Creative Destruction in Medicare, 2013-2023

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Abstract

The health sector of the U.S. economy is more research-intensive, and innovative, than the overall economy. Innovation is a double-edged sword: it is a process of "creative destruction," because when a new and better product enters the market, the companies selling the older products lose out. This study analyzes the "destructive" (business-stealing) impact of biomedical innovation on several outcomes within the U.S. Medicare program during the period 2013-2023.

We analyze the relationship across 1898 treatments between a measure of innovation or entry relevant to a treatment—i.e., the growth in the number of treatments determined by CMS to be "reasonable and necessary" (r&n) for treatment of the same disease(s)—and the growth of the quantity and price of and expenditure on that treatment. We allow the effect of entry of new treatments on existing treatments to be subject to a lag, because peak expenditure on a treatment tends to occur 8-9 years after the code for the treatment was established.

Our measure of entry of new treatments is subject to measurement error: it may be incomplete, but according to CMS and a previous study, it should capture most treatments determined by CMS to be "reasonable and necessary" for treatment of a disease.

The growth in the quantity and price of a treatment is significantly inversely related to the growth in the number of treatments for the same diseases 2-9 years and 0-10 years earlier, respectively. The growth in total expenditure on a treatment is significantly inversely related to the growth in the number of treatments for the same diseases 0-10 years earlier. It is most strongly inversely related to the growth in the number of r&n treatments for the same diseases 4 years earlier.

We calculate how much the quantity and price of and expenditure on treatments provided in both 2013 and 2023 would have increased during that decade if the number of r&n treatments for the same diseases had not increased and compare those counterfactual changes to the actual changes in those variables.

The weighted mean 2013-2023 increase in treatment expenditure was 11.9%. The estimates indicate that if the number of r&n treatments had not increased from 2009 to 2019, the weighted mean 2013-2023 increase in expenditure on services would have been 65.3%. The 2009-2019 growth in r&n treatments is estimated to have reduced total expenditure in 2023 on r&n treatments already sold in 2013 by $22.1 billion. 2023 expenditure on r&n treatments that were established during 2010-2019 was $17.3 billion—smaller than the reduction in expenditure on existing treatments. This is consistent with the findings of a previous study, which found that one important type of biomedical innovation—pharmaceutical innovation—has reduced the average cost of U.S. health care episodes.

All data used in this study are publicly available on the internet.
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I. Introduction

The health sector of the U.S. economy is more research-intensive, and innovative, than the overall economy. According to Research America (2026), medical and health R&D as a percent of U.S. health spending was 5.13% in 2018, while, according to the National Center for Science and Engineering Statistics (2026), the ratio of U.S. R&D to GDP was 2.92%.

It has long been recognized by social scientists that innovation is a double-edged sword. Joseph Schumpeter coined the term "creative destruction" to describe how new innovations disrupt old technologies and business models, resulting in economic growth, but also in job losses and industry disruptions. Aghion, Akcigitz, and Howitt (2015) observed that growth in the Schumpeterian model involves both positive and negative externalities. The positive externality is…a 'knowledge spillover effect': innovation raises productivity…forever, i.e., the benchmark technology for any subsequent innovation. But innovation also has a negative externality as it destroys the rents of the previous innovator; Aghion and Howitt (1992) refer to this as the 'business-stealing effect' of innovation. When it awarded the 2025 Nobel Prize in Economic Sciences to three economists, the Royal Swedish Academy of Sciences (2025) declared that "sustained economic growth occurs when new technologies replace old ones as part of the process known as creative destruction." The Academy cited the paper by Aghion and Howitt (1992), in which they constructed a mathematical model incorporating the ideas that "when a new and better product enters the market, the companies selling the older products lose out. The innovation represents something new and is thus creative. However, it is also destructive, as the company whose technology becomes passé is outcompeted."

A number of studies have provided evidence about the 'creative' aspects of biomedical innovation, i.e., its impact on mortality and disability. For example, Lichtenberg and Krstovski (2025) demonstrated that premature mortality from a disease in the U.S. is significantly inversely related to measures of biomedical innovation about the disease and that, in the absence of biomedical innovation, age-adjusted mortality rates would not have declined during 1999-2019. Lichtenberg (2025) estimated that 85% of the 2003–2017 decline in the cancer mortality rate in 37 countries was attributable to previous biomedical innovation. Lichtenberg and Wang (2026) demonstrated that growth in Medicare-covered technology is associated with meaningful, long-run reductions in multiple dimensions of disability.

Evidence about the "destructive" (business-stealing) aspect of biomedical innovation is more limited. Two studies examined the impact of entry of new drugs on the prices of existing drugs within the same therapeutic class in two countries—the USA and Denmark.[1] Lichtenberg (2021) found that entry of new drugs during 1985−2005 reduced the average 2017 U.S. price of drugs that were already sold in 1997 by 35%. Lichtenberg (2022) found that entry of new drugs during 1997−2017 reduced the average 2017 Danish price of drugs that were already sold in 1997 by 18%. Those studies indicate that there is a destructive (business-stealing) aspect of pharmaceutical innovation, but they examined just one outcome (prices), and retail prescription drugs accounted for only 9% of 2023 U.S. health spending.

This study will analyze the "destructive" (business-stealing) impact on several outcomes of a much broader type of biomedical innovation within the U.S. Medicare program during the period 2013-2023.[2] First, we will analyze the effect of the rate of entry of new "treatments" (i.e., medical services, supplies, and equipment) on the rate of exit of old treatments. Even if new treatment entry does not result in old treatment exit, it may result in reductions in the prices and quantities of, and expenditure on, old treatments. Therefore, we will also analyze the effect of new treatment entry on old treatment prices, quantities, and expenditure.

II. Measurement of innovation relevant to each treatment and other variables

Each year in the U.S., health care insurers process over 5 billion claims for payment. Standardized coding systems are essential so that Medicare and other health insurance programs can process claims in an orderly and consistent manner. The Healthcare Common Procedure Coding System (HCPCS) was established in 1978 by the Federal government to standardize the reporting of medical services, supplies, and equipment, essentially creating a unified system for

[1] A study by the Ways and Means Committee Staff (2019) analyzed prices in 2017 and 2018 of 79 drugs sold in the U.S. and 11 other countries. Among these 12 countries, Denmark had the lowest annual pharmaceutical spending per capita ($318), and the U.S. had the highest ($1220). Differences in prices were a major reason for this spending differential: the study found that the average Danish drug price was 60 percent lower than the average U.S. drug price. A study cited by Ronning-Andersson (2021) concluded that Denmark has the cheapest generic medicines in Europe.

[2] Medicare was the second largest (after Social Security) Federal program in 2024. Medicare spending was higher than defense spending (Center on Budget and Policy Priorities (2026)).

medical billing across different healthcare providers and payers.[3] While initially voluntary, the Health Insurance Portability and Accountability Act (HIPAA) of 1996 made the use of HCPCS codes mandatory for all healthcare transactions (see Applied Policy (2024)).

HCPCS is divided into 2 main subsystems — Level I and Level II. The American Medical Association (AMA) had already developed the Current Procedural Terminology (CPT) coding system in 1966, which became the basis for Level I HCPCS codes. The need for a separate coding system for non-physician services and supplies led to the creation of HCPCS Level II codes, which focus on items like drugs, devices, and durable medical equipment. The establishment of a new Level II code requires approval by the CMS HCPCS Workgroup, which is made up of physicians and healthcare professionals within CMS, as well as other pertinent federal agencies such as the Department of Veterans Affairs and the Department of Defense (Gutmann (2024)).[4] In reviewing requests for new codes, the Workgroup considers whether a product performs a significantly different function or operates in a significantly different manner from items in existing coding categories. The company requesting the code must show in the application that there is a significant therapeutic distinction compared to existing coded treatments or products. The application includes other questions to determine why a new code is needed. For example, for devices, there are questions pertaining to the coding for the FDA predicate device, and why the new device should not be coded in the same manner.

CMS publishes three databases that provide information about HCPCS codes. One database, the Restructured BETOS Classification System (Centers for Medicare and Medicaid Services (2026e)), indicates the "HCPCS Code Add Date": the date when each HCPCS code was established. As shown in Figure 1, the number of HCPCS codes ever established has increased substantially during the last 40 years. By the end of 1984, 4994 codes had been established. By the end of 2023, 17,997 codes had been established—a 260% increase.[5]

Medicare coverage is limited to treatments that have been determined to be reasonable and necessary for the diagnosis or treatment of an illness or injury (and within the scope of a

[3] The system was initially called the "HCFA Common Procedure Coding System" as "HCFA" was the previous name for the Centers for Medicare and Medicaid Services which manages HCPCS today.
[4] Establishment of new Level I (CPT) codes is discussed in American Medical Association (2026).
[5] As shown in Appendix Table 1, the Restructured BETOS Classification System (RBCS) is a taxonomy that groups the 17,997 codes into clinically meaningful categories (N = 8) and subcategories (N = 53). Appendix Table 2 shows the number of HCPCS codes ever established by 2000 and 2023, by RBCS category. Appendix Table 3 shows the number of services provided and total amount Medicare paid in 2019, by RBCS category and subcategory.

Medicare benefit category). The second CMS database, the "Current and Retired Articles" component of the Medicare Coverage Database (Centers for Medicare and Medicaid Services (2026b, 2026c)), enumerates treatments that have been designated, via Local Coverage Determinations (LCD)[6], by one or more Medicare Administrative Contractors (MACs) as 'reasonable and necessary' (r&n) to treat a disease.[7] This database contains 575,664 links between 3404 HCPCS codes and 7344 (narrowly defined) covered disease (ICD-10-CM) codes.[8] As shown in Appendix Table 1, these medical items and services fall into many categories and subcategories, e.g., molecular testing, imaging, chemotherapy, and cardiovascular procedures. A given treatment is often used to treat many diseases: the mean number of diseases designated as reasonable and necessary for a HCPCS code is 169.1. Appendix Table 2 provides an illustration of the data for a single disease, Salmonella sepsis (A02.1). Thirty-one HCPCS codes (listed in order of year of HCPCS code establishment) are covered for that disease. As shown in Appendix Figure 1, the number of HCPCS contained in Local Coverage Determinations ever established has grown at a higher rate than the total number of HCPCS ever established.

Due to data limitations, our measures of R&N treatments, by disease and year, will be based solely on treatments covered by LCDs.[9] Our R&N treatment measures are therefore subject to measurement error, but according to CMS (2026a), "most Medicare coverage decisions are made locally by the MACs."[10] Moneer et al (2024) also noted that "local coverage determinations…represent the vast majority of Medicare's coverage decisions for new technologies."

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[6] Local Coverage Determinations began in the early 1990s, but they were called Local Medical Review Policies, (LMRPs). In 2003, LMRPs were renamed to Local Coverage Determinations (LCDs).

[7] Articles prior to 2015 are not included in the all_article.mdb file because, on October 1, 2015, the healthcare industry transitioned from ICD-9 to ICD-10 codes for diagnoses and inpatient procedures.

[8] This database does not cover all HCPCS codes. It covers 28% (= 2601/9297) of the HCPCS codes provided in 2023. But expenditure on covered HCPCS codes is higher than average: covered HCPCS codes account for 40% (= $57 billion/ $143 billion) of 2023 expenditure.

[9] There are three ways in which an item or service can be covered by Medicare. First, it can be covered under a National Coverage Determination (NCD): a determination by the Centers for Medicare & Medicaid Services (CMS) that a particular item or service is covered nationally under Medicare. Second, it can be covered under a Local Coverage Determination (LCD). LCDs may be developed in the absence of an NCD or as a supplement to an NCD, as long as the LCD policy does not conflict with national policy. Third, in the absence of an LCD or NCD, claims are reviewed on a claim-by-claim basis by the MACs. In such cases, the MACs review the claim on an individual basis to ensure that all CMS requirements have been met prior to paying the claim.

[10] The number of treatments (HCPCS codes) covered by LCDs (3404) is more than ten times the number covered by NCDs (200-300). According to the Medicare Coverage Database (Centers for Medicare and Medicaid Services (2025b)), as of 21 December 2024, there were 338 NCDs and 2324 LCDs.

From the data contained in these two databases, we can construct the following treatment-specific variables:

$year_estab_h$ = the year HCPCS code h was established by CMS

$established_{ht}$ = 1 if $year_estab_h \leq t$ (t = 2000, 2001, …, 2023)
= 0 if $year_estab_h > t$

$r\&n_{hd}$ = 1 if HCPCS code h is r&n for treatment of disease d
= 0 if HCPCS code h is not r&n for treatment of disease d

$same_disease_{hj}$ = 1 if $\sum_d (r\&n_{hd} * r\&n_{jd}) > 0$
= 0 if $\sum_d (r\&n_{hd} * r\&n_{jd}) = 0$

cum_hcpcs_{ht} $\sum_j same_disease_{hj} * established_{jt}$ = the number of hcpcs established by year t that were r&n for any disease for which hcpcs code h is r&n

$same_disease_{hj}$ is a dummy variable indicating whether HCPCS codes h and j overlap, i.e., whether any of the diseases for which HCPCS codes h and j are r&n are the same. $\ln(cum_hcpcs_{h,2023}/cum_hcpcs_{h,2013})$ is the log change from 2013 to 2023 of the number of hcpcs codes ever established that were r&n for any disease for which hcpcs code h is r&n. Using treatment-specific data, we will analyze the relationship across treatments between this measure of innovation or entry relevant to treatment h and the growth of the quantity and price of and expenditure on treatment h.

Growth in the number of distinct treatments (HCPCS codes) ever established and covered by LCDs has varied considerably across diseases. This is illustrated by Figure 2, which displays 1988-2023 data for four diseases, which had similar numbers of covered treatments (between 169 and 175) in 1988. In 2023, the number of covered treatments ranged from 244 to 310.

Since growth in the number of distinct treatments has varied considerably across diseases, and the diseases treated by HCPCS code A tend to differ from those treated by HCPCS code B, those two HCPCS codes were exposed to different rates of entry. This is illustrated by Figure 3, which shows the number of treatments established by 2003 and 2023 that are reasonable and necessary for the same diseases for which 5 specific treatments are reasonable and necessary. In 2003, the number of treatments that were r&n for some of the same diseases that HCPCS 31500 (intubation, endotracheal, emergency procedure) were r&n for was almost the same as the number of treatments that were r&n for some of the same diseases that HCPCS 0005U (oncology (prostate) gene expression profile by real-time rt-pcr of 3 genes (erg, pca3, and

spdef), urine, algorithm reported as risk score) were r&n for. In 2023, the number of treatments that were r&n for some of the same diseases that HCPCS 31500 and HCPCS 0005U were r&n for were quite different (1363 versus 1755).

The third database, Medicare Physician & Other Practitioners - by Geography and Service (Centers for Medicare and Medicaid Services (2026d)), provides information on services and procedures provided to Original Medicare (fee-for-service) Part B (Medical Insurance) beneficiaries by physicians and other healthcare professionals, aggregated by geography and service (HCPCS code). It provides annual data on the quantity (number of services) and price (average Medicare allowed amount) of each HCPCS treatment provided during the period 2013-2023. From the data contained in this database, we can construct the following treatment-specific variables:

q_{ht} = the quantity (number of services provided) of HCPCS treatment h in year t

$provided2023_h$ = 1 if $q_{h,2013} > 0$ and $q_{h,2023} > 0$
= 0 if $q_{h,2013} > 0$ and $q_{h,2023} = 0$

p_{ht} = the price (average Medicare allowed amount[11]) of HCPCS treatment h in year t

$expend_{ht} = q_{ht} * p_{ht}$ = expenditure on HCPCS treatment h in year t

III. Econometric models

To analyze the effect of entry of new treatments on the probability that treatments provided in 2013 were still provided in 2023, we will estimate the following models for k = 0, 1, 2, …,10:

$$provided2023_h = \alpha + \beta_k \ln(cum_hcpcs_{h,2023-k}/cum_hcpcs_{h,2013-k}) + \varepsilon_h \quad (1)$$

To analyze the effect of entry of new treatments on the quantity and price of and expenditure on old treatments that were provided in both 2013 and 2023, we will estimate the following models:

$$\ln(q_{h,2023}/q_{h,2013}) = \alpha + \beta_k \ln(cum_hcpcs_{h,2023-k}/cum_hcpcs_{h,2013-k}) + \varepsilon_h \quad (2)$$

$$\ln(p_{h,2023}/p_{h,2013}) = \alpha + \beta_k \ln(cum_hcpcs_{h,2023-k}/cum_hcpcs_{h,2013-k}) + \varepsilon_h \quad (3)$$

[11] Medicare allowed amounts includes the amount Medicare pays, the deductible and coinsurance amounts that the beneficiary is responsible for paying, and any amounts that a third party is responsible for paying.

$$\ln(\text{expend}_{h,2023}/\text{expend}_{h,2013}) = \alpha + \beta_k \ln(\text{cum_hcpcs}_{h,2023\text{-}k}/\text{cum_hcpcs}_{h,2013\text{-}k}) + \varepsilon_h \quad (4)$$

Eq. (1) will be estimated by weighted least-squares, weighting by $\text{expend}_{h,2013}$.[12] Eqs. (2)-(4) will be estimated by weighted least-squares, weighting by $(\text{expend}_{h,2013} + \text{expend}_{h,2023})/2$.

Descriptive statistics are provided in Table 1. Our sample includes 1996 procedures that were provided in 2013. About 5% (98) of these procedures were no longer provided in 2023. However, the procedures that were no longer provided in 2023 accounted for only 0.6% of 2013 expenditure. 1898 procedures were provided in both 2013 and 2023. Weighted (by $(\text{expend}_{h,2013} + \text{expend}_{h,2023})/2$) mean growth in treatment quantity, price, and expenditure was 15.5%, -3.2%, and 11.9%, respectively. The average annual growth in cum_hcpcs_{ht} was about 4%.

Eqs. (1)-(4) allow the effect of entry of new procedures to be subject to a lag of 0-10 years. This is appropriate because peak utilization of and expenditure on a procedure tends to occur years after the code for the procedure was established. We can obtain some evidence about the shape of the typical procedure "age-utilization profile"—the relationship between time since procedure code establishment and procedure utilization—by estimating the following model, using data on expenditure, by treatment and year during 2023:

$$\ln(\text{expend}_{ha}) = \gamma_a + \delta_h + \varepsilon_{ha} \quad (5)$$

where

expend_{ha} = expenditure on HCPCS code h a years after code was established (a = 0, 1, 2, …, 20)

γ_a = a fixed effect for age a

δ_h = a fixed effect for HCPCS code h

$\exp(\gamma_a - \gamma_{10})$ is the ratio of mean expenditure a years after procedure code establishment to mean expenditure 10 years after procedure code establishment. Estimates of $\exp(\gamma_a - \gamma_{10})$ are plotted in Figure 4. The estimates indicate that peak expenditure on a procedure tends to occur 8-9 years after the code for the procedure was established.[13]

The dependent variables of eqs. (1)-(4) are likely to depend on the growth of incidence of the diseases treated by procedure h, which is also likely to be correlated with the regressor

[12] Estimating eq. (1) as a probit model yielded similar results.
[13] These estimates are based on data on procedures included in LCDs. Estimates based on all procedures have a similar shape. Estimates based on the quantity of procedures included in LCDs also have a similar shape.

$\ln(\text{cum_hcpcs}_{h,2023-k}/\text{cum_hcpcs}_{h,2013-k})$. Unfortunately, reliable longitudinal data on disease incidence are not available. But inability to control for incidence growth is likely to make our estimates of β_k conservative—to bias them towards zero—because higher incidence growth is likely to stimulate entry of new procedures as well as to increase expenditure on existing procedures.

IV. Empirical results

Estimates of β_k from eqs. (1)-(4) are presented in Table 2 and plotted in Figure 5. Each estimate is from a separate model. In Figure 5, solid squares indicate statistically significant (p-value < .05) estimates, larger squares indicate the most significant estimates, and dashed lines indicate 95% confidence intervals.

Estimates of β_k from eq. (1), in which the dependent variable is provided2023_h, are shown in panel A of the table and figure. The probability that a treatment provided in 2013 was still provided in 2023 is significantly inversely related to the growth in the number of treatments designated as reasonable and necessary for any of the same diseases 0-10 years earlier. It is most strongly inversely related to the growth in the number of r&n treatments for the same diseases 6 years earlier. The estimate of β_6 indicates that the probability that a treatment provided in 2013 exited the market, i.e. was no longer provided in 2023, is higher, the greater the 2007-2017 increase in the number of treatments for the same diseases.

Estimates of β_k from eq. (2), in which the dependent variable is 2013-2023 growth in the quantity (number of services) of treatment h ($\ln(q_{h,2023}/q_{h,2013})$), are shown in panel B of the table and figure. The estimate of β_k is not statistically significant when $k = 0$ or $k = 1$, but it is negative and significant for $2 \leq k \leq 9$: the growth in the quantity of a treatment is inversely related to the growth in the number of treatments for the same diseases 2-9 years earlier. It is most strongly inversely related to the growth in the number of r&n treatments for the same diseases 3 years earlier.

Estimates of β_k from eq. (3), in which the dependent variable is 2013-2023 growth in the price (average Medicare allowed amount) of treatment h, are shown in panel C of the table and figure. The estimates of β_k are negative and statistically significant for $0 \leq k \leq 10$: the growth in the price of a treatment is inversely related to the growth in the number of treatments for the

same diseases 0-10 years earlier. It is most strongly inversely related to the contemporaneous growth in the number of r&n treatments for the same diseases.

Estimates of β_k from eq. (4), in which the dependent variable is 2013-2023 growth in the total expenditure on treatment h, are shown in panel D of the table and figure. Once again, the estimates of β_k are negative and statistically significant for $0 \leq k \leq 10$: the growth in total expenditure on a treatment is inversely related to the growth in the number of treatments for the same diseases 0-10 years earlier. It is most strongly inversely related to the growth in the number of r&n treatments for the same diseases 4 years earlier.[14]

V. Discussion

The estimates presented in Table 2 and Figure 5 may be used to calculate how much the quantity and price of and expenditure on treatments provided in both 2013 and 2023 would have increased during that decade if the number of r&n treatments for the same diseases had not increased, and compare those counterfactual changes to the actual changes in those variables.[15] These calculations are shown in Figure 5. The weighted mean 2013-2023 increase in the quantity of services was 15.6%. The estimate of β_3 from eq. (2) implies that if the number of r&n treatments had not increased from 2010 to 2020, the weighted mean 2013-2023 increase in the quantity of services would have been 45.7%.

The weighted mean 2013-2023 increase in the price of services was -3.2%. The estimate of β_0 from eq. (3) implies that if the number of r&n treatments had not increased from 2013 to 2023, the weighted mean 2013-2023 increase in the price of services would have been 22.8%.

The weighted mean 2013-2023 increase in treatment expenditure was 11.9%. The estimate of β_4 from eq. (4) implies that if the number of r&n treatments had not increased from 2009 to 2019, the weighted mean 2013-2023 increase in expenditure on services would have been 65.3%.

Total expenditure in 2013 on r&n treatments that were also provided in 2023 was $41.4 billion. Total expenditure in 2023 on r&n treatments already sold in 2013 was about 11.9%

[14] Although these estimates are highly statistically significant (many have p-values < .0001), the R^2 of the equations are quite low. For example, the R^2 of eq. (4) when k=4 is 0.0195.
[15] The intercepts of eqs. (2)-(4) are estimates of the counterfactual changes.

higher: $46.4 billion. The estimate of β_4 from eq. (4) implies that if the number of r&n treatments had not increased from 2009 to 2019, total expenditure in 2023 on r&n treatments already sold in 2013 would have been 65.3% higher: $68.5 billion. Hence the 2009-2019 growth in r&n treatments is estimated to have reduced total expenditure in 2023 on r&n treatments already sold in 2013 by $22.1 billion (= $68.5 billion - $46.4 billion).

While the 2009-2019 growth of r&n treatments evidently reduced expenditure on existing treatments, the new treatments were costly themselves. However, the data indicate that 2023 expenditure on r&n treatments that were established during 2010-2019 was $17.3 billion—smaller than the reduction in expenditure on existing treatments. The difference between the two figures may not be statistically significant. But a recent study (Lichtenberg (2023)) found that one important type of biomedical innovation—pharmaceutical innovation—has reduced the average cost of U.S. health care episodes.

VI. Summary and conclusions

The health sector of the U.S. economy is more research-intensive, and innovative, than the overall economy. Innovation is a double-edged sword: it is a process of "creative destruction," because when a new and better product enters the market, the companies selling the older products lose out. This study analyzed the destructive (business-stealing) impact of biomedical innovation on several outcomes within the U.S. Medicare program during the period 2013-2023.

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Our measure of entry of new treatments is subject to measurement error: it may be incomplete, but according to CMS and a previous study, it should capture most treatments determined by CMS to be "reasonable and necessary" for treatment of a disease.

The growth in the quantity and price of a treatment is significantly inversely related to the growth in the number of treatments for the same diseases 2-9 years and 0-10 years earlier, respectively. The growth in total expenditure on a treatment is significantly inversely related to the growth in the number of treatments for the same diseases 0-10 years earlier. It is most strongly inversely related to the growth in the number of r&n treatments for the same diseases 4 years earlier.

We calculated how much the quantity and price of and expenditure on treatments provided in both 2013 and 2023 would have increased during that decade if the number of r&n treatments for the same diseases had not increased and compared those counterfactual changes to the actual changes in those variables.

The weighted mean 2013-2023 increase in treatment expenditure was 11.9%. The estimates indicated that if the number of r&n treatments had not increased from 2009 to 2019, the weighted mean 2013-2023 increase in expenditure on services would have been 65.3%. The 2009-2019 growth in r&n treatments is estimated to have reduced total expenditure in 2023 on r&n treatments already sold in 2013 by $22.1 billion. 2023 expenditure on r&n treatments that were established during 2010-2019 was $17.3 billion—smaller than the reduction in expenditure on existing treatments. This is consistent with the findings of a previous study, which found that one important type of biomedical innovation—pharmaceutical innovation—has reduced the average cost of U.S. health care episodes.

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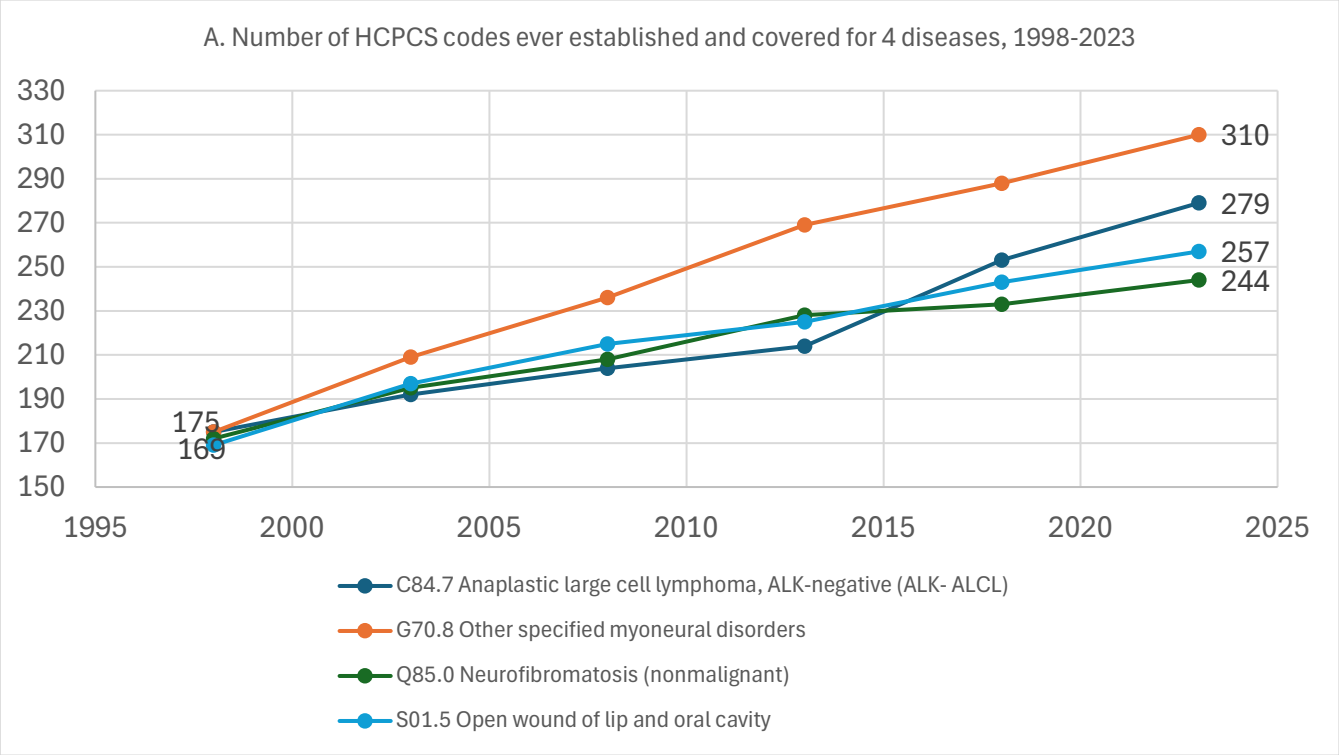
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Figure 1


A. Number of HCPCS codes ever established and covered for 4 diseases, 1998-2023
330
310
290
270
250
230
210
190
170
150
1995
2000
2005
2010
2015
2020
2025
310
279
257
244
175
169
C84.7 Anaplastic large cell lymphoma, ALK-negative (ALK- ALCL)
G70.8 Other specified myoneural disorders
Q85.0 Neurofibromatosis (nonmalignant)
S01.5 Open wound of lip and oral cavity

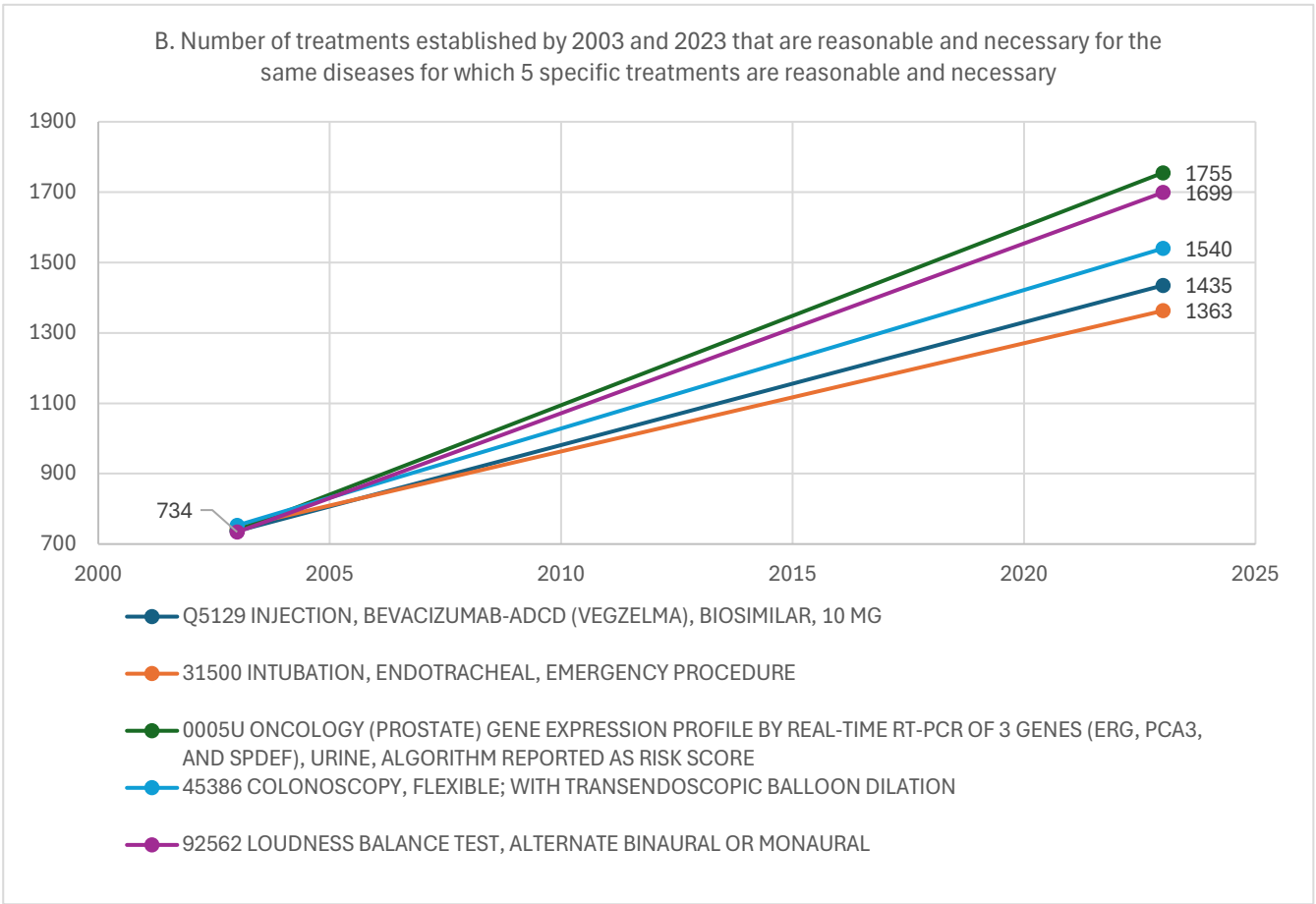
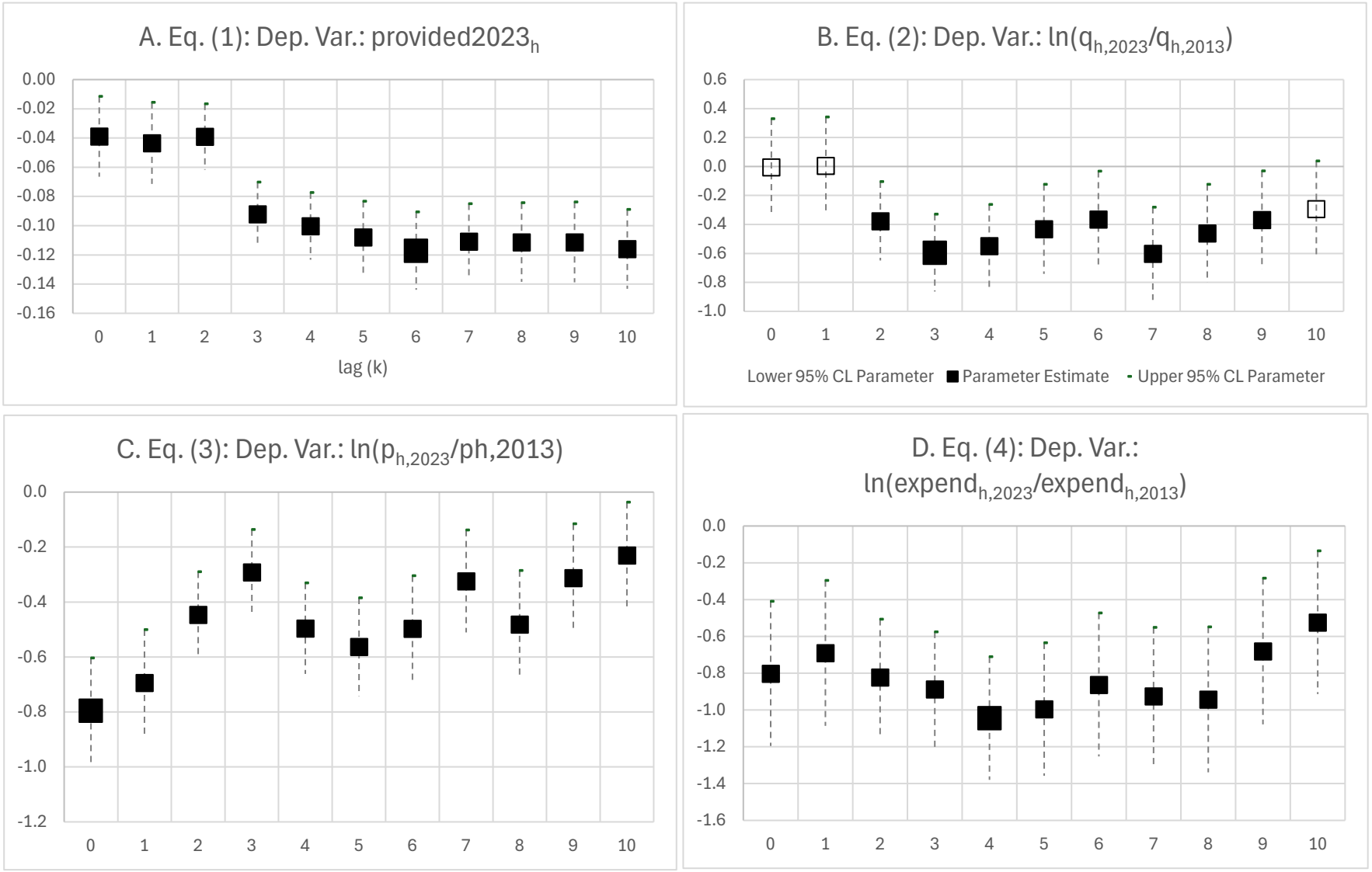

B. Number of treatments established by 2003 and 2023 that are reasonable and necessary for the same diseases for which 5 specific treatments are reasonable and necessary
1900
1700
1500
1300
1100
900
700
2000
2005
2010
2015
2020
2025
1755
1699
1540
1435
1363
734
Q5129 INJECTION, BEVACIZUMAB-ADCD (VEGZELMA), BIOSIMILAR, 10 MG
31500 INTUBATION, ENDOTRACHEAL, EMERGENCY PROCEDURE
0005U ONCOLOGY (PROSTATE) GENE EXPRESSION PROFILE BY REAL-TIME RT-PCR OF 3 GENES (ERG, PCA3, AND SPDEF), URINE, ALGORITHM REPORTED AS RISK SCORE
45386 COLONOSCOPY, FLEXIBLE; WITH TRANSENDOSCOPIC BALLOON DILATION
92562 LOUDNESS BALANCE TEST, ALTERNATE BINAURAL OR MONAURAL

Figure 2

Estimates of β_k from eqs. (1)-(4)



Each estimate is from a separate model. Dashed lines indicate 95% confidence intervals.

Solid squares indicate statistically significant (p-value < .05) estimates. Larger squares indicate the most significant estimates.

Figure 3
Weighted mean 2013-2023 growth in the
quantity and price of and expenditure on treatments sold in both years:
actual versus counterfactual, in the absence of innovation

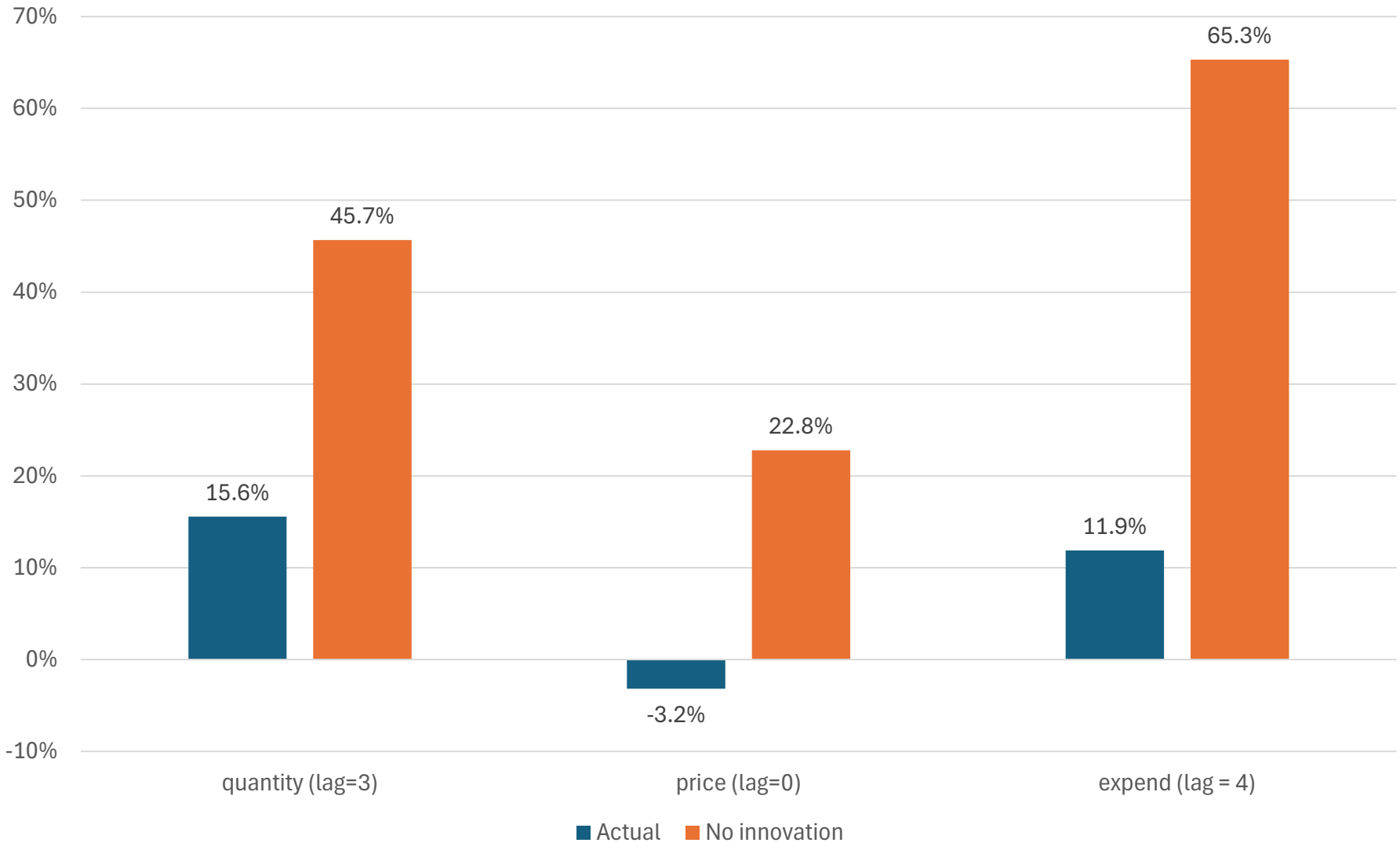


Table 1

Descriptive statistics

Procedures provided in 2013 (weighted by $expend_{h,2013}$)					
Variable	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
provided2023	1996	0.994109	349.81211	0	1

Procedures provided in 2013 and 2023 (weighted by $(expend_{h,2013} + expend_{h,2023})/2$)					
Variable	**N**	**Mean**	**Std Dev**	**Minimum**	**Maximum**
$\ln(q_{h,2023}/q_{h,2013})$	1898	0.145	4120.280	-11.878	6.963
$\ln(p_{h,2023}/p_{h,2013})$	1898	-0.032	2400.290	-4.324	2.406
$\ln(expend_{h,2023}/expend_{h,2013})$	1898	0.112	4843.650	-11.653	6.557
$\ln(cum_hcpcs_{h,2023}/cum_hcpcs_{h,2013})$	1898	0.298	553.287	0.000	0.847
$\ln(cum_hcpcs_{h,2023\text{-}1}/cum_hcpcs_{h,2013\text{-}1})$	1898	0.331	550.616	0.000	0.847
$\ln(cum_hcpcs_{h,2023\text{-}2}/cum_hcpcs_{h,2013\text{-}2})$	1898	0.372	682.849	0.000	1.050
$\ln(cum_hcpcs_{h,2023\text{-}3}/cum_hcpcs_{h,2013\text{-}3})$	1898	0.389	691.972	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}4}/cum_hcpcs_{h,2013\text{-}4})$	1898	0.374	646.375	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}5}/cum_hcpcs_{h,2013\text{-}5})$	1898	0.361	599.482	0.000	1.153
$\ln(cum_hcpcs_{h,2023\text{-}6}/cum_hcpcs_{h,2013\text{-}6})$	1898	0.351	557.161	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}7}/cum_hcpcs_{h,2013\text{-}7})$	1898	0.349	578.842	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}8}/cum_hcpcs_{h,2013\text{-}8})$	1898	0.363	548.365	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}9}/cum_hcpcs_{h,2013\text{-}9})$	1898	0.373	547.531	0.000	1.099
$\ln(cum_hcpcs_{h,2023\text{-}10}/cum_hcpcs_{h,2013\text{-}10})$	1898	0.361	559.352	0.000	1.099

Table 2

Estimates of β_k from eqs. (1)-(4)

A. Eq. (1): Dep. Var.: provided2023$_h$				
lag (k)	**Estimate**	**Std. Err.**	**t Value**	**Pr > |t|**
0	-0.039	0.014	-2.79	0.005
1	-0.044	0.014	-3.06	0.002
2	-0.039	0.011	-3.41	0.001
3	-0.092	0.011	-8.26	<.0001
4	-0.100	0.012	-8.55	<.0001
5	-0.108	0.013	-8.61	<.0001
6	-0.117	0.014	-8.66	<.0001
7	-0.111	0.013	-8.43	<.0001
8	-0.111	0.014	-8.07	<.0001
9	-0.111	0.014	-7.93	<.0001
10	-0.116	0.014	-8.40	<.0001

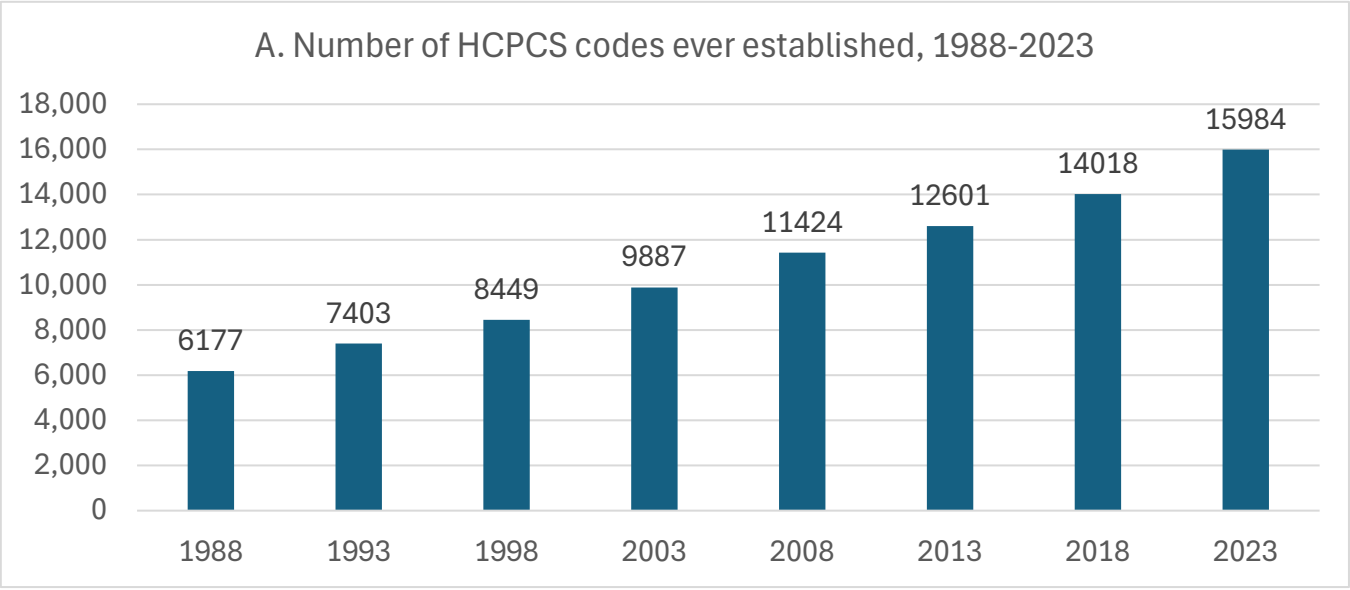
B. Eq. (2): Dep. Var.: $\ln(q_{h,2023}/q_{h,2013})$				
lag (k)	**Estimate**	**Std. Err.**	**t Value**	**Pr > |t|**
0	-0.006	0.171	-0.04	0.970
1	0.004	0.172	0.02	0.983
2	-0.377	0.138	-2.72	0.007
3	-0.596	0.136	-4.38	<.0001
4	-0.549	0.146	-3.76	0.000
5	-0.433	0.158	-2.75	0.006
6	-0.366	0.170	-2.16	0.031
7	-0.602	0.163	-3.69	0.000
8	-0.462	0.172	-2.68	0.007
9	-0.369	0.173	-2.14	0.033
10	-0.294	0.169	-1.74	0.082

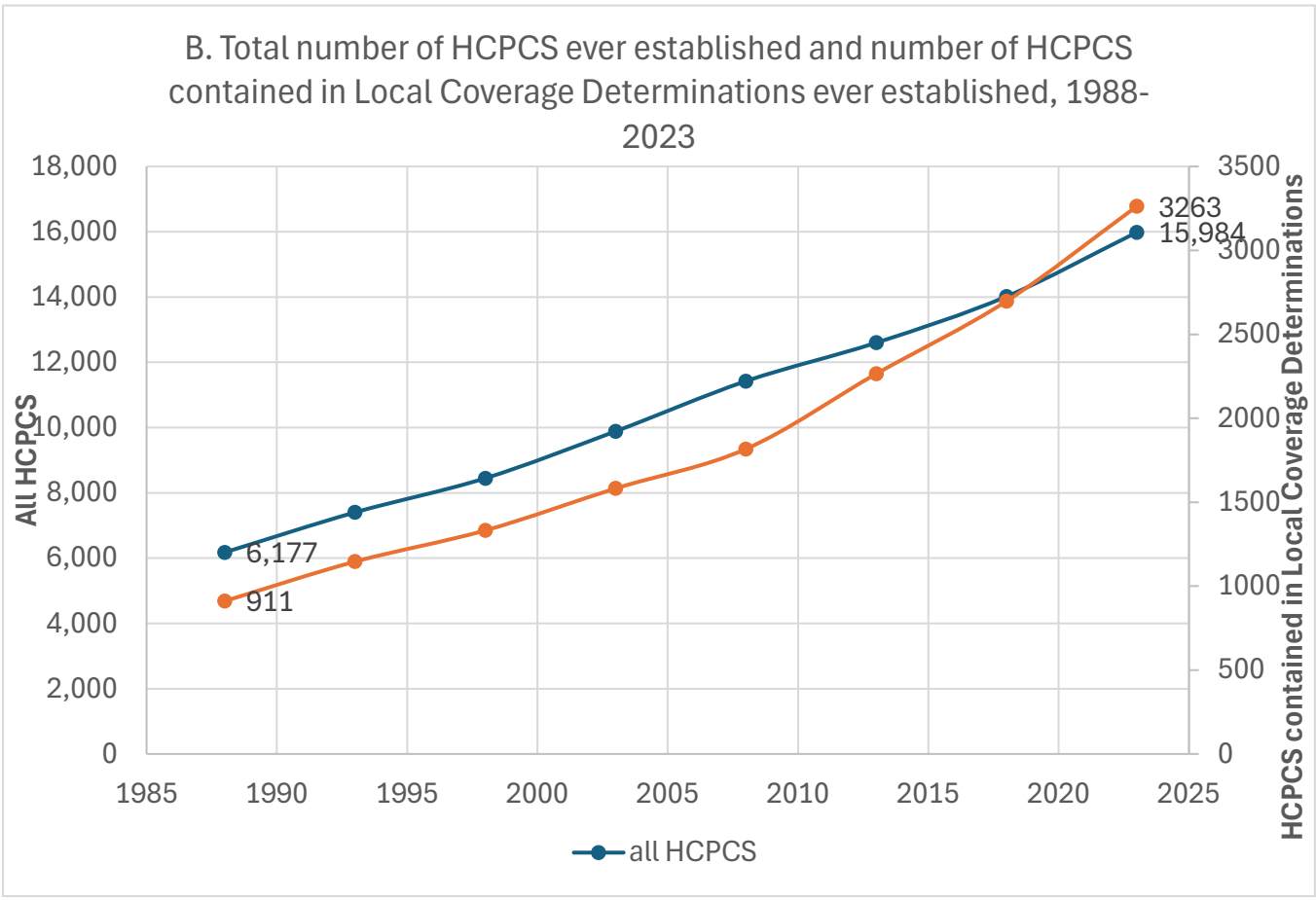
C. Eq. (3): Dep. Var.: $\ln(p_{h,2023}/p_{h,2013})$				
lag (k)	**Estimate**	**Std. Err.**	**t Value**	**Pr > |t|**
0	-0.796	0.098	-8.13	<.0001
1	-0.694	0.099	-7.03	<.0001
2	-0.447	0.080	-5.58	<.0001
3	-0.292	0.079	-3.68	0.000
4	-0.496	0.085	-5.87	<.0001
5	-0.563	0.091	-6.19	<.0001
6	-0.497	0.098	-5.06	<.0001
7	-0.324	0.095	-3.41	0.001
8	-0.482	0.100	-4.82	<.0001
9	-0.312	0.100	-3.11	0.002
10	-0.230	0.098	-2.34	0.020

D. Eq. (4): Dep. Var.: $\ln(expend_{h,2023}/expend_{h,2013})$				
lag (k)	**Estimate**	**Std. Err.**	**t Value**	**Pr > |t|**
0	-0.803	0.200	-4.01	<.0001
1	-0.691	0.201	-3.43	0.001
2	-0.824	0.162	-5.09	<.0001
3	-0.888	0.159	-5.57	<.0001
4	-1.045	0.170	-6.13	<.0001
5	-0.996	0.184	-5.41	<.0001
6	-0.863	0.199	-4.34	<.0001
7	-0.926	0.191	-4.85	<.0001
8	-0.944	0.202	-4.68	<.0001
9	-0.681	0.203	-3.36	0.001
10	-0.524	0.199	-2.64	0.008

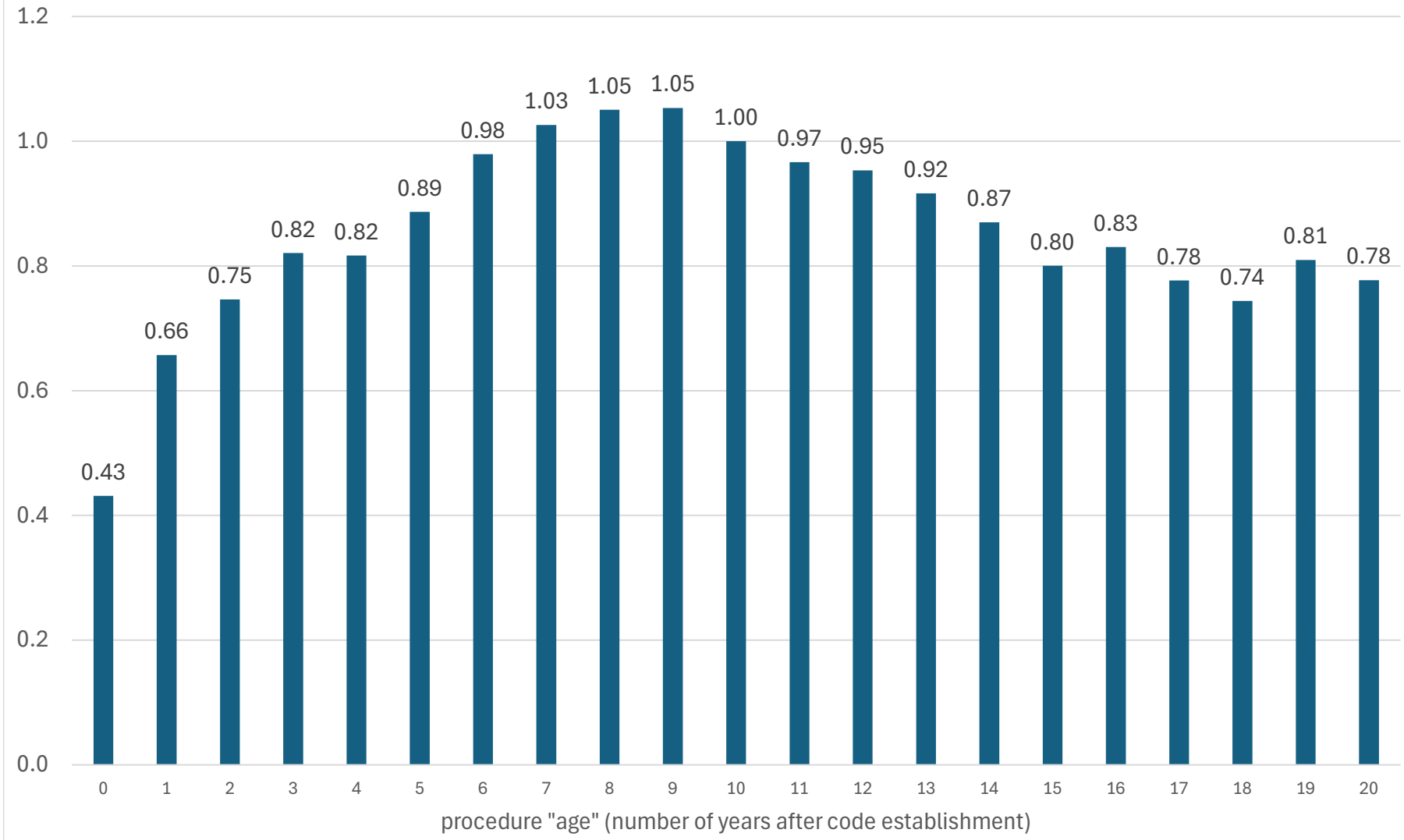
Each estimate is from a separate equation.

Appendix Figure 1





Appendix Figure 2
Ratio of mean expenditure on a procedure a years after procedure code establishment to mean expenditure 10 years after procedure code establishment:
procedures covered by Local Coverage Determinations



Appendix Table 1

No. of HCPCS codes ever established by end of 2023, by RBCS Category/subcategory

RBCS Category/subcategory	No. of HCPCS codes, end of 2023
Anesthesia	**308**
Anesthesia	308
DME	**3196**
Drugs Administered Through DME	81
Hospital Beds	37
Medical/Surgical Supplies	691
Orthotic Devices	1264
Other DME	616
Oxygen and Supplies	25
Wheelchairs	482
E&M	**717**
Behavioral Health Services	153
Care Management/Coordination	104
Critical Care Services	20
E&M - Miscellaneous	108
Emergency Department Services	19
Home Services	47
Hospice	9
Hospital Inpatient Services	33
Nursing Facility Services	29
Observation Care Services	12
Office/Outpatient Services	136
Ophthalmological Services	47
Imaging	**1136**
CT Scan	131
Imaging - Miscellaneous	41
Magnetic Resonance	111
Nuclear	249
Standard X-ray	445
Ultrasound	159
Other	**234**
Ambulance	21
Enteral and Parenteral	49
Vision, Hearing, and Speech Services	164
Procedure	**7294**
Breast	85
Cardiovascular	650
Digestive/Gastrointestinal	1012
Eye	361
Hematology	70

Appendix Table 1

No. of HCPCS codes ever established by end of 2023, by RBCS Category/subcategory

RBCS Category/subcategory	No. of HCPCS codes, end of 2023
Musculoskeletal	2206
Other Organ Systems	1948
Skin	475
Vascular	487
Test	**3128**
Anatomic Pathology	147
Cardiography	120
General Laboratory	1368
Molecular Testing	1071
Neurologic	150
Pulmonary	49
Pulmonary Function	43
Test - Miscellaneous	180
Treatment	**1984**
Chemotherapy	341
Dialysis	123
Injections and Infusions (nononcologic)	1088
Physical, Occupational, and Speech Therapy	76
Radiation Oncology	173
Spinal Manipulation	9
Treatment - Miscellaneous	174
Grand Total	**17997**

Appendix Table 2

Number of HCPCS codes ever established by 2000 and 2023, by Restructured BETOS Classification System category

Restructured BETOS Classification System category	2000	2023	% change
Anesthesia	234	308	32%
DME	1215	2546	110%
E&M	193	650	237%
Imaging	533	1044	96%
Procedure	4730	6730	42%
Test	1175	2645	125%
Treatment	586	1837	213%

Appendix Table 3

Number of services provided to, and total amount Medicare paid (after deductible and coinsurance amounts) for, original Medicare (fee-for-service) Part B (Medical Insurance) beneficiaries by physicians and other healthcare professionals, 2019

RBCS category	RBCS subcategory	Tot_Srvcs	tot_mdcr_pymt_amt
		3,277,811,140	**$104,144,090,242**
Anesthesia		**2,239,251**	**$31,189,727**
Anesthesia	Anesthesia	2,239,251	$31,189,727
DME		**4,658,401**	**$381,779,429**
DME	Drugs Administered Through DME	1,628,681	$106,963,103
DME	Hospital Beds	.	.
DME	Medical/Surgical Supplies	2,063,786	$198,550,559
DME	Orthotic Devices	937,746	$55,888,996
DME	Other DME	28,188	$20,376,771
DME	Oxygen and Supplies	.	.
DME	Wheelchairs	.	.
E&M		**500,321,352**	**$35,656,662,635**
E&M	Behavioral Health Services	22,737,039	$1,386,854,006
E&M	Care Management/Coordination	11,465,795	$725,031,097
E&M	Critical Care Services	6,463,481	$1,094,042,314
E&M	E&M - Miscellaneous	1,853,204	$58,655,018
E&M	Emergency Department Services	20,109,397	$2,132,900,483
E&M	Home Services	5,095,032	$344,616,889
E&M	Hospice	29,846	$2,409,557
E&M	Hospital Inpatient Services	102,802,158	$7,913,501,526
E&M	Nursing Facility Services	33,124,115	$2,186,033,052
E&M	Observation Care Services	5,244,388	$492,207,422
E&M	Office/Outpatient Services	265,749,980	$17,501,283,446
E&M	Ophthalmological Services	25,646,917	$1,819,127,825
Imaging		**329,546,396**	**$8,483,260,774**
Imaging	CT Scan	25,091,974	$1,548,769,415
Imaging	Imaging - Miscellaneous	10,774,938	$325,671,359
Imaging	Magnetic Resonance	8,466,701	$921,101,901
Imaging	Nuclear	54,719,432	$1,301,686,775
Imaging	Standard X-ray	195,200,334	$2,274,239,893
Imaging	Ultrasound	35,293,017	$2,111,791,431

Other		**159,925,918**	**$5,012,055,863**
Other	Ambulance	154,848,389	$4,778,086,295
Other	Enteral and Parenteral	.	.
Other	Vision, Hearing, and Speech Services	5,077,529	$233,969,568
Procedure		**146,423,171**	**$20,111,558,429**
Procedure	Breast	478,641	$180,376,831
Procedure	Cardiovascular	3,229,838	$1,153,362,216
Procedure	Digestive/Gastrointestinal	10,721,566	$2,234,866,302
Procedure	Eye	18,292,768	$3,323,358,520
Procedure	Hematology	50,435	$6,925,718
Procedure	Musculoskeletal	26,776,916	$5,418,376,809
Procedure	Other Organ Systems	11,674,529	$2,020,100,414
Procedure	Skin	71,507,627	$3,731,993,771
Procedure	Vascular	3,690,851	$2,042,197,848
Test		**536,936,656**	**$10,083,520,240**
Test	Anatomic Pathology	40,229,670	$1,651,091,292
Test	Cardiography	45,430,016	$945,716,100
Test	General Laboratory	413,661,498	$4,631,410,450
Test	Molecular Testing	9,496,629	$1,919,929,139
Test	Neurologic	4,737,574	$628,886,819
Test	Pulmonary	5,592,547	$150,821,280
Test	Test - Miscellaneous	17,788,722	$155,665,160
Treatment		**1,597,759,995**	**$24,384,063,145**
Treatment	Chemotherapy	283,705,205	$5,964,994,014
Treatment	Dialysis	6,052,623	$841,313,231
Treatment	Injections and Infusions (nononcologic)	1,106,558,577	$11,883,772,329
Treatment	Physical, Occupational, and Speech Therapy	145,953,767	$3,233,643,411
Treatment	Radiation Oncology	12,591,193	$1,583,723,255
Treatment	Spinal Manipulation	20,536,624	$560,253,064
Treatment	Treatment - Miscellaneous	22,362,006	$316,363,842

Appendix Table 4
HCPCS codes (listed in order of year of HCPCS code establishment) covered in at least one LCD for A02.1 Salmonella sepsis

year_hcpcs	hcpcs	long_description
1982	93005	ELECTROCARDIOGRAM, ROUTINE ECG WITH AT LEAST 12 LEADS; TRACING ONLY, WITHOUT INTERPRETATION AND REPORT
1982	93000	ELECTROCARDIOGRAM, ROUTINE ECG WITH AT LEAST 12 LEADS; WITH INTERPRETATION AND REPORT
1982	93010	ELECTROCARDIOGRAM, ROUTINE ECG WITH AT LEAST 12 LEADS; INTERPRETATION AND REPORT ONLY
1982	93320	DOPPLER ECHOCARDIOGRAPHY, PULSED WAVE AND/OR CONTINUOUS WAVE WITH SPECTRAL DISPLAY (LIST SEPARATELY IN ADDITION TO CODES FOR ECHOCARDIOGRAPHIC IMAGING); COMPLETE
1984	93040	RHYTHM ECG, 1-3 LEADS; WITH INTERPRETATION AND REPORT
1984	93041	RHYTHM ECG, 1-3 LEADS; TRACING ONLY WITHOUT INTERPRETATION AND REPORT
1984	93042	RHYTHM ECG, 1-3 LEADS; INTERPRETATION AND REPORT ONLY
1984	87188	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; MACROBROTH DILUTION METHOD, EACH AGENT
1984	87190	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; MYCOBACTERIA, PROPORTION METHOD, EACH AGENT
1984	87186	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; MICRODILUTION OR AGAR DILUTION (MINIMUM INHIBITORY CONCENTRATION [MIC] OR BREAKPOINT), EACH MULTI-ANTIMICROBIAL, PER PLATE
1984	87181	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; AGAR DILUTION METHOD, PER AGENT (EG, ANTIBIOTIC GRADIENT STRIP)
1984	87184	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; DISK METHOD, PER PLATE (12 OR FEWER AGENTS)
1988	87187	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; MICRODILUTION OR AGAR DILUTION, MINIMUM LETHAL CONCENTRATION (MLC), EACH PLATE (LIST SEPARATELY IN ADDITION TO CODE FOR PRIMARY PROCEDURE)
1989	93312	ECHOCARDIOGRAPHY, TRANSESOPHAGEAL, REAL-TIME WITH IMAGE DOCUMENTATION (2D) (WITH OR WITHOUT M-MODE RECORDING); INCLUDING PROBE PLACEMENT, IMAGE ACQUISITION, INTERPRETATION AND REPORT
1990	93325	DOPPLER ECHOCARDIOGRAPHY COLOR FLOW VELOCITY MAPPING (LIST SEPARATELY IN ADDITION TO CODES FOR ECHOCARDIOGRAPHY)
1990	93321	DOPPLER ECHOCARDIOGRAPHY, PULSED WAVE AND/OR CONTINUOUS WAVE WITH SPECTRAL DISPLAY (LIST SEPARATELY IN ADDITION TO CODES FOR ECHOCARDIOGRAPHIC IMAGING); FOLLOW-UP OR LIMITED STUDY (LIST SEPARATELY IN ADDITION TO CODES FOR
1993	93313	ECHOCARDIOGRAPHY, TRANSESOPHAGEAL, REAL-TIME WITH IMAGE DOCUMENTATION (2D) (WITH OR WITHOUT M-MODE RECORDING); PLACEMENT OF TRANSESOPHAGEAL PROBE ONLY
1993	93314	ECHOCARDIOGRAPHY, TRANSESOPHAGEAL, REAL-TIME WITH IMAGE DOCUMENTATION (2D) (WITH OR WITHOUT M-MODE RECORDING); IMAGE ACQUISITION, INTERPRETATION AND REPORT ONLY
1997	93317	TRANSESOPHAGEAL ECHOCARDIOGRAPHY FOR CONGENITAL CARDIAC ANOMALIES; IMAGE ACQUISITION, INTERPRETATION AND REPORT ONLY

Appendix Table 4
HCPCS codes (listed in order of year of HCPCS code establishment) covered in at least one LCD for A02.1 Salmonella sepsis

year_hcpcs	hcpcs	long_description
1997	93316	TRANSESOPHAGEAL ECHOCARDIOGRAPHY FOR CONGENITAL CARDIAC ANOMALIES; PLACEMENT OF TRANSESOPHAGEAL PROBE ONLY
1997	93315	TRANSESOPHAGEAL ECHOCARDIOGRAPHY FOR CONGENITAL CARDIAC ANOMALIES; INCLUDING PROBE PLACEMENT, IMAGE ACQUISITION, INTERPRETATION AND REPORT
2001	93318	ECHOCARDIOGRAPHY, TRANSESOPHAGEAL (TEE) FOR MONITORING PURPOSES, INCLUDING PROBE PLACEMENT, REAL TIME 2-DIMENSIONAL IMAGE ACQUISITION AND INTERPRETATION LEADING TO ONGOING (CONTINUOUS) ASSESSMENT OF (DYNAMICALLY CHANGING)
2001	87185	SUSCEPTIBILITY STUDIES, ANTIMICROBIAL AGENT; ENZYME DETECTION (EG, BETA LACTAMASE), PER ENZYME
2006	76377	3D RENDERING WITH INTERPRETATION AND REPORTING OF COMPUTED TOMOGRAPHY, MAGNETIC RESONANCE IMAGING, ULTRASOUND, OR OTHER TOMOGRAPHIC MODALITY WITH IMAGE POSTPROCESSING UNDER CONCURRENT SUPERVISION; REQUIRING IMAGE POSTPROC
2006	76376	3D RENDERING WITH INTERPRETATION AND REPORTING OF COMPUTED TOMOGRAPHY, MAGNETIC RESONANCE IMAGING, ULTRASOUND, OR OTHER TOMOGRAPHIC MODALITY WITH IMAGE POSTPROCESSING UNDER CONCURRENT SUPERVISION; NOT REQUIRING IMAGE POST
2008	C8926	TRANSESOPHAGEAL ECHOCARDIOGRAPHY (TEE) WITH CONTRAST, OR WITHOUT CONTRAST FOLLOWED BY WITH CONTRAST, FOR CONGENITAL CARDIAC ANOMALIES; INCLUDING PROBE PLACEMENT, IMAGE ACQUISITION, INTERPRETATION AND REPORT
2008	C8925	TRANSESOPHAGEAL ECHOCARDIOGRAPHY (TEE) WITH CONTRAST, OR WITHOUT CONTRAST FOLLOWED BY WITH CONTRAST, REAL TIME WITH IMAGE DOCUMENTATION (2D) (WITH OR WITHOUT M-MODE RECORDING); INCLUDING PROBE PLACEMENT, IMAGE ACQUISITION
2008	C8927	TRANSESOPHAGEAL ECHOCARDIOGRAPHY (TEE) WITH CONTRAST, OR WITHOUT CONTRAST FOLLOWED BY WITH CONTRAST, FOR MONITORING PURPOSES, INCLUDING PROBE PLACEMENT, REAL TIME 2-DIMENSIONAL IMAGE ACQUISITION AND INTERPRETATION LEADING
2015	87505	INFECTIOUS AGENT DETECTION BY NUCLEIC ACID (DNA OR RNA); GASTROINTESTINAL PATHOGEN (EG, CLOSTRIDIUM DIFFICILE, E. COLI, SALMONELLA, SHIGELLA, NOROVIRUS, GIARDIA), INCLUDES MULTIPLEX REVERSE TRANSCRIPTION, WHEN
2015	93355	ECHOCARDIOGRAPHY, TRANSESOPHAGEAL (TEE) FOR GUIDANCE OF A TRANSCATHETER INTRACARDIAC OR GREAT VESSEL(S) STRUCTURAL INTERVENTION(S) (EG, TAVR, TRANSCATHETER PULMONARY VALVE REPLACEMENT, MITRAL VALVE REPAIR, PARAVALVULAR RE
2022	93319	3D ECHOCARDIOGRAPHIC IMAGING AND POSTPROCESSING DURING TRANSESOPHAGEAL ECHOCARDIOGRAPHY, OR DURING TRANSTHORACIC ECHOCARDIOGRAPHY FOR CONGENITAL CARDIAC ANOMALIES, FOR THE ASSESSMENT OF CARDIAC STRUCTURE(S) (EG, CARDIAC C