are interested in $\frac{\partial \bar{Z}(OOPC)}{\partial OOPC}$, which also allows us to define the clinical appropriateness of the marginal consumer. We can estimate $\frac{\partial \bar{Z}(OOPC)}{\partial OOPC}$ using an exogenous change in $OOPC$.

To construct a measure of clinical appropriateness for treatment Z_i, we take a series of steps. First, we predict CPAP consumption in the pre-period. To do this, we estimate a logit regression using beneficiary-year data.[38] To avoid potential changes after the CBP, only the pre-CBP year of 2010 is used for estimation. We then predict the CPAP usage probability for all beneficiary-years and aggregate to the geographic area by year level. We use a number of clinical and demographic predictors of CPAP usage: OSA diagnosis, SA diagnoses, age bins, gender, dual and SSDI (social security disability insurance) status.

The results from this analysis are summarized in Appendix Table A22. As the results there show, diagnosis is a very strong predictor of CPAP use. A beneficiary with a SA diagnosis is 76.7 ($e^{4.353} - 1$) times higher in odds ratio of having a CPAP claim than a beneficiary without such a diagnosis. The oldest beneficiaries are significantly less likely to have one or more CPAP claims, as are duals and women. Using these results, we can construct the empirical analogue of Z_i above – the clinical appropriateness of treatment. We note that this variable measures clinical appropriateness conditional on the administrative price mechanism.

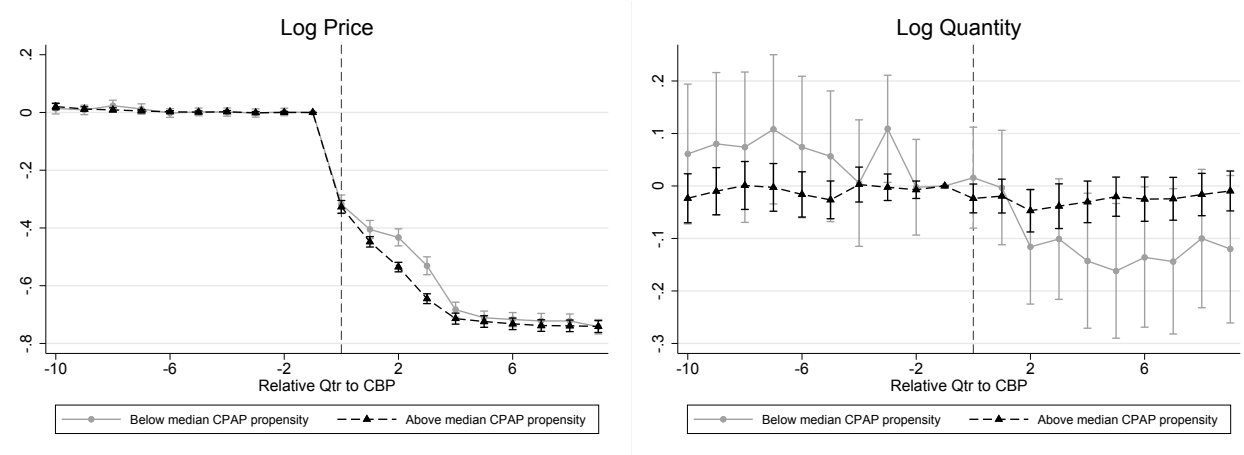
We next plot the impact of competitive bidding for consumers with above and below median CPAP propensities. The results are in Figure 3. As noted above, prices fall similarly for those with above and below median clinical appropriateness.[39] However, the quantity series diverge. For consumers with above median clinical appropriateness for treatment, quantities are virtually unchanged. However, there is a large and persistent drop in CPAP use for consumers with below

[38] We restrict attention to beneficiaries with full 3-month Part B non-HMO Medicare enrollment in the current quarter and three previous quarters.

[39] The small differences are again due to the use of grandfathered suppliers.

median predicted CPAP propensity.[40] The differential effect is more precisely estimated in the difference-in-difference specification, as shown in Table 3 Column 5. The difference between the two coefficients, for below and above median propensity interacted with post indicator, is -0.106 (p-value = 0.0160). Taken together, these results suggest that utilization declined more for those who derive less benefit from CPAP use.

Figure 3: The Impact of Competitive Bidding on CPAP Prices and Quantities by CPAP Propensity



Notes: These figures plot event study coefficients of relative years interacting with group dummies (estimated CPAP propensity below vs. above median). CPAP propensity is estimated using OSA/SA diagnosis and demographic variables in 2010, restricted to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis. The observation is at CBSA by year-quarter by subgroup level. Outcome variables include price and quantity (total number of product/service counts per 1000 Medicare FFS recipients), all in log terms. The blue solid lines show point estimates for the effect of the CBP for CPAP propensity below median and the red dashed lines show point estimates for the effect of the CBP for CPAP propensity above median. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010.

Our results suggest that some of the quantity reduction that we observe may be "efficient"; that is, the quantity reductions are concentrated among consumers for whom a CPAP machine is less likely to be clinically appropriate. To further explore this idea, we isolate the "marginal" consumers in an additional set of specifications. To do this, we follow the logic of Gruber et al. (1999). We

[40] Appendix Figure A7 plots coefficients separately by dual status and clinical appropriateness. The entire quantity effect is driven by dual enrollees. Within duals, the point estimate for quantity reduction is large in the below-median propensity group. However, we cannot reject that the impact is the same across subgroups of dual enrollees.

estimate the following equation:

$$Y_{st} = \beta_1 \cdot log\left(D_{st}/M_{st}\right) + \sigma_s + \theta_t + \varepsilon_{pst},$$

where Y_{st} is the average demographic characteristics of CPAP users (corresponding to variables we used to define subgroups in Table 3) and the endogenous independent variable of interest is the log of the CPAP rate, calculated as total demand D_{st} divided by Medicare beneficiaries M_{st}. The excluded instrument is the interaction from the difference in difference specification described above. The coefficients estimate the gap in demographics and outcomes between the marginal and the average consumer, where the marginal consumer is *less* likely to obtain a CPAP post-CBP.

Table 5: Marginal Consumer of CPAP

	(1) Dual	(2) Male	(3) SA Diagnosed	(4) OSA Diagnosed	(5) CPAP Propensity
Log CPAP rate	0.459***	-0.160*	-0.398***	-0.576***	-0.0956**
	(0.155)	(0.0908)	(0.153)	(0.199)	(0.0456)
Mean	0.186	0.546	0.792	0.727	0.201
N	26,762	26,762	23,872	23,872	19,108
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
CBSA FE	Yes	Yes	Yes	Yes	Yes

Notes: This table presents the results of regression analysis for the effect of the CBP on the average demographic characteristics of CPAP users. The observation is at CBSA by year-quarter level. For Sleep Apnea (SA) and Obstructive Sleep Apnea (OSA) diagnosis, we restrict to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis (sample period starts 2009Q4). For CPAP propensity which is estimated using 2010 data, we only use observations since 2011Q1 to estimate marginal consumer. Outcome variables include average CPAP propensity predicted as shown above, demographic characteristics and SA/OSA diagnosed. We instrument for the explanatory variable, Log CPAP rate, using the treatment indicator of the CBP. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Column 5 of Table 5 shows that marginal consumers are 0.0956 pp lower in CPAP propensity than average consumers, as suggested by the graphical analyses. Columns 1-2 show that marginal consumers are more likely to be duals, consistent with our findings that duals reduce quantity

more, and are less likely to be male. Columns 3 and 4 show that marginal consumers are also less likely to have an SA or OSA diagnosis in the past year, again consistent with our findings with subgroups. Appendix Figure A8 shows event study results for the impact of CBP on the outcomes in Table 5 and confirms that the average demographic characteristics of CPAP users do not have different pre-trends in treated and untreated areas.

5 Policy Analysis

To draw normative conclusions about the impact of the CBP, we must view our results in context. A full accounting of the welfare impacts of this significant change to the Medicare reimbursement policy is outside the scope of this paper. However, we develop a simple cost-benefit comparison from the government's perspective that also incorporates the effects on patient health. We ignore the impact of the program on firm profits. We begin with the approximation that the benefits of competitive bidding are the savings on inframarginal units: $dP * D_2$. The costs of competitive bidding may fall on the government or on consumers. First, government expenditures may increase (decrease) if other covered services are substitutes (complements) for competitive bidding items; let E represent such average government expenditure. Second, consumers value consumption of durable medical goods; let B represent (monetized) health benefits to consumers and let η represent the weight that the government places on consumer benefits.

The benefits of competitive bidding exceed the costs if and only if:

$$dP * D_2 > dE + \eta dB.$$

The first three objects in this equation are easy to calculate. According to Table 2, the average price drop is $e^{-0.594} - 1 = 44.8\%$ from a baseline average price of \$71.33, which gives us $dP = 44.8\% * \$71.33 = \$31.96$ per month, or \$415.43 over the thirteen month rental period. We can multiply this by the number of inframarginal units; 8.30 beneficiaries per one thousand Medicare beneficiaries have a CPAP claim. Therefore, the total savings are \$3448.07 per one thousand

Medicare beneficiaries. In Appendix Table A13, we show that (non-DME) Medicare expenditures actually fall post-competitive bidding; we (conservatively) ignore dE.

The last object – the loss of the health benefits to consumers no longer purchasing DME under competitive bidding – is harder to calculate. While we can characterize marginal consumers, our empirical analysis makes it difficult to measure their willingness-to-pay.[41] To quantify the benefits of a CPAP machine, we turn to the clinical literature. We measure the health benefits of CPAP machines in terms of quality-adjusted life years (QALYs); 1 QALY is one year in perfect health. We then calculate the "cost-per-QALY", known as an incremental cost-effectiveness ratio (ICER). According to external estimates from the United Kingdom's National Institute for Health and Care Excellence (NICE, 2008), the cost for the average consumer is £20,585 per QALY for patients with mild OSA, assuming a CPAP price of £250-£550. Given the midpoint of that estimate, we calculate that a CPAP generates 0.0194 QALYs (400 / 20585). For moderate and severe OSA, NICE estimated £9391 and £4413 per QALY respectively, which leads to CPAP values of 0.042 and 0.091 per QALY.

We can calculate the change in the number of consumers from our estimates: there are 0.37 $(e^{-0.0439}-1)*8.30)$ fewer CPAP consumers per one thousand Medicare beneficiaries. The benefits of the CBP will exceed its costs if the value of a QALY is less than the savings divided by the number of new consumers multiplied by the benefits (in QALYs) per consumer. In our setting, this is given by $3448.07/(0.0194*0.37) = \$480,366.40$. The QALY threshold is \$221,883.53 if the marginal CPAP user has moderate OSA, or \$102,407.78 if the marginal CPAP user has severe OSA. In our analyses above we find that the marginal consumer has a lower CPAP propensity than the average consumer, so they are less likely to have severe OSA. Estimates within the literature value a year of life in perfect health at \$75,000 to \$100,000 (Cutler and Meara, 2000). Therefore, we find that the saving from the reduction in Medicare spending substantially exceed the costs of

[41] We know that (for non-dual) consumers, willingness to pay is at least $.2*P_1$. However, we are probably more interested in the upper bound; this requires considering the "worst case scenario" from the perspective of the consumer. There are two main concerns. The first, and potentially more damaging, is that changes in reimbursement could lead to under-diagnosis. Second, changes in reimbursement could lead to increases in spending elsewhere in the medical system. Medicare will still cover all of the services associated with a sleep apnea diagnosis.

reduced access to CPAP devices in our setting.

Taken together, our results suggest that the benefits of the lower health care expenditures outweigh any access loss from reduced quantity. However, there are several caveats. We do not account for supplier profits, nor is this meant to be a complete welfare analysis. We make several assumptions – about both social welfare weights and cash prices – that are not innocuous. However, our conservative estimates still highlight the potential for large government savings under the program. Future work should explore optimal reimbursement policy.

6 Conclusion

We estimate the impact of Medicare's CBP, which was introduced a decade ago. We find that the roll-out of competitive bidding – staggered across product, space, and time – led to large reductions in the prices paid for DME. If the categories in the CBP were representative of all categories, we would expect a cost savings of 43.0%. The total non-CBP DME spending in 2015 was $5 billion (Appendix Table A1), among which 2.6 billion are from CBAs. As a result, we would expect an additional $1.1 billion in savings were CBP extended to all DME categories in the CBAs that used competitive bidding. However, reductions in quantities accompanied these price reductions. We explore the CPAP market in particular to show that the marginal consumer is more likely to be a dual-eligible who faces no cost-sharing. The results suggest that changes in supply, rather than demand, are driving the overall reduction in quantity.

To separate supply and demand-side factors, we compare the impact of the CBP on dual eligible and non-dual eligible Medicare enrollees. We show that reductions in out-of-pocket costs mitigate the impact of the program on utilization; there are no reductions in quantities for non-dual eligibles (who see a reduction in their out-of-pocket price as a result of the CBP). Finally, we show that rates of diagnosis do not change. The reduction in quantity is significantly higher among consumers without a formal sleep apnea diagnosis. Our model and empirical analysis indicates these consumers are less clinically appropriate for treatment. Given our results for price, utilization, and

Medicare spending, we perform a cost benefit analysis. The calculations indicate that the benefits of the price reduction on infra-marginal units more than offsets the costs of any loss in consumer surplus.

While highlighting the success of the CBP in reducing Medicare spending, our findings suggest that Medicare faces a serious challenge in setting prices for health care services within its fee-for-service program. While most Medicare recipients obtain coverage for prescription drugs through private Medicare Part D plans and nearly 40 percent obtain their health insurance through private Medicare Advantage plans, the majority of Medicare recipients have traditional Medicare fee-for-service coverage. Future work should consider whether market mechanisms such as competitive bidding could be effective in other areas of Medicare's fee-for-service program.

In both regulation and procurement, governments often face serious challenges. Governments may lack the information necessary to set prices at the efficient level (Chan and Dickstein, 2019). However, market mechanisms must be well-designed. In our setting, the auction we study is unlikely to produce efficient outcomes, despite the price reductions we observe. Various features of the auction – such as a median-bid pricing rule and non-binding bids – may lead prices to fall beyond the efficient level (Cramton et al., 2015). Auction rules should also be designed to prevent gaming by firms (Decarolis, 2015). The problems they face are often challenging and complex, especially in health care.

At the same time, there are looming challenges for Medicare financing, with expenditures for the program projected to more than double from 750 billion in 2018 to 1.559 trillion by 2028. This would represent a 7.6 percent annual growth rate in total spending (5.0 percent annual on a per-recipient basis) compared with an annual growth rate in total spending of just 4.9 percent during the preceding 10 years (CMS, 2020b). Our results suggest that Medicare's future funding challenges could be reduced by targeted reforms of price-setting in this program, which currently provides health insurance to one-in-five Americans.

References

AHIP, "Trends in Medigap enrollment and coverage options, 2015," 2017. https://www.ahip.org/wp-content/uploads/2017/05/Medigap_Report_5.1.17.pdf.

Anderson, Gerard F, Uwe E Reinhardt, Peter S Hussey, and Varduhi Petrosyan, "It's the prices, stupid: Why the United States is so different from other countries," *Health Affairs*, 2003, *22* (3), 89–105.

Borusyak, Kirill, Xavier Jaravel, and Jann Spiess, "Revisiting event study designs: Robust and efficient estimation," *arXiv preprint arXiv:2108.12419*, 2021.

Cao, Shengmao, Xuejie Yi, and Chuan Yu, "Competitive bidding in drug procurement: Evidence from China," *Available at SSRN 3940088*, 2021.

Chaisemartin, Clément De and Xavier d'Haultfoeuille, "Two-way fixed effects estimators with heterogeneous treatment effects," *American Economic Review*, 2020, *110* (9), 2964–96.

Chan, David C and Michael J Dickstein, "Industry input in policy making: Evidence from Medicare," *The Quarterly Journal of Economics*, 2019, *134* (3), 1299–1342.

Chandra, Amitabh, Amy Finkelstein, Adam Sacarny, and Chad Syverson, "Health care exceptionalism? Performance and allocation in the US health care sector," *American Economic Review*, 2016, *106* (8), 2110–44.

_ **and Douglas O Staiger**, "Productivity spillovers in health care: Evidence from the treatment of heart attacks," *Journal of Political Economy*, 2007, *115* (1), 103–140.

Choi, Su Jung, Eun Yeon Joo, Young Jun Lee, and Seung Bong Hong, "Suicidal ideation and insomnia symptoms in subjects with obstructive sleep apnea syndrome," *Sleep Medicine*, 2015, *16* (9), 1146–1150.

Clemens, Jeffrey and Joshua D Gottlieb, "Do physicians' financial incentives affect medical treatment and patient health?," *American Economic Review*, 2014, *104* (4), 1320–49.

_ **and** _ , "In the shadow of a giant: Medicare's influence on private physician payments," *Journal of Political Economy*, 2017, *125* (1), 1–39.

_ **,** _ **, and Tímea Laura Molnár**, "Do health insurers innovate? Evidence from the anatomy of physician payments," *Journal of Health Economics*, 2017, *55*, 153–167.

CMS, "Medicare Part A and Part B summary: Persons with utilization, program payments, and cost sharing for all original Medicare beneficiaries, by type of coverage and type of service, calendar years 2010-2015," 2015. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/CMSProgramStatistics/2015/Downloads/UTIL/2015_CPS_MDCR_SUMMARY_AB_1.pdf.

_ , "CMS Fast Fact: Medicare, Medicaid, and CHIP Populations for CY 2020," 2020. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/CMS-Fast-Facts.

_ , "National Health Expenditure Projections 2019-2028," 2020. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NationalHealthAccountsProjected.

Cooper, Zack, Stuart V Craig, Martin Gaynor, and John Van Reenen, "The price ain't right? Hospital prices and health spending on the privately insured," *The Quarterly Journal of Economics*, 2019, *134* (1), 51–107.

Cramton, Peter, Sean Ellermeyer, and Brett Katzman, "Designed to fail: The Medicare auction for durable medical equipment," *Economic Inquiry*, 2015, *53* (1), 469–485.

Curto, Vilsa, Liran Einav, Amy Finkelstein, Jonathan Levin, and Jay Bhattacharya, "Health care spending and utilization in public and private Medicare," *American Economic Journal: Applied Economics*, 2019, *11* (2), 302–32.

_ , _ , **Jonathan Levin, and Jay Bhattacharya**, "Can health insurance competition work? Evidence from Medicare Advantage," *Journal of Political Economy*, 2021, *129* (2), 570–606.

Cutler, David M and Ellen Meara, "The technology of birth: Is it worth it?," in "Forum for Health Economics & Policy," Vol. 3 De Gruyter 2000.

Decarolis, Francesco, "Medicare part D: Are insurers gaming the low income subsidy design?," *American Economic Review*, 2015, *105* (4), 1547–80.

_ **and Cristina Giorgiantonio**, "Public procurement of healthcare in Europe: The case of medical devices," *Rivista di Politica Economica*, 2015, *104*, 4.

Dranove, David, Christopher Ody, and Amanda Starc, "A dose of managed care: Controlling drug spending in Medicaid," *American Economic Journal: Applied Economics*, 2021, *13* (1), 170–97.

Duggan, Mark and Fiona M Scott Morton, "The distortionary effects of government procurement: Evidence from Medicaid prescription drug purchasing," *The Quarterly Journal of Economics*, 2006, *121* (1), 1–30.

_ **and Fiona Scott Morton**, "The effect of Medicare Part D on pharmaceutical prices and utilization," *American Economic Review*, 2010, *100* (1), 590–607.

_ **and Valerie Scimeca**, *State of the Union: Health*, Stanford Center on Poverty and Inequality, 2018.

GAO, "Review of the first year of CMS's Durable Medical Equipment Competitive Bidding Program's Round 1 Rebid," 2012.

_ , "CMS's Round 2 Durable Medical Equipment and National Mail-order Diabetes Testing Supplies Competitive Bidding Programs," 2016.

Grennan, Matthew and Ashley Swanson, "Transparency and negotiated prices: The value of information in hospital-supplier bargaining," *Journal of Political Economy*, 2020, *128* (4), 1234–1268.

Gruber, Jonathan, Phillip Levine, and Douglas Staiger, "Abortion legalization and child living circumstances: Who is the "marginal child"?," *The Quarterly Journal of Economics*, 1999, *114* (1), 263–291.

Hoerger, T, S Karon, S Bernard, K Tate, R Lindrooth, T Waters, and K Jewell, "Evaluation of Medicare's competitive bidding demonstration for DMEPOS: Final evaluation report," *Research Triangle Park NC: RTI International*, 2003.

Ji, Yunan, "The impact of competitive bidding in health care: The case of Medicare durable medical equipment," 2019.

Kaufmann, Christopher N, Ryoko Susukida, and Colin A Depp, "Sleep apnea, psychopathology, and mental health care," *Sleep Health*, 2017, *3* (4), 244–249.

MACPAC, "Report to the Congress: The evolution of managed care in Medicaid," 2011. https://www.macpac.gov/wp-content/uploads/2011/06/June-2011-Report-to-Congress-The-Evolution-of-Managed-Care-in-Medicaid.pdf.

Manning, Willard G, Joseph P Newhouse, Naihua Duan, Emmett B Keeler, and Arleen Leibowitz, "Health insurance and the demand for medical care: Evidence from a randomized experiment," *The American Economic Review*, 1987, pp. 251–277.

Marin, Jose M, Santiago J Carrizo, Eugenio Vicente, and Alvar GN Agusti, "Long-term cardiovascular outcomes in men with obstructive sleep apnoea-hypopnoea with or without treatment with continuous positive airway pressure: An observational study," *The Lancet*, 2005, *365* (9464), 1046–1053.

Martin, Kristi and Jeremy Sharp, "Old lessons for the new Medicare Part B drug payment model," 2018. https://www.commonwealthfund.org/blog/2018/new-medicare-part-b-drug-payment-model.

McCall, William V, Ruth M Benca, Meredith E Rumble, Doug Case, Peter B Rosenquist, and Andrew D Krystal, "Prevalence of obstructive sleep apnea in suicidal patients with major depressive disorder," *Journal of Psychiatric Research*, 2019, *116*, 147–150.

Merlob, Brian, Charles R Plott, and Yuanjun Zhang, "The CMS auction: Experimental studies of a median-bid procurement auction with nonbinding bids," *The Quarterly Journal of Economics*, 2012, *127* (2), 793–827.

Morgenthaler, Timothy I, Sheldon Kapen, Teofilo Lee-Chiong, Cathy Alessi, Brian Boehlecke, Terry Brown, Jack Coleman, Leah Friedman, Vishesh Kapur, Judith Owens, Jeffrey Pancer, and Todd Swick, "Practice parameters for the medical therapy of obstructive sleep apnea," *Sleep*, 2006, *29* (8), 1031–1035.

Newman, David, Eric Barrette, and Katharine McGraves-Lloyd, "Medicare competitive bidding program realized price savings for durable medical equipment purchases," *Health Affairs*, 2017, *36* (8), 1367–1375.

NICE, "Continuous positive airway pressure for the treatment of obstructive sleep apnoea/hypopnoea syndrome: Technology appraisal guidance," 2008. https://www.nice.org.uk/guidance/ta139/chapter/4-Evidence-and-interpretation.

OIG, "Round 2 Competitive Bidding for CPAP/RAD: Disrupted Access Unlikely," 2017. https://www.oig.hhs.gov/oei/reports/oei-01-15-00040.asp.

Patil, Susheel P, Indu A Ayappa, Sean M Caples, R John Kimoff, Sanjay R Patel, and Christopher G Harrod, "Treatment of adult obstructive sleep apnea with positive airway pressure: An American Academy of Sleep Medicine clinical practice guideline," *Journal of Clinical Sleep Medicine*, 2019, *15* (2), 335–343.

Ramar, Kannan, Leslie C Dort, Sheri G Katz, Christopher J Lettieri, Christopher G Harrod, Sherene M Thomas, and Ronald D Chervin, "Clinical practice guideline for the treatment of obstructive sleep apnea and snoring with oral appliance therapy: An update for 2015," *Journal of Clinical Sleep Medicine*, 2015, *11* (7), 773–827.

Senaratna, Chamara V, Jennifer L Perret, Caroline J Lodge, Adrian J Lowe, Brittany E Campbell, Melanie C Matheson, Garun S Hamilton, and Shyamali C Dharmage, "Prevalence of obstructive sleep apnea in the general population: A systematic review," *Sleep Medicine Reviews*, 2017, *34*, 70–81.

Sun, Liyang and Sarah Abraham, "Estimating dynamic treatment effects in event studies with heterogeneous treatment effects," *Journal of Econometrics*, 2021, *225* (2), 175–199.

Town, Robert and Su Liu, "The welfare impact of Medicare HMOs," *RAND Journal of Economics*, 2003, pp. 719–736.

Appendix

Table A1: Medicare spending by category

	2010 (Before CBP)				2015 (Last year of our data)			
	# Patients (million)	Medicare Payment (billion)	Patient OOPC (billion)	Payment per Capita (thousand)	# Patients (million)	Medicare Payment (billion)	Patient OOPC (billion)	Payment per Capita (thousand)
Part A/B	**32.9**	**342.1**	**57.9**	**12.2**	**34.5**	**350.4**	**60.0**	**11.9**
Part A	**7.4**	**173.5**	**14.2**	**25.3**	**7.0**	**163.3**	**14.4**	**25.2**
- Inpatient Hospital	6.9	132.7	10.4	20.8	6.6	129.8	10.5	21.2
- Skilled Nursing Facility	1.5	22.2	3.8	17.6	1.5	22.5	3.9	17.4
- Home Health Agency[42]	1.7	8.0	0.0	4.6				
- Hospice	0.9	10.7	0.0	11.9	1.0	11.0	0.0	11.1
Part B	**32.7**	**168.6**	**43.7**	**6.5**	**34.3**	**187.1**	**45.7**	**6.8**
- Physician	32.4	92.7	25.9	3.7	33.9	95.8	26.0	3.6
- Outpatient	24.1	51.4	14.5	2.7	25.8	64.6	17.3	3.2
- Home Health Agency	1.9	13.2	0.0	7.0	3.5	18.5	0.0	5.2
- DME	11.2	11.3	3.3	1.3	10.4	8.2	2.3	1.0
- DME (in CBP)	6.8	5.8	1.7	1.1	5.7	3.3	1.0	0.7
- DME (not in CBP)	7.9	5.5	1.5	0.9	7.3	5.0	1.4	0.9
Part D	**17.5**	**35.0**	**8.9**	**2.5**	**23.3**	**57.0**	**9.5**	**2.9**
Part A/B/D Total	**33.1**	**377.1**	**66.8**	**13.4**	**34.8**	**407.4**	**69.5**	**13.7**

Notes: This table shows the Medicare payments calculated based on 20% Medicare FFS claim data. We multiplied the total by 5 to get estimates for total number of patients and spending (normalized to 2015 dollar value based on CPI.[43] Medicare beneficiaries are restricted to people who have FFS plan. Medicare payments in Part A and B only include the total amount paid by Medicare, excluding cost-sharing paid by beneficiaries or other supplemental insurance plans. Part D payment is calculated based on the amount paid by the Part D plan (among beneficiaries who have an FFS Medicare plan). Patient out-of-pocket cost (OOPC) includes deductible, coinsurance, and Part D coverage gap, paid by beneficiaries themselves or their supplemental insurance. Payment per capital is calculated based on total cost (both Medicare and patient payment) and number of patients for each category.

[42] Home Health Agency claims are classified into items covered by Medicare Part A or Part B, but always shown as Part B in our data after 2013. According to CMS Program Statistics, the home health agency payment in 2015 has $6.9 billion covered by Part A and $11.3 billion covered by Part B (CMS, 2015).

[43] https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator/consumer-price-index-1913-

Table A2: Top 20 DME products and CBP lead items in 2010

	HCPCS	Description (* Lead)	CBP Round	Price			Payment (million)	
				2010 FFS	2015 FFS	2015 SPA	2010	2015
1	E1390-RR	Oxygen concentrator*	R1, R2, R1RC	189.0	180.9	93.3	1977.9	1208.7
2	A4253-NU-KL	Diabetic test strips, mail	R1, NMO	35.3	34.4	10.4	995.9	148.3
3	A4253-NU	Diabetic test strips		41.0	10.4		551.2	166.1
4	K0823-NU	Power wheelchair, new	R1[44]	3964.3			540.3	
5	E0260-RR	Hospital bed*	R1, R2, R1RC	138.1	134.4	70.6	234.8	88.1
6	E0601-RR	CPAP device*	R1, R2, R1RC	105.2	102.4	47.0	209.9	202.3
7	B4035	Enteral feeding supply kit*	R1, R2, R1RC	12.3	12.0	6.0	171.1	73.2
8	E0431-RR	Portable oxygen system	R1, R2, R1RC	31.3	30.4	19.4	160.8	91.3
9	A5500	Diabetic shoe		72.6	70.6		131.5	75.9
10	E2402-RR	NPWT pump*	R2, R1RC	1694.5	1648.3	817.9	131.5	97.6
11	A4259-KL	Lancets, mail	R1, NMO	11.5	11.1	1.6	125.5	9.6
12	A7034-NU	Nasal application device	R1, R2, R1RC	116.2	113.0	62.8	115.9	128.3
13	B4154	Enteral formula, metabolic	R1, R2, R1RC	1.3	1.3	0.7	112.2	37.8
14	E0470-RR	Respiratory assist device	R1, R2, R1RC	238.2	231.8	117.0	99.7	84.7
15	A7030-NU	CPAP full face mask	R1, R2, R1RC	186.3	181.2	101.9	98.8	150.5
16	B4150	Enteral formula, complete	R1, R2, R1RC	0.7	0.7	0.4	92.9	39.2
17	A5513	Diabetic shoe, customized		44.2	43.0		91.2	54.1
18	E0143-NU	Walker*	R1, R2, R1RC	114.9	111.7	53.7	91.1	52.1
19	A5512	Diabetic shoe, direct formed		29.6	28.8		87.9	50.2
20	E0748-NU	Osteogenesis stimulator		4463.7	4342.1		86.5	92.5
21	E0277-RR	Pressure-reducing mattress*	R1, R2, R1RC	681.8	663.2	239.3	81.8	16.3
33	E0570-RR	Nebulizer*	R1RC	18.4	17.9	10.2	55.0	42.3
36	E0163-NU	Commode chair*	R1RC	122.4	119.1	63.8	47.1	26.6
43	E0784-RR	External infusion pump*	R1RC	478.3	465.2	380.2	39.5	51.1
61	E0630-RR	Patient lift*	R1RC	111.5	108.5	63.3	27.5	21.4
63	A4595	TENS supplies*	R1RC	32.8	32.0	15.2	26.9	9.6
247	K0823-RR	Power wheelchair, rent*	R1, R2, R1RC	396.4	578.5	297.6	2.0	56.2

Notes: This table shows the price and payment in 2010 for the top 20 DME products (based on 2010 payment) and lead items in the CBP (labelled with *). Products are identified based on HCPCS code with key modifier, ie. "NU", "RR", "UE", "MS", "KL", "BA", "KC". DME products included in the CBP in different rounds, including Round 1 (R1), Round 2 (R2), Round 1 Recompete (R1RC), or National Mail Order (NMO). Prices are the average across states or competitive bidding areas. Payments are calculated based on 20% Medicare FFS claim data. We multiplied the total by 5 to get estimates for total spending. Payments are Medicare allowed amount, which includes both total amount paid by Medicare and cost-sharing paid by beneficiaries or other supplemental insurance plans. All prices and payments are normalized to 2015 dollar value based on CPI (same as in Table A1).

[44] Purchasing option was included in Round 1, but only rental option in later rounds.

Table A3: The Impact of Competitive Bidding on DME Price and Quantity - Lead Items/Categories

	(1) Log Price	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries	(5) Log Spending
Panel A: Lead Items					
1(Competitive Bidding)	-0.541***	-0.0976***	-0.0930***	-0.0757***	-0.638***
	(0.0190)	(0.0199)	(0.0198)	(0.0245)	(0.0158)
Mean	113.9	52.02	18.35	3.580	6834
N	250,917	250,917	250,917	207,263	250,917
Panel B: Category Level					
1(Competitive Bidding)	-0.481***	-0.0808***	-0.0933***	-0.0858***	-0.562***
	(0.0192)	(0.0158)	(0.0140)	(0.0199)	(0.0132)
Mean	70.61	296.8	23.18	3.820	8788
N	284,080	284,080	284,080	240,038	284,080

Notes: This table shows the effect of the CBP on the price and quantity of 12 lead items (Panel A) or product categories (Panel B) in the program. The observation is at product by CBSA by year-quarter level. Treatment indicator CBP_{pst} is turned on if the item p is included in the CBP in area s during quarter t. Since not all products within one category are added into the program in the same time, the treatment variable CBP_{cst} is not a binary variable, but the percentage of payment for category c in the area s in 2010 that is included in the CBP during quarter t. Outcome variables include price, quantity, number of (new) beneficiaries, and total spending, all denominated by one thousand Medicare FFS beneficiaries except price, and all in log terms (the mean of dependant variable shown is in level terms). All regressions include CBSA, product/category, year-quarter fixed effects and their double interactions. All regressions are weighted by the number of claims in each CBSA for each product/category in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A4: The Impact of Competitive Bidding on DME Price and Quantity - Lead Items/Categories, Population Weighted

	(1) Log Price	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries	(5) Log Spending
Panel A: Lead Items					
1(Competitive Bidding)	-0.550***	-0.195***	-0.187***	-0.117***	-0.745***
	(0.0198)	(0.0283)	(0.0301)	(0.0268)	(0.0208)
Mean	227.5	20.45	5.343	1.904	1519
N	257,431	257,431	257,431	209,832	257,431
Panel B: Category Level					
1(Competitive Bidding)	-0.499***	-0.169***	-0.172***	-0.146***	-0.668***
	(0.0197)	(0.0254)	(0.0260)	(0.0330)	(0.0244)
Mean	76.46	245.2	7.514	2.160	2460
N	286,964	286,964	286,964	241,594	286,964

Notes: This table shows the effect of the CBP on the price and quantity of 12 lead items (Panel A) or product categories (Panel B) in the program. The observation is at product by CBSA by year-quarter level. Treatment indicator CBP_{pst} is turned on if the item p is included in the CBP in area s during quarter t. Since not all products within one category are added into the program in the same time, the treatment variable CBP_{cst} is not a binary variable, but the percentage of payment for category c in the area s in 2010 that is included in the CBP during quarter t. Outcome variables include price, quantity, number of (new) beneficiaries, and total spending, all denominated by one thousand Medicare FFS beneficiaries except price, and all in log terms (the mean of dependant variable shown is in level terms). All regressions include CBSA, product/category, year-quarter fixed effects and their double interactions. All regressions are weighted by Medicare FFS population in each CBSA in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A5: Robustness Checks - Lead Items

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	R1/2 Only		R1/2 + Large Non-CBA		State FEs		Full Enrollment	
	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity
1(Competitive Bidding)	-0.463***	-0.174***	-0.492***	-0.149***	-0.541***	-0.0976***	-0.539***	-0.0869***
	(0.00961)	(0.0214)	(0.0140)	(0.0199)	(0.0190)	(0.0199)	(0.0192)	(0.0247)
Mean	103.3	42.67	105.7	43.09	113.9	52.02	113	41.48
N	36,371	36,371	50,103	50,103	250,917	250,917	214,981	214,981
Product*YQ FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Product*CBSA FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CBSA*YQ FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	No	No	No	No	Yes	Yes	No	No

Notes: This table presents robustness checks for Table A3 Panel A. Basic sample construction and variable definitions are the same. Columns 1-2 further restrict the sample to only round 1 and 2 competitive bidding areas. Columns 3-4 restrict the sample to large non-CBAs (>9000 Medicare FFS population in 2010), round 1 and 2 competitive bidding areas. Columns 5-6 add a state-by-post-CBP indicator which turns on when any place in the state has been included in the CBP to control for state-level policies, including Medicaid. Columns 7-8 restrict attention to Medicare FFS beneficiaries who are enrolled during our entire sample period. All regressions include CBSA, product, year-quarter fixed effects and their double interactions. All regressions are weighted by the number of claims in each CBSA for each product in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A6: The Impact of Competitive Bidding on DME Prices and Quantities, Lead Item/Category, by Wave

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	R1 + Non-CBA (R1 Items)		R1 + Non-CBA (R1 Items Before R1RC)		R2 + Non-CBA (R2 Items)		R1 + Non-CBA (R1RC Items)	
	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity
Panel A: Lead Items								
1(Competitive Bidding)	-0.484***	-0.122***	-0.403***	-0.106***	-0.626***	-0.0867***	-0.493***	-0.382***
	(0.0215)	(0.0308)	(0.0204)	(0.0323)	(0.00407)	(0.0172)	(0.0256)	(0.0391)
Mean	141.2	71.75	141.8	74.54	139	61.65	52.08	25.18
Observations	110,805	110,805	79,829	79,829	149,057	149,057	99,569	99,569
Panel B: Category Level								
1(Competitive Bidding)	-0.465***	-0.103***	-0.392***	-0.105***	-0.594***	-0.0377***	-0.350***	-0.344***
	(0.0146)	(0.0260)	(0.0152)	(0.0249)	(0.00465)	(0.0123)	(0.0207)	(0.0272)
Mean	86.68	302.3	87.33	306.9	81.67	357	29.69	60.17
Observations	115,563	115,563	83,005	83,005	156,226	156,226	124,793	124,793

Notes: This table replicates Columns 1-2 in Table A3 by CBP waves. The observation is at product (Panel A) or category (Panel B) by CBSA by year-quarter level. In panel B, we restrict to items within each category that are included in all waves. Sample used for Columns 1-2 includes Round 1 items in Round 1 CBAs and non-CBAs. Sample used for Columns 3-4 includes Round 1 items in Round 1 CBAs and non-CBAs, from 2009Q1 to 2013Q4. Sample used for Columns 5-6 includes Round 2 items in Round 2 CBAs and non-CBAs. Sample used for Columns 7-8 includes Round 1 Recompete items (not in Round 1) in Round 1 CBAs and non-CBAs. Outcome variables include price and quantity denominated by one thousand Medicare FFS beneficiaries (all in log terms, the mean of dependant variable shown is in level terms). All regressions include CBSA-by-product/category and year-quarter-by-product/category fixed effects. All regressions are weighted by the number of claims in each CBSA for each product/category in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A7: The Impact of Competitive Bidding on Prices and Quantities - 12 Lead Items Separately

	(1) CPAP	(2) Commode Chair	(3) Enteral Nutrient	(4) External Infusion	(5) Hospital Bed	(6) NPWT	(7) Nebulizer	(8) Oxygen Concentrator	(9) Patient Lift	(10) Support Surface	(11) TENS	(12) Walker
Panel A: Log Price												
1(Competitive Bidding)	-0.594***	-0.572***	-0.571***	-0.129***	-0.485***	-0.675***	-0.476***	-0.588***	-0.426***	-0.723***	-0.615***	-0.633***
	(0.0150)	(0.0249)	(0.0158)	(0.0120)	(0.00942)	(0.0113)	(0.0274)	(0.0151)	(0.0127)	(0.0292)	(0.0716)	(0.0146)
Mean	71.33	112.7	10.09	362	96.63	1372	13.97	156.8	85.91	458.7	29.64	93.89
N	26,762	20,841	19,699	14,694	25,708	16,943	26,839	26,979	19,431	10,990	22,171	26,457
Panel B: Log Quantity												
1(Competitive Bidding)	-0.0442***	-0.350*	-0.101***	-0.205	-0.136***	-0.0185	-0.144***	-0.0856***	-0.0765	-0.437***	-2.343***	-0.321***
	(0.0163)	(0.187)	(0.0262)	(0.140)	(0.0508)	(0.0264)	(0.0472)	(0.0166)	(0.0489)	(0.0593)	(0.147)	(0.0221)
Mean	20.47	2.579	96.68	0.932	12.43	0.672	25.47	65.73	2.221	0.962	5.164	5.470
N	26,762	20,841	19,699	14,694	25,708	16,943	26,839	26,979	19,431	10,990	22,171	26,457

Notes: This table presents the effect of the CBP on price and quantity for 12 lead items separately. The observation is at product by CBSA by year-quarter level. Outcome variables include price and quantity (denominated by one thousand Medicare FFS beneficiaries), all in log terms (the mean of dependant variable shown is in level terms). All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by the number FFS beneficiaries in each geographic area in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A8: The Impact of Competitive Bidding on CPAP Prices and Quantities, by Wave

	(1)	(2)	(3)	(4)	(5)	(6)
	R1 + Non-CBA		R1 + Non-CBA (Before R1RC)		R2 + Non-CBA	
	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity
1(Competitive Bidding)	-0.499***	-0.0872***	-0.421***	-0.105***	-0.639***	-0.0307*
	(0.0270)	(0.0322)	(0.0190)	(0.0328)	(0.00824)	(0.0183)
Mean	71.33	20.45	71.33	20.45	71.33	20.45
Observations	23,962	23,962	17,094	17,094	26,510	26,510

Notes: This table replicates Columns 1-2 in Table 2 by CBP waves. The observation is at CBSA by year-quarter level. Sample used for Columns 1-2 includes Round 1 CBAs and non-CBAs. Sample used for Columns 3-4 includes Round 1 CBAs and non-CBAs, from 2009Q1 to 2013Q4. Sample used for Columns 5-6 includes Round 2 CBAs and non-CBAs. Outcome variables are price and quantity denominated by one thousand Medicare FFS beneficiaries except price (all in log terms, the mean of dependant variable shown is in level terms). All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A9: The Impact of Competitive Bidding on CPAP Market Structure, by Wave

	(1)	(2)	(3)	(4)	(5)	(6)
	R1 + Non-CBA		R1 + Non-CBA (Before R1RC)		R2 + Non-CBA	
	HHI	Suppliers	HHI	Suppliers	HHI	Suppliers
1(Competitive Bidding)	0.0248***	-6.096***	0.0314***	-6.502***	0.0402***	-5.420***
	(0.00317)	(0.611)	(0.00343)	(0.685)	(0.00483)	(0.480)
Mean	0.149	16.17	0.149	16.17	0.149	16.17
Observations	23,962	23,962	17,094	17,094	26,510	26,510

Notes: This table replicates shows the effect of CBP on the market structure for CPAP by CBP waves. The observation is at CBSA by year-quarter level. Sample used for Columns 1-2 includes Round 1 CBAs and non-CBAs. Sample used for Columns 3-4 includes Round 1 CBAs and non-CBAs, from 2009Q1 to 2013Q4. Sample used for Columns 5-6 includes Round 2 CBAs and non-CBAs. Outcome variables are HHI and number of suppliers (identified using NPI) with at least 1% market share. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A10: The Impact of Competitive Bidding on DME Market Structure, Lead Item/Category, by Wave

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	R1 + Non-CBA (R1 Items)		R1 + Non-CBA (R1 Items Before R1RC)		R2 + Non-CBA (R2 Items)		R1 + Non-CBA (R1RC Items)	
	HHI	Suppliers	HHI	Suppliers	HHI	Suppliers	HHI	Suppliers
Panel A: Lead Items								
1(Competitive Bidding)	0.0186***	-3.731***	0.0205***	-3.139***	0.0214***	-3.939***	0.0194***	-3.731***
	(0.00363)	(0.926)	(0.00320)	(0.777)	(0.00295)	(0.353)	(0.00289)	(0.789)
Mean	0.211	12.36	0.203	12.69	0.165	15.08	0.220	12.47
Observations	111,805	111,805	79,829	79,829	149,057	149,057	217,646	217,646
Panel B: Category Level								
1(Competitive Bidding)	0.0204***	-4.026***	0.0219***	-3.436***	0.0252***	-4.240***	0.0191***	-2.542***
	(0.00311)	(1.014)	(0.00265)	(0.889)	(0.00259)	(0.337)	(0.00376)	(0.678)
Mean	0.201	12.74	0.195	13.02	0.158	15.37	0.230	13.46
Observations	115,563	115,563	83,005	83,005	156,226	156,226	124,793	124,793

Notes: This table replicates Columns 1-2 in Table A3 by CBP waves. The observation is at product (Panel A) or category (Panel B) by CBSA by year-quarter level. In panel B, we restrict to items within each category that are included in all waves. Sample used for Columns 1-2 includes Round 1 items in Round 1 CBAs and non-CBAs. Sample used for Columns 3-4 includes Round 1 items in Round 1 CBAs and non-CBAs, from 2009Q1 to 2013Q4. Sample used for Columns 5-6 includes Round 2 items in Round 2 CBAs and non-CBAs. Sample used for Columns 7-8 includes Round 1 Recompete items (not in Round 1) in Round 1 CBAs and non-CBAs. Outcome variables are HHI and number of suppliers (identified using NPI) with at least 1% market share. All regressions include CBSA-by-product/category and year-quarter-by-product/category fixed effects. All regressions are weighted by the number of claims in each CBSA for each product/category in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A11: The Impact of Competitive Bidding on CPAP Price, Quantity, and Market Structure, Spatial Spillover

	(1)	(2)	(3)	(4)
	Log Price	Log Quantity	HHI	Suppliers
Panel A: Drop Adjacent Non-CBAs				
1(Competitive Bidding)	-0.575***	-0.0508***	0.0377***	-5.535***
	(0.0185)	(0.0176)	(0.00417)	(0.436)
Mean	69.21	19.90	0.132	17.44
Observations	16,475	16,475	16,475	16,475
Panel B: Only Adjacent Non-CBAs as Controls				
1(Competitive Bidding)	-0.572***	-0.0478***	0.0393***	-5.543***
	(0.0185)	(0.0176)	(0.00416)	(0.440)
Mean	68.96	19.55	0.123	17.87
Observations	13,339	13,339	13,339	13,339
Panel C: Only Non-CBAs, Placebo Effect for Adjacent Non-CBAs				
1(Competitive Bidding)	-0.00184**	-0.0127	-0.00215	0.0786
	(0.000749)	(0.0160)	(0.00428)	(0.172)
Mean	80.69	23.56	0.242	10.01
Observations	23,710	23,710	23,710	23,710
Panel C - Panel A	0.573	0.0381	-0.0399	5.614
p-value	0.000	0.0774	0.000	0.000

Notes: This table replicates test the spatial spillover effect of CBP on price, quantity, and market structure for CPAP. The observation is at CBSA by year-quarter level. Sample used in Panel A includes Round 1 CBAs, Round 2 CBAs, and non-CBAs not adjacent to any CBAs. Sample used for Panel B includes Round 1 CBAs, Round 2 CBAs, and non-CBAs adjacent to at least one CBAs. Sample used for Panel C includes only non-CBAs adjacent to at least one CBAs, and the treatment indicator is turned on when their adjacent CBAs started CBP. Outcome variables are log price, log quantity denominated by one thousand Medicare FFS beneficiaries, HHI, and number of suppliers (identified using NPI) with at least 1% market share. The mean of dependant variables are shown in level terms. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A12: The Impact of Competitive Bidding on DME Price, Quantity, and Market Structure, Spatial Spillover

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Lead Items				Category Level			
	Log Price	Log Quantity	HHI	Suppliers	Log Price	Log Quantity	HHI	Suppliers
Panel A: Drop Adjacent Non-CBAs								
1(Competitive Bidding)	-0.523***	-0.113***	0.0314***	-2.789***	-0.463***	-0.0993***	0.0334***	-2.926***
	(0.0184)	(0.0212)	(0.00277)	(0.275)	(0.0191)	(0.0165)	(0.00226)	(0.307)
Mean	110.2	49.16	0.140	17.25	68.16	311.1	0.133	17.27
Observations	153,260	153,260	153,260	153,260	166,971	166,971	166,971	166,971
Panel B: Only Adjacent Non-CBAs as Controls								
1(Competitive Bidding)	-0.520***	-0.120***	0.0309***	-2.837***	-0.456***	-0.103***	0.0317***	-2.906***
	(0.0180)	(0.0203)	(0.00279)	(0.274)	(0.0181)	(0.0164)	(0.00224)	(0.307)
Mean	109.9	48.10	0.133	17.61	67.93	312	0.126	17.69
Observations	134,028	134,028	134,028	134,028	143,232	143,232	143,232	143,232
Panel C: Only Adjacent Non-CBAs as Controls, Placebo Effect								
1(Competitive Bidding)	-0.00318***	0.00337	0.000830	0.106	-0.00869	-0.00230	0.000466	0.0128
	(0.000582)	(0.0103)	(0.00302)	(0.120)	(0.00659)	(0.0102)	(0.00252)	(0.110)
Mean	127.7	64.30	0.248	10.47	78.98	253.7	0.232	11.05
Observations	214,546	214,546	214,546	214,546	237,257	237,257	237,257	237,257

Notes: This table replicates test the spatial spillover effect of CBP on price, quantity, and market structure for lead items (Column 1-4) and categories (Column 5-8). The observation is at product/category by CBSA by year-quarter level. For each category, we restrict to items that are included in all waves. Sample used in Panel A includes Round 1 CBAs, Round 2 CBAs, and non-CBAs not adjacent to any CBAs. Sample used for Panel B includes Round 1 CBAs, Round 2 CBAs, and non-CBAs adjacent to at least one CBAs. Sample used for Panel C includes only non-CBAs adjacent to at least one CBAs, and the treatment indicator is turned on when their adjacent CBAs started CBP. Outcome variables are log price, log quantity denominated by one thousand Medicare FFS beneficiaries, HHI, and number of suppliers (identified using NPI) with at least 1% market share. The mean of dependant variables are shown in level terms.All regressions include CBSA-by-product/category and year-quarter-by-product/category fixed effects. All regressions are weighted by the number of claims in each CBSA for each product/category in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A13: Obstructive Sleep Apnea (OSA)

	(1) Log Diagnosis	(2) Log MCR A/B Spending	(3) Log MCR DME Spending
1(Competitive Bidding)	0.0415**	-0.0343***	-0.349***
	(0.0172)	(0.00855)	(0.0148)
Mean	3.870	4070	285.6
N	26,127	26,950	26,831
Year-Quarter FE	Yes	Yes	Yes
CBSA FE	Yes	Yes	Yes

Notes: This table presents the changes in the incidence of obstructive sleep apnea after the introduction of the CBP, as well as the Medicare spending of the diagnosed OSA patients. The observation is at CBSA by year-quarter level. Outcome variables are the number of patients newly diagnosed with OSA (primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33 in inpatient, outpatient or physician carrier table) among one thousand Medicare FFS population, average Medicare Part A/B spending (non-DME), and DME spending among patients diagnosed with OSA in the current or previous 3 quarters. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A14: The Impact of Competitive Bidding on Obstrutive Sleep Apnea (OSA) Oral Device

	(1) Log Price	(2) Log Quantity	(3) Quantity
1(Competitive Bidding)	0.0105	0.325***	0.00669
	(0.0108)	(0.0599)	(0.00545)
Mean	1418	0.114	0.0568
Observations	2,324	2,324	19,200

Notes: This table replicates shows the effect of CBP on the price and quantity for one substitute of CPAP – the oral appliances for treating OSA (HCPCS code E0486). The observation is at CBSA by year-quarter level. Outcome variables are log price, log quantity denominated by one thousand Medicare FFS beneficiaries, and quantity denominated by one thousand Medicare FFS beneficiaries in level terms. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A15: The Impact of Competitive Bidding on CPAP Oral/Nasal Mask

	(1)	(2)	(3)	(4)
	Direct Effect		Spillover Effect	
	Log Price	Log Quantity	Log Price	Log Quantity
1(Competitive Bidding)	-0.388***	-0.156***	0.00379	-0.167
	(0.00977)	(0.0536)	(0.00266)	(0.103)
Mean	177.8	0.147	193.5	0.251
Observations	7,484	7,484	3,956	3,956

Notes: This table replicates shows the effect of CBP on the price and quantity for one accessory of CPAP – the Combination Oral/Nasal Mask used with CPAP device (HCPCS code A7027). The observation is at CBSA by year-quarter level. Outcome variables are log price and log quantity denominated by one thousand Medicare FFS beneficiaries. Sample used in Columns 1-2 includes all CBSAs, with treatment indicator turned on when CBP actually started to include the item – R2 and R1RC. Sample used in Columns 3-4 includes R1 CBAs and non-CBAs in 2009Q1-2013Q4, with treatment indicator turned on when CBP started to include CPAP device in R1. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A16: The Impact of Competitive Bidding on CPAP Quantities by Subgroups, Duals Only

	(1) No SA vs. SA	(2) No OSA vs. OSA	(3) Below vs. Above Median Propensity
1(Competitive Bidding) * No SA/No OSA/Below Median	-0.254***	-0.274***	-0.230***
	(0.0492)	(0.0521)	(0.0680)
1(Competitive Bidding) * SA/OSA/Above Median	-0.132***	-0.106***	-0.140***
	(0.0296)	(0.0281)	(0.0356)
Mean of Dep Var (No SA/No OSA/Below Median)	4.339	5.446	4.692
Mean of Dep Var (SA/OSA/Above Median)	151.2	148.5	34.28
Observations	33,036	34,109	23,396

Notes: This table replicates Columns 3-4 in Table 3 for duals only. The observation is at CBSA by year-quarter by subgroups level. Subgroups are defined as whether diagnosed with Sleep Apnea (SA, primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in an inpatient, outpatient, or physician carrier table) in the previous year, whether diagnosed with Obstructive Sleep Apnea (OSA, primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) in the previous year, and CPAP propensity above vs below median. OSA/SA diagnosis and CPAP propensity samples are restricted to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis (sample period starts from 2009Q4). CPAP propensity is estimated using OSA/SA diagnosis and demographic variables in 2010 (details in Section 4.3). Main variables of interests are the CBP indicator interacting with group dummies. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A17: The Impact of Competitive Bidding on CPAP Demand By Medigap Share

	(1) Below Median	(2) Above Median	(3) Bottom Tercile	(4) Middle Tercile	(5) Top Tercile
			Log Quantity		
Panel A: OLS					
1(Competitive Bidding)*Nondual	0.157***	0.0952***	0.189***	0.0874***	0.0935***
	(0.0335)	(0.0266)	(0.0389)	(0.0318)	(0.0354)
1(Competitive Bidding)	-0.189***	-0.107***	-0.228***	-0.104***	-0.0879***
	(0.0414)	(0.0273)	(0.0480)	(0.0327)	(0.0326)
Panel B: IV					
OOPC	-0.0215***	-0.0134***	-0.0262***	-0.0129***	-0.0120**
	(0.00485)	(0.00372)	(0.00581)	(0.00462)	(0.00467)
1(Competitive Bidding)	-0.189***	-0.107***	-0.228***	-0.104***	-0.0879***
	(0.0414)	(0.0273)	(0.0480)	(0.0327)	(0.0326)
Elasiticity	-0.341	-0.211	-0.414	-0.199	-0.194
Mean of OOPC (Nondual)	15.81	15.69	15.85	15.44	16.08
Medigap Share	25.54	37.58	23.19	32.67	41.29
F-Stats	812.4	873.4	528.2	631.6	1,004
N	24,988	25,250	17,154	16,278	16,806

Notes: This table replicates Table 4 column 2 presenting demand elasticity estimation within subgroups of CBSAs based on share of traditional Medicare beneficiaries with Medigap coverage. The observation is at CBSA by year-quarter by dual/nondual level. Outcome variable is log quantity (denominated by one thousand Medicare FFS beneficiaries). Panel A shows the OLS result, while Panel B shows the IV result using 1(Competitive Bidding)*Nondual as the instrument for OOPC. Medigap share in each CBSA is calculated using state level Medigap share reported in AHIP (2017) based on 2015 National Association of Insurance Commissioners (NAIC) data. For CBSAs across state borders, average Medigap share is calculated using 2015 FFS Medicare population as weight. Columns 1-2 cut the sample into CBSAs above or below median Medigap share, and columns 3-5 cut the sample into tercile. All regressions include CBSAs fixed effects, year-quarter fixed effects, and their interactions with dummy variable for dual eligible status. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. F-statistics is estimated using Kleibergen-Paap rk Wald F test. Significance levels: *10%, **5%, ***1%.

Table A18: Robustness Checks - CPAP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	R1/2 Only		R1/2 + Large Non-CBA		State FEs		Full Enrollment	
	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity	Log Price	Log Quantity
1(Competitive Bidding)	-0.433***	-0.0837***	-0.469***	-0.0833***	-0.397***	-0.0563***	-0.429***	-0.0351**
	(0.0130)	(0.0250)	(0.0189)	(0.0196)	(0.0181)	(0.0146)	(0.0156)	(0.0161)
Mean	65.42	18.52	66.93	18.86	71.33	20.47	71.07	20.01
N	3,052	3,052	4,228	4,228	26,762	26,762	26,325	26,325
CBSA FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
YQ FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State-Post FE	No	No	No	No	Yes	Yes	No	No

Notes: This table presents robustness checks for Table 2. Basic sample construction and variable definitions are the same. Columns 1-2 further restrict the sample to only round 1 and 2 competitive bidding areas. Columns 3-4 restrict the sample to large non-CBAs (>9000 Medicare FFS population in 2010), round 1 and 2 competitive bidding areas. Columns 5-6 add a state-by-post-CBP indicator which turns on when any place in the state has been included in the CBP to control for state-level policies, including Medicaid. Columns 7-8 restrict attention to Medicare FFS beneficiaries who are enrolled during our entire sample period. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by the number FFS beneficiaries in each geographic area in 2010. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A19: The Impact of Competitive Bidding on CPAP Demand - State FEs

	(1) OOPC	(2) Log Quantity	(3) Log Beneficaries	(4) Log New Beneficiaries
Panel A: OLS				
1(Competitive Bidding)*Nondual	-7.183***	0.146***	0.132***	0.132***
	(0.177)	(0.0247)	(0.0235)	(0.0250)
1(Competitive Bidding)	0	-0.171***	-0.157***	-0.161***
		(0.0261)	(0.0242)	(0.0234)
Panel B: IV				
OOPC		-0.0203***	-0.0184***	-0.0185***
		(0.00348)	(0.00329)	(0.00338)
1(Competitive Bidding)		-0.171***	-0.157***	-0.161***
		(0.0261)	(0.0242)	(0.0234)
Elasticity		-0.320	-0.290	-0.291
Mean of OOPC (Nondual)	15.76	15.76	15.76	15.77
F-Stats		1,706	1,706	1,669
N	50,477	50,477	50,477	41,656
State-Dual-Post FE	Yes	Yes	Yes	Yes

Notes: This table presents robustness checks for Table 4, with state-by-dual-by-post-CBP fixed effects. The observation is at CBSA by year-quarter by dual/nondual level. Outcome variables include out-of-pocket cost (OOPC, defined as 20% of price for non-dual and 0 for dual), quantity and number of (new) beneficiaries, all denominated by one thousand Medicare FFS beneficiaries, and all in log terms except OOPC. Panel A shows the OLS result, while Panel B shows the IV result using 1(Competitive Bidding)*Nondual as the instrument for OOPC. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for dual eligible status. Also included is a state-by-dual-by-post-CBP indicator which turns on for dual and non-dual group separately when any place in the state has been included in the CBP to control for state-level policies, including Medicaid. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. F-statistics is estimated using Kleibergen-Paap rk Wald F test. Significance levels: *10%, **5%, ***1%.

Table A20: The Impact of Competitive Bidding on CPAP Demand - Full Medicaid Payment

	(1) OOPC	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries
Panel A: OLS				
1(Competitive Bidding)*Nondual	-7.815***	0.113**	0.0976**	0.101**
	(0.220)	(0.0461)	(0.0378)	(0.0391)
1(Competitive Bidding)	-0	-0.164***	-0.148***	-0.131***
		(0.0521)	(0.0394)	(0.0401)
Panel B: IV				
OOPC		-0.0144**	-0.0125***	-0.0129***
		(0.00585)	(0.00480)	(0.00487)
1(Competitive Bidding)		-0.164***	-0.148***	-0.131***
		(0.0521)	(0.0394)	(0.0401)
Elasticity		-0.233	-0.201	-0.209
Mean of OOPC (Nondual)	16.11	16.11	16.11	16.13
F-Stats		1,265	1,265	1,203
N	20,493	20,493	20,493	16,436

Notes: This table presents robustness checks for Table 4, restricted to states setting the Medicaid rate the same as the Medicare rate or paying dual eligible patients full Medicare OOPC. The observation is at CBSA by year-quarter by dual/nondual level. Outcome variables include out-of-pocket cost (OOPC, defined as 20% of price for non-dual and 0 for dual), quantity and number of (new) beneficiaries, all denominated by one thousand Medicare FFS beneficiaries, and all in log terms except OOPC. Panel A shows the OLS result, while Panel B shows the IV result using 1(Competitive Bidding)*Nondual as the instrument for OOPC. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for dual eligible status. All regressions are weighted by Medicare FFS population in 2010. Standard errors are clustered at CBSA level. F-statistics is estimated using Kleibergen-Paap rk Wald F test. Significance levels: *10%, **5%, ***1%.

Table A21: The Impact of Competitive Bidding on the Demand of 12 Lead Items

	(1) OOPC	(2) Log Quantity	(3) Log Beneficiaries	(4) Log New Beneficiaries
Panel A: OLS				
1(Competitive Bidding)*Nondual	-10.80***	0.0328**	0.0290**	0.0735***
	(0.727)	(0.0150)	(0.0132)	(0.0218)
1(Competitive Bidding)	0	-0.112***	-0.105***	-0.114***
		(0.0244)	(0.0227)	(0.0226)
Panel B: IV				
OOPC		-0.00304**	-0.00269**	-0.00695***
		(0.00141)	(0.00124)	(0.00193)
1(Competitive Bidding)		-0.112***	-0.105***	-0.114***
		(0.0244)	(0.0227)	(0.0226)
Elasticity		-0.0753	-0.0666	-0.172
Mean of OOPC (Nondual)	24.79	24.79	24.79	24.77
F-Stats		220,7	220.7	198.9
N	433,409	433,409	433,409	290,542

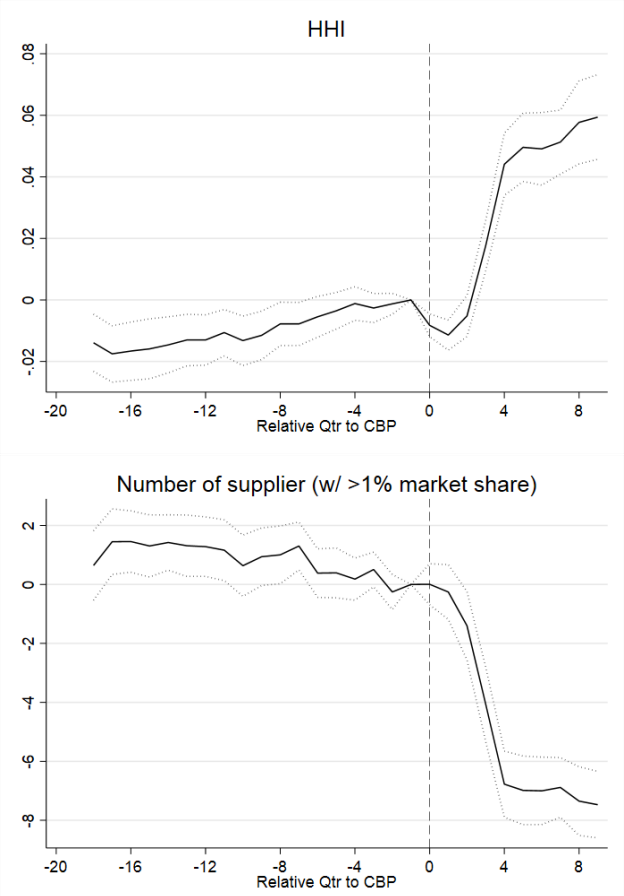
Notes: This table presents the results of regression analysis for the effect of the CBP on price and quantity of 12 lead items among duals and non-duals. The observation is at product by CBSA by year-quarter by dual/nondual level. Outcome variables include out-of-pocket cost (OOPC, defined as 20% of price for non-dual and 0 for dual), quantity and number of (new) beneficiaries, all denominated by one thousand Medicare FFS beneficiaries, and all in log terms except OOPC. Panel A shows the OLS result, while Panel B shows the IV result using 1(Competitive Bidding)*Nondual as the instrument for OOPC. All regressions include product by CBSA fixed effects, year-quarter by product fixed effects, CBSA by year-quarter fixed effects, and their interactions with a dummy variable for dual eligible status. All regressions are weighted by the number of claims in each CBSA for each product in 2010. F-statistics is estimated using Kleibergen-Paap rk Wald F test. Standard errors are clustered at CBSA level. Significance levels: *10%, **5%, ***1%.

Table A22: Predict CPAP

	CPAP	
	Beta	SE
Obstructive Sleep Apnea (OSA)	0.803***	(0.00939)
Sleep Apnea (SA)	4.353***	(0.0101)
Male	0.147***	(0.00532)
Age group (65-69 as baseline)		
<65	-0.0512***	(0.0179)
70-74	-0.189***	(0.00770)
75-79	-0.325***	(0.00864)
80-84	-0.528***	(0.0104)
85-89	-0.891***	(0.0156)
90+	-1.656***	(0.0341)
Dual	-0.163***	(0.00742)
SSDI	-0.151***	(0.0177)
Observations	23,927,627	
R2_p	0.413	

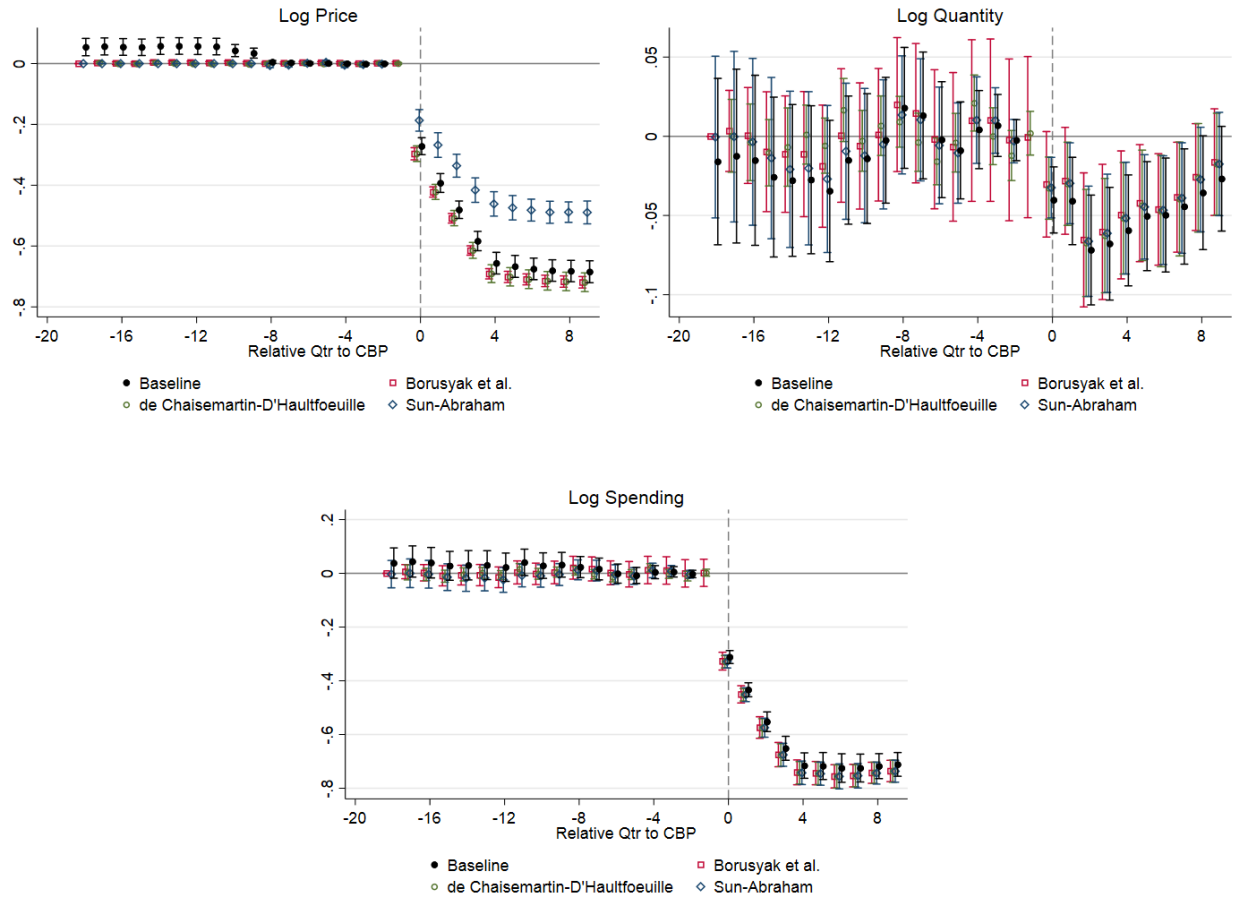
Notes: This table presents the results of predicting CPAP utilization using beneficiaries' demographic characteristics and diagnosis. The observation is at beneficiary level, restricting to beneficiaries with continuous Part B non-HMO Medicare enrollment in the current quarter and three previous quarters. To avoid potential changes after the CBP, only the pre-CBP year 2010 is used for estimation. OSA diagnosis is identified as primary diagnosis ICD-9 code 327.23 or ICD-10 code G47.33 in an inpatient, outpatient or physician carrier table. SA diagnosis is identified as all codes under ICD-9 code 327.2 or ICD-10 code G47.3. Significance levels: *10%, **5%, ***1%.

Figure A1: The Impact of Competitive Bidding on CPAP Supplier and Market Concentration



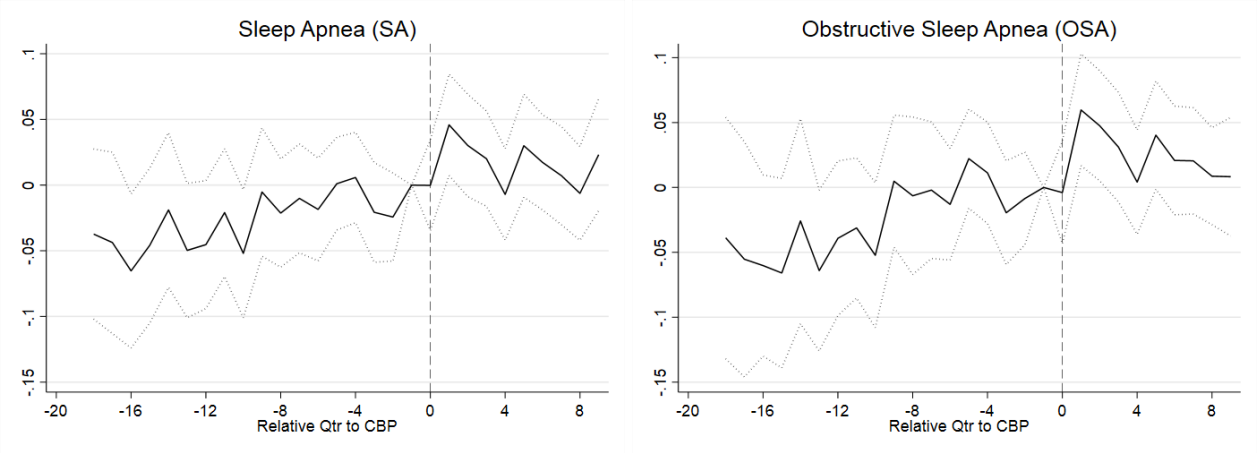
Notes: These figures replicate Figure 1 for CPAP suppliers and market structure. The observation is at CBSA by year-quarter level. Outcome variables include HHI (calculated based on total payments for CPAP) and number of suppliers (with more than 1% market share based on CPAP payment), all based on supplier NPIs. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010. The solid line is point estimates for the effect of quarter pre/post-CBP and the dotted lines are the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level.

Figure A2: The Impact of Competitive Bidding on CPAP Prices and Quantities, New Estimators



Notes: These figures replicate Figure 1 using different difference-in-difference estimations, including baseline two-way fixed effect model, Borusyak et al. (2021), De Chaisemartin and d'Haultfoeuille (2020), and Sun and Abraham (2021). The observation is at CBSA by year-quarter level. Outcome variables include price, quantity (total number of product/service counts per 1000 Medicare FFS recipients), and spending (total Medicare allowed amount per 1000 Medicare FFS recipients), all in log terms. The solid lines are point estimates for the effect of quarter pre/post-CBP and the dotted lines are the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at CBSA level. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010.

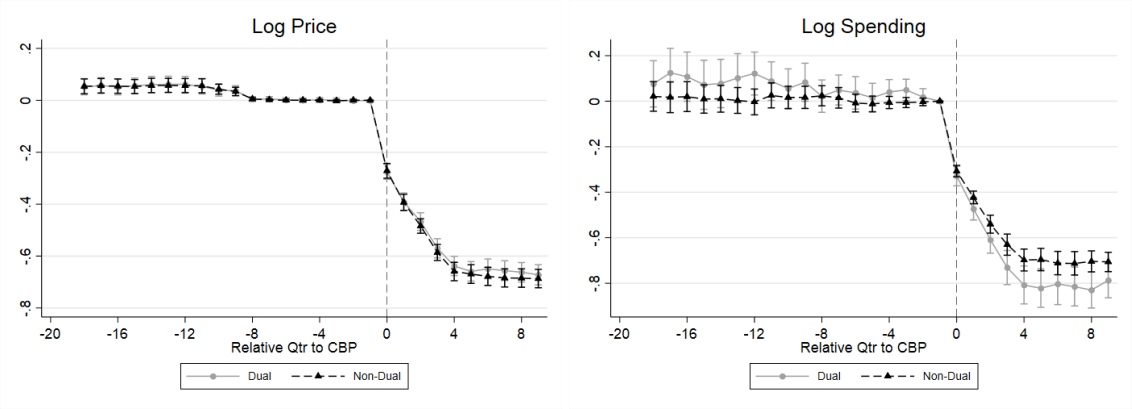
Figure A3: The Impact of Competitive Bidding on Diagnosis



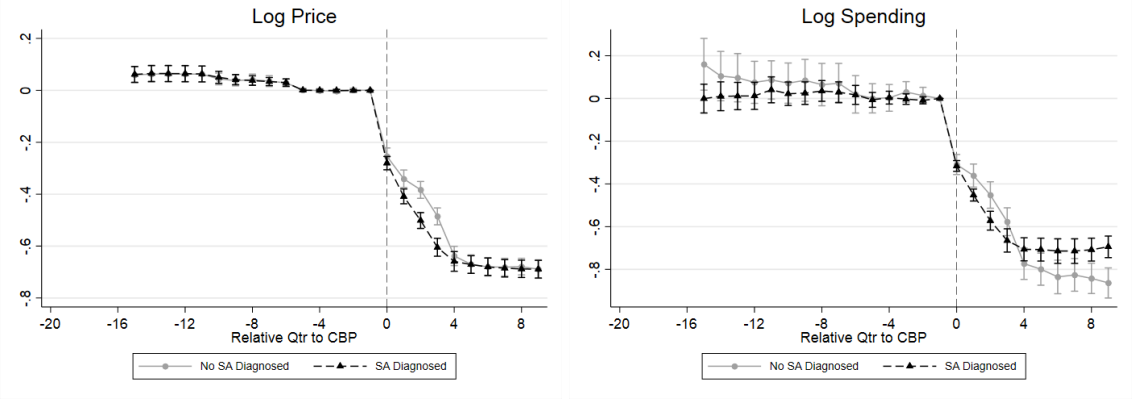
Notes: These figures replicate Figure 1 for the incidence of (obstructive) sleep apnea after the introduction of the CBP. The observation is at CBSA by year-quarter level. Outcome variables are the number of patients newly diagnosed with SA (primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in inpatient, outpatient or physician carrier table) and OSA (primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) among one thousand Medicare FFS population. The solid line is point estimates for the effect of quarter pre/post-CBP and the dotted lines are the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered by the CBSA level. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010.

Figure A4: The Impact of Competitive Bidding on CPAP Price by Subgroups

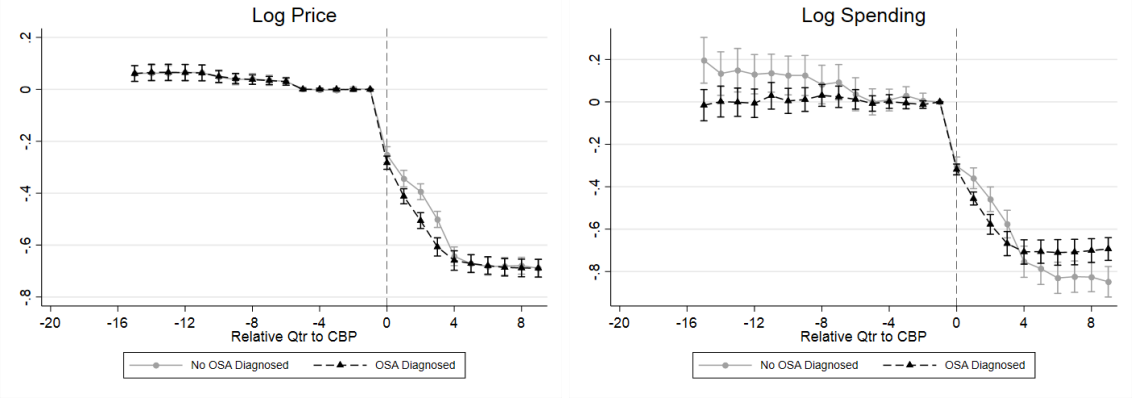
(a) Dual vs. Non-Dual



(b) Sleep Apnea (SA) Diagnosed vs. Not Diagnosed

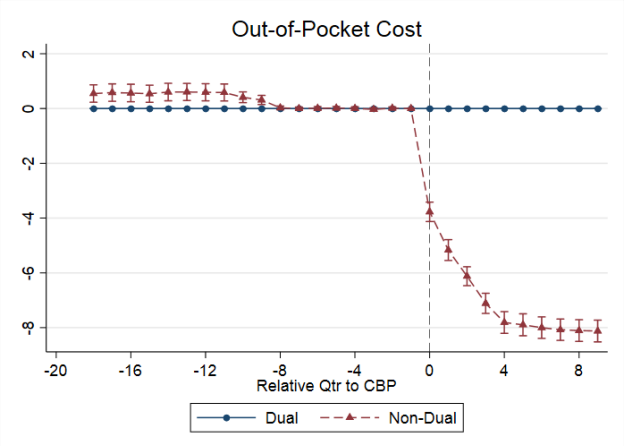


(c) Obstructive Sleep Apnea (OSA) Diagnosed vs. Not Diagnosed



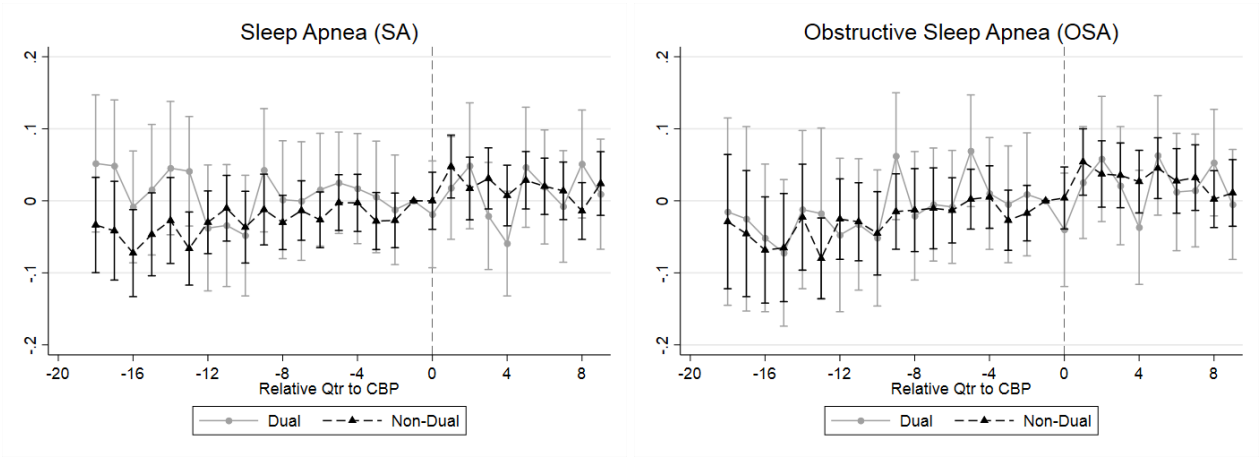
Notes: These figures plot event study coefficients of relative years interacting with group dummies. The observation is at CBSA by year-quarter by subgroup level. Panel A groups sample to duals vs nonduals. Panel B and C define subgroups as those diagnosed with either SA (primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in an inpatient, outpatient, or physician carrier table) or OSA (primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) in the previous year, restricting to patients who remained enrolled in Medicare for the current and previous 3 quarters to get full information on their diagnosis (sample period starts from 2009Q4). Outcome variable is the log price among each subgroup. The blue solid lines show point estimates for the effect of the CBP for duals / No SA / No OSA diagnosis and the red dashed lines show point estimates for the effect of the CBP for nonduals / SA / OSA diagnosed. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with a dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010.

Figure A5: The Impact of Competitive Bidding on CPAP Out-of-Pocket Price



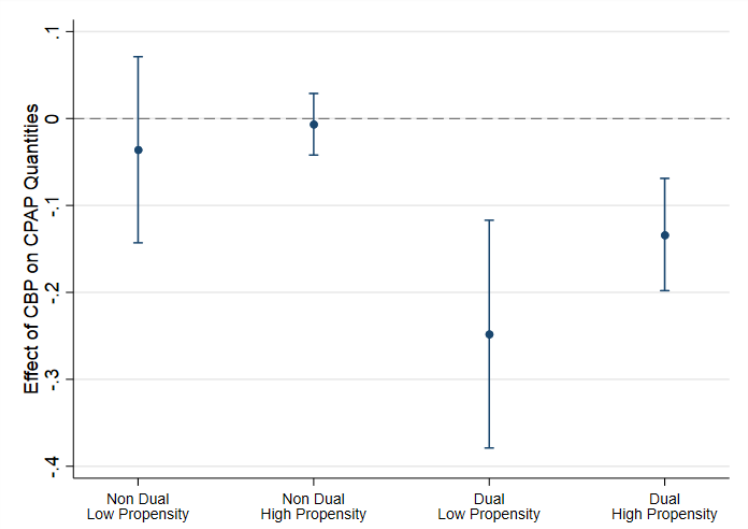
Notes: These figures plot event study coefficients of relative years interacting with dual/nondual dummies. The observation is at geographic area by year-quarter by subgroup level. Outcome variable is out-of-pocket price of CPAP. The blue solid lines show point estimates for the effect of the CBP for duals and the red dashed lines show point estimates for the effect of the CBP for nonduals. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered by geographic area. All regressions include geographic area and year-quarter fixed effect, and their interactions with a dummy variable for duals. All regressions are weighted by Medicare FFS population in 2010.

Figure A6: The Impact of Competitive Bidding on Diagnosis, by Dual Status



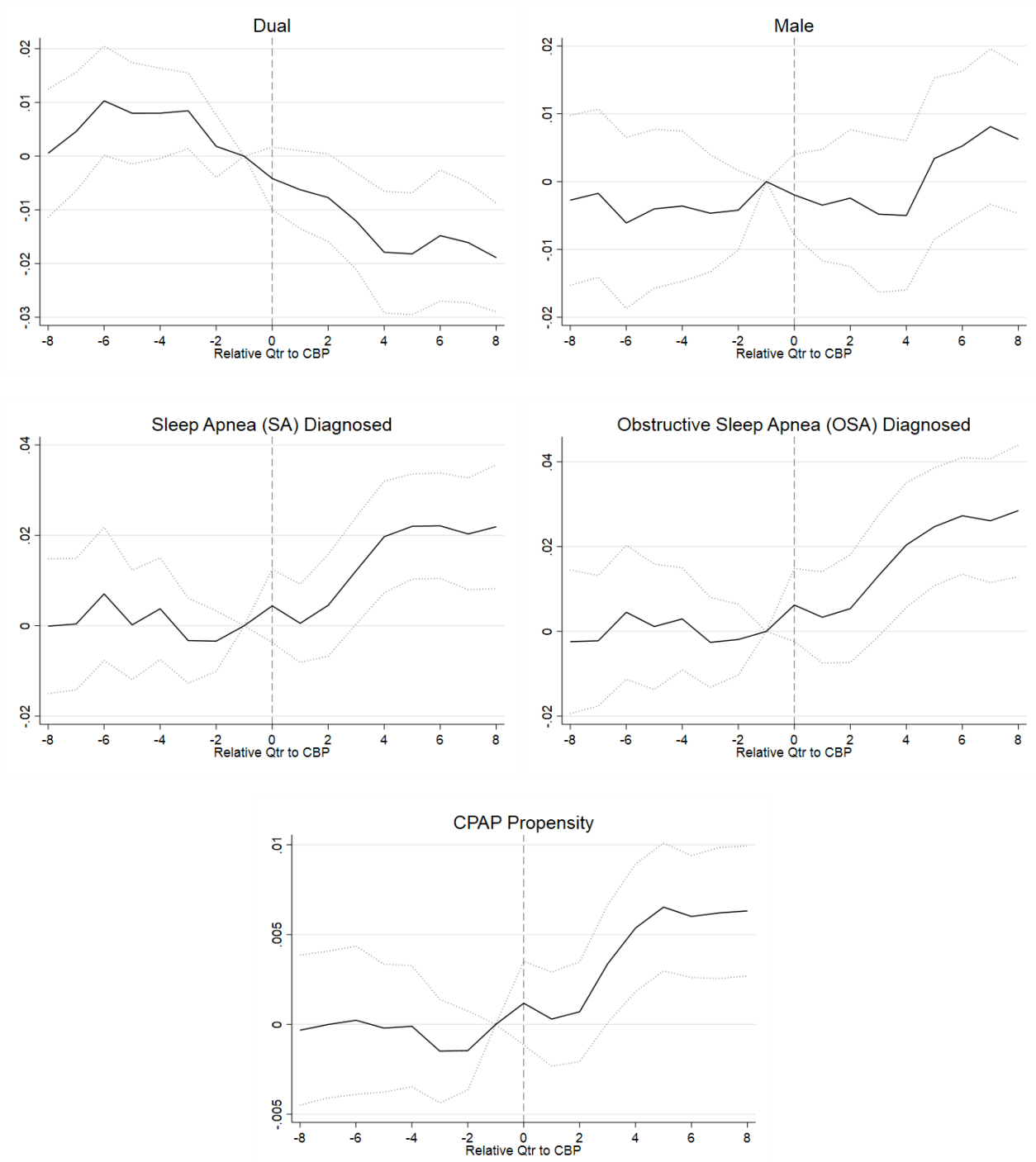
Notes: These figures replicate Figure 2 Panel A for the incidence of (obstructive) sleep apnea after the introduction of the CBP among duals and non-duals separately. The observation is at CBSA by year-quarter by dual/nondual level. Outcome variables are the number of patients newly diagnosed with Sleep Apnea (SA, primary diagnosis recorded as ICD-9 code 327.2 or ICD-10 code G47.3 in an inpatient, outpatient, or physician carrier table) or Obstructive Sleep Apnea (OSA, primary diagnosis recorded as ICD-9 code 327.23 or ICD-10 code G47.33) among one thousand Medicare FFS population. Coefficients of relative years interacting with dual indicator are plotted. The blue solid lines show point estimates for the effect of the CBP for duals and the red dashed lines show point estimates for non-duals. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include CBSA fixed effects, year-quarter fixed effects, and their interactions with dummy variable for each group. All regressions are weighted by Medicare FFS population in 2010.

Figure A7: The Impact of Competitive Bidding on CPAP Quantity, by Dual and Clinical Appropriateness



Notes: This figure presents the effect of CBP on CPAP quantity, by dual eligibility and above or below clinical appropriateness within each group. Separate regressions are used to estimate the effect for each subgroup. Vertical lines show the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include CBSA fixed effects and year-quarter fixed effects. All regressions are weighted by Medicare FFS population in 2010.

Figure A8: The Impact of Competitive Bidding on the Average Demographic Characteristics of CPAP Users



Notes: These figures shows the event study result for the impact of CBP on the average demographic characteristics of CPAP users. The observation is at CBSA by year-quarter level, capped at 8 years before and after the CBP. Outcome variables are the share of male, share of dual, and average CPAP propensity among CPAP users (corrpsonding to Columns 1-5 in Table 5). The solid line is point estimates for the effect of quarter pre/post-CBP and the dotted lines are the 95 percent confidence interval for those coefficients, based upon standard errors that are clustered at the CBSA level. All regressions include product fixed effects, CBSA fixed effects, year-quarter fixed effects, and their double interaction. All regressions are weighted by the number of claims in each CBSA for each product in 2010.