Experimental Disease Based Price Indexes

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Abstract

The Bureau of Labor Statistics(BLS) is releasing an experimental disease based price index series. This article starts by explaining the reasons for generating these type of indexes. It derives the ideal indexes based on Cost of Living Theory and then documents the constraints toward acheiving this ideal. Next, we describe the recommendations made by the Committee on National Statistics (CNSTAT) on the construction of an experimental disease based price index and how BLS has implemented this recommendation. We present our reults for these disease based price indexes produced through 2014.

1 Introduction

It is very important to measure the healthcare sector correctly. First, in 2012 healthcare spending was 17.6% of Gross Domestic Product (GDP) and in 1960, it was only 5.2%. We all need to understand the reasons for this 3.4 fold growth. Second, correct measurement of the healthcare economy is a prerequisite to correctly measuring the entire economy because of its large share. Mismeasuring healthcare output will lead to mismeasuring total output. Finally, accurate measurement of the healthcare economy is an essential ingredient in the successful referring of the healthcare policy debate. Healthcare measures such as expenditures and price indexes need to give the public clear and transparent understanding of both the trends and causes for healthcare output growth and inflation. If healthcare price indexes are biased upward, then the public is getting more for its healthcare dollar than the statistics portray. The reverse is true if healthcare price indexes are biased downward. Any bias in healthcare price

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indexes can lead the public to draw incorrect inferences about the healthcare policy debate and to make poor decisions.

For over a hundred years, the Bureau of Labor Statistics (BLS) and the other statistical agencies have published their health care statistics by medical goods and services such as hospital services or pharmaceuticals. Many health economists and other healthcare experts are calling on BLS and the rest of the Federal statistical community to publish their healthcare statistics by disease rather than by medical goods and services because they will better measure the healthcare sector and they will provide the essential tools to investigate the reason behind the changes in nominal healthcare spending as well as referring the policy debate.

This article explains the reasons that healthcare statistics published on a disease basis can provide better information on the well being of the American healthcare economy and ultimately on the over all economy. While generating statistics on a disease basis improves our understanding of the healthcare economy, other improvements such as monitoring and accounting for quality changes are also essential.

When BLS set out to construct disease based price indexes, it had several goals. The first goal was feasibility. The construction of these indexes could not disrupt existing programs and would not require additional spending on new data. Second, the method had to be transparent. Third, the indexes had to be timely and lastly, there needed to be a cost of living basis for the indexes. The experimental indexes reported in this article attempt to satisfy all these goals.

Even though from 1999 to 2014 disease based price indexes on average grow less rapidly than indexes created from traditional methods, there is a large variation of results across diseases. There are several diseases were traditional indexes growth more slowly than the disease indexes. The organs, tissue and other body parts provide heterogeneous functionality and the services and products used to treat these various parts are also highly heterogeneous. Then, it should not be surprising that there is a wide variety of results across diseases. The major factor behind the lower growth rate for disease based price index are the reduction in the use of all services treating diseases. Some disease price indexes such as infectious/parasitic disease and diseases of the respiratory system grew more rapidly than the traditional indexes. For both of these diseases there was a utilization shift from physician services to inpatient hospital services and this was the factor that induced their disease based price indexes to be greater than their traditional price indexes.

We can use disease based price indexes to decompose nominal expenditure growth into the part that comes from price growth and disease prevalence growth. On average the price growth is greater than the prevalence growth. But, there are important exceptions. For endrocrine and metabolic disease expenditure growth, prevalence is the major factor that drives nominal expenditure growth. Diabetes growth is the big culprit in this category.

Section 2 of this article provides an intuitive explanation of the reasons that a disease based approach to reporting healthcare statistics is better than a goods and service based index. Section 3 starts by outlining the ideal economic approach to disease price indexes and then discusses the constraints toward achieving this ideal.[1] Section 4 contains the recommendation from the Committee on National Statistics 2002 on BLS's generation of experimental disease based price index methods and then shows how BLS has implemented this recommendation. Section 5 gives the results and Section 6 discusses necessary improvements for disease based price indexes.

2 Benefits of Reporting by Disease

Federal statistical agencies still report healthcare statistics by medical goods and services even though most experts acknowledge that a disease based approach is better. This is currently done because the firms that sell these goods and services can be sampled and can disseminate data on their utilizations and reimbursements. Collecting data on a disease basis is difficult because there is no firm that purchases all the physician, hospital, pharmaceutical and other inputs to treat a disease and then charges one price for the treatment of the entire disease. Therefore, there is no one price or expenditure for treating a disease that a statistical agency can collect.

Yet, starting with Scitovsky (1967), numerous studies find that one can draw different inferences about the healthcare economy when reporting on a disease basis than a service basis. A disease based approach better accounts for technical innovations that alter how medical goods and services are used to treat diseases than a medical goods and services approach.

If expenditures and price indexes are reported on a disease basis, we can better find i) what diseases are contributing most to aggregate healthcare costs in the economy, ii) once we have identified the diseases that are contributing the most to expenditures, we can further drill down to determine if the growth for that disease is coming from higher inflation, higher prevalence, or higher utilization of goods and services to treat the particular disease and iii) we can account for utilization changes that come from technical innovations in treating diseases.

The following identity for disease, d, can be useful for determining the parts of nominal expenditure growth, $E_{d,t}/E_{d,t-1}$, from period $t-1$ to t that come from inflation, $P_{d,t}/P_{d,t-1}$,[2] U.S. Population growth, Pop_t/Pop_{t-1}, the growth in the rate of treatment prevalence, $r_{d,t}/r_{d,t-1}$, and real output per patient, $Q_{d,t}/Q_{d,t-1}$,treated for disease d :

$$\frac{E_{d,t}}{E_{d,t-1}} = \frac{P_{d,t}}{P_{d,t-1}} \frac{Pop_t}{Pop_{t-1}} \frac{r_{d,t}}{r_{d,t-1}} \frac{Q_{d,t}}{Q_{d,t-1}}. \tag{1}$$

The total number of individuals treated for disease d in period t is $N_{d,t} = Pop_t \times r_{d,t}$. The reason that it is important to decompose $N_{d,t}$ into Pop_t and

[1] There are three approaches to price indexes - 1) the economic (Cost of Living) approach, 2) the axiomatic approach and 3) the stochastic approach. BLS attempts to pursue the economic approach.

[2] $P_{d,t}/P_{d,t-1}$ is the price index for disease d with the base period $t-1$ and the comparison period t.

$r_{d,t}$ is that it is useful to understand how $N_{d,t}$ is changing. If $r_{d,t}/r_{d,t-1}$ is greater than one, an increasing fraction of the population is either contracting or being diagnosed with disease d or in other words, the population is "getting relatively sicker with disease d." Healthcare experts might then be motivated to re direct research into the finding reasons that an increasing fraction of the nation's population is being treated for disease d. Likewise, if inflation growth, $P_{d,t}/P_{d,t-1}$, is the key driver then research is more effectively directed at finding the causes of this inflation growth rather than prevalence.[3]

Here we present a price index approach to decomposing the growth in nominal expenditures. Other studies use the growth in the average treatment cost per patient in place of $P_{d,t}/P_{d,t-1}$ and $Q_{d,t}/Q_{d,t-1}$ (i.e. Average Cost Growth $=(P_{d,t}Q_{d,t}/N_{d,t})/(P_{d,t-1}Q_{d,t-1}/N_{d,t-1})$. Starr et. al (2014), Roehrig et. al (2010), Thorpe et. al (2004) and Bundorf et. al (2009) have done decompositions using the average cost approach. Cost is price multiplied times quantity(output) and does not decompose the two. When using a price index approach, it is possible to decompose the two. Our results have inflation as the major factor behind nominal expenditure growth, but this does not hold for each individual disease.

The results from previous decomposition studies vary. Thorpe et. al conclude that the growing prevalence of chronic disease is the largest contributor to historical healthcare cost growth while the rest conclude that it is the growth in the average cost of treating a patient. The studies are conducted during different time periods and this may influence the different results. Starr et. al cover the longest time period that starts in 1980 and ends in 2006. None cover the period after 2008 when the healthcare expenditure growth began to slow and become closer to real GDP growth.

Our future goal is to be able to track the characteristic improvements of the various medical goods and services and find how they create better health outcomes. This would allow us to generate "quality adjusted" disease based price indexes and provide a better understanding of the condition of the US healthcare sector. Denote $h_{d,t}$ as the health outcome of treating disease d in period t. The consumer's value for $h_{d,t}$ is $v(h_{d,t})$. Then, we could rewrite the decomposition in (1) as:

$$\frac{E_{d,t}}{E_{d,t-1}} = \frac{P_{d,t} \times v(h_{d,t-1})}{P_{d,t-1} \times v(h_{d,t})} \frac{Pop_t}{Pop_{t-1}} \frac{r_{d,t}}{r_{d,t-1}} \frac{O_{d,t} \times v(h_{d,t})}{O_{d,t-1} v(h_{d,t-1})}. \tag{2}$$

The left side of (2) is the same as (1). The right sides differ because in (2) both the price index and the output index have a quality adjustment reflecting the value of the change in health outcomes.

[3] Even if inflation is the primary driver behind nominal expenditure growth, healthcare experts still might find that it is more effective to reduce nominal expenditure growth by attempting to reduce treatment prevalence.

3 Economic Approach to Disease Price Indexes

The past criticisms of the service price index approach can be cast using an economic (or Cost of Living (COL)) approach first established by Konüs (1939).[4] Both the CPI and PPI are "two stage" indexes. In the first stage, sub indexes for items such as food, apparel, and medical care are computed. In the second stage, an "All Items" indexes is constructed from the first stage sub indexes. The medical price index must then serve two basic purposes: i) it must measure medical inflation and ii) it is an input into computing the overall inflation rate. Past COL critiques have ignored these purposes.[5] When using a COL approach to price indexes, the ability to derive an "all-item" index from subindexes such as food, clothing, and medical requires separability in preferences among these items, and I use here a Constant Elasticity of Substitution (CES) utility form so that this separability assumption is satisfied.[6]

On the consumer (demand) side, in period t there is a consumption good, c_t, and a stock of health capital, $H_{d,t}$ for an individual with disease, d.[7] This individual's CES utility function is

$$U(c_t, H_{d,t}) = [(a_c c_t)^{1/\rho} + (a_H H_{d,t})^{1/\rho}]^{1/\rho}. \tag{3}$$

Suppose that additional units of health stock, $h_{d,t}$, could be purchased at price $p_{h_d,t}$.[8] Then the COL price index between a base period s and a comparison period t is a ratio of the expenditure functions of the two periods or

$$I(\{p_{c,r}, p_{h_d,r}\}_{r=s,t}) = \frac{[(p_{c,t}/a_c)^{1-\sigma} + (p_{h_d,t}/a_H)^{1-\sigma}]^{1/(1-\sigma)}}{[(p_{c,s}/a_c)^{1-\sigma} + (p_{h_d,s}/a_H)^{1-\sigma}]^{1/(1-\sigma)}}, \tag{4}$$

where $p_{c,t}$ is the price of the consumer good, and $\sigma = -1/(\rho - 1)$. Since (3) is homogeneous, the reference utility levels cancel in (4). The index derived in (4) is the "ideal" index for all consumer items that a statistical agency wishes to measure. In this simple economy Sato (1976) shows that the statistical agency can compute $I(\{p_{c,r}, p_{h_d,r}\}_{r=s,t})$ without knowing σ, a_c, or a_H with the Sato-Vartia index,

$$SV_{s,t} = \exp\{w_c(s,t)\ln(p_{c,t}/p_{c,s}) + w_h(s,t)\ln(p_{h_d,t}/p_{h_d,s}\} = I(\{p_{c,r}, p_{h_d,r}\}_{r=s,t}), \tag{5}$$

[4] The COL (or Konüs) index is the ratio of the comparison period (t) expenditure function to the base period (s) expenditure function. It is the minimum increase in income necessary to keep utility levels constant between the base and comparison period. Both periods have the same reference utility level. Since the utility functions here are homogeneous, the reference utility level cancels out.

[5] The COL approach that I use here differs from the compensating variation approach used in Cutler et. al. (1998) where they treat the consumption good as the numeraire. Since BLS must compute a subindex for each consumer item to generate the all items CPI or PPI, it cannot treat any one item as a numeraire.

[6] The CPI and PPI use Lowe and Geometric mean indexes. Both of these are elements of indexes derived from the CES family of preferences and/or production.

[7] Here, I treat c_t as a single non medical consumption good. It could be an aggregate from many non medical consumption goods indexed by k. In this case under nested CES preferences $c_t = \left(\sum_k [a_{c,k} c_{k,t}]^\theta\right)^{1/\theta}$.

[8] $h_{d,t}$ is the same variable here as it is in Section 2.

where $w_i(s,t)$ is the logarithmic mean weight for good i, or for example,

$$w_c(s,t) = \frac{s_{c,t} - s_{c,s}}{\ln(s_{c,t}) - \ln(s_{c,s})}. \tag{6}$$

For CES preferences, the Sato Vartia in (5) is a *superlative* index because it equals the COL index and it does not require any estimation of the utility function's parameters. One challenge to determining the "ideal" (3) is that in medical markets, $h_{d,t}$ is not traded at a market price, $p_{h_d,t}$.[9] In fact, $p_{h_d,t}$ cannot be observed or measured since it does not exist. Instead, there are a set of K input services and goods, denoted by a $K \times 1$ vector, $z_{d,t}$,which has measurable and observable prices. Suppose $h_{d,t}$ is produced under the production function

$$h_{d,t} = f_{d,t}(z_{d,t}). \tag{7}$$

Since $z_{t,d}$ has observable and measurable prices while $h_{d,t}$ does not, statistical agencies such as the US Bureau of Economic Analysis and BLS view them as final goods and services. Therefore items in $z_{d,t}$ such as physician visits, outpatient procedures, and prescription fills find themselves included as final goods when computing GDP instead of being treated as inputs. BLS constructs a separate service price index for each of these items and the CPI and PPI "all-medical" price indexes are an expenditure weighted average of these service price indexes.

Despite this, the inability to measure $h_{d,t}$ and its price should not stop us from computing an exact COL or superlative index. For example, if $f_{d,t}(.)$ is a CES production function and the patient alone knowing the production function (or the physician acting as a perfect agent) chooses $z_{t,d}$, we could still construct a nested COL. Letting the production function be

$$f_{d,t}(z_{d,t}) = \left(\sum_{k=1}^{K} [b_{k,d} z_{k,d,t}]^{\gamma} \right)^{1/\gamma}. \tag{8}$$

$z_{k,d,t}$ is the k^{th} element of $z_{d,t}$. We could easily substitute $f_{d,t}(z_{d,t})$ for $h_{d,t}$ and have a nested CES utility function along the lines of Sato (1967). The aggregate price for a unit of $h_{d,t}$ is then equivalent to

$$p_{h_d,t} = \left(\sum_{k=1}^{K} [p_{k,t}/b_{k,d}]^{1-\omega} \right)^{1/(1-\omega)}, \quad \omega = -1/(\gamma - 1). \tag{9}$$

[9] For example, in the Cutler et al. (1998) study for heart attacks, $h_{d,t}$ is the additional expected life years coming from Acute Myocardial Infarction treatment. However, the provider is not reimbursed at a fixed market price per quality adjusted life year for the number of life years delivered. As a result, they establish three different "dollar values" for an additional life year, and compute three separate indexes using these three values. In Berndt et al. (2002) $h_{d,t}$ is the remission from mental illness. For each combination of inputs such as drug and office therapy, they derive from a consensus estimate made by medical health experts the probability of remission given these inputs. Again, the provider is not reimbursed on the outcome of remission but on the goods and services delivered to treat this depression. The price here is the total cost of the treatment combination. For Shapiro Wilcox (1996), $h_{d,t}$ is the elimination of cataracts. Even, if cataract surgery fails, the providers are still reimbursed.

Here $p_{k,t}$ is the market price of the k^{th} service. To compute $p_{h_d,t}/p_{h_d,s}$ in (5), the statistical agency would compute a Sato-Vartia Index for the medical inputs:

$$p_{h_d,t}/p_{h_d,s} = \exp\{\sum_{k=1}^{K} w_k(s,t)\ln(p_{k,t}/p_{k,s})\}, \tag{10}$$

and plug this into (5). Therefore, the statistical agency could still compute a superlative medical index, superlative indexes for non medical goods, and a superlative "all-items" index. Total expenditure growth for disease d can be decomposed into a price index and output (quantity) index:

$$\frac{E_{d,t}}{E_{d,t-1}} = \frac{p_{h_d,t}}{p_{h_d,s}}\frac{f_{d,t}(z_{d,t})}{f_{d,t-1}(z_{d,t-1})}.$$ [10]

However, as the medical price index critics have shown for particular diseases, $b_{k,d}$ in (8) changes (and in most cases increases) over time. Therefore, there must be an added time subscript, $b_{k,d,t}$. When these coefficients vary over time, the Sato-Vartia index is no longer superlative for the CES form. When d is heart disease, depression, or cataracts, Cutler et al. (1998), Berndt et al. (1996,2001,2002), and Shapiro and Wilcox (1996) respectively show that for some good or service k, and $s < t$, $b_{k,d,t} > b_{k,d,s}$. The true price equivalent of $h_{d,t}$ is

$$p_{h_d,t} = \left(\sum_{k=1}^{K}[p_{k,t}/b_{k,d,t}]^{1-\omega}\right)^{1/(1-\omega)}. \tag{11}$$

This differs from (9) because the $b_{k,d,t}$ coefficients are now variable. Since ω is bounded below by 0, $\partial p_{h_d,t}/\partial b_{k,d,t} \leq 0$ (exactly zero at $\omega = \infty$).[11] It is possible that while the service price for the k^{th} service is rising, $p_{k,t} > p_{k,s}$, $s < t$, the marginal healing product is also rising, $b_{k,d,t} > b_{k,d,s}$, $s < t$. When the statistical agency does not account for the latter, its price index is greater than the ideal, COL, index. When $b_{k,d,t}$ is changing and $h_{d,t}$ and $p_{h_d,t}$ cannot be measured, the ideal medical price index for one with disease d,

$$I(\{p_{k,r}\}_{r=s,t;k=1..K}) = \frac{\left(\sum_{k=1}^{K}[p_{k,t}/b_{k,d,t}]^{1-\omega}\right)^{1/(1-\omega)}}{\left(\sum_{k=1}^{K}[p_{k,s}/b_{k,d,s}]^{1-\omega}\right)^{1/(1-\omega)}}, \tag{12}$$

cannot be estimated with a parameter free superlative.

There are changes in the characteristics of service k that induce changes in $b_{k,d,t}$. Let $c_{k,t}$ be a $C \times 1$ vector of characteristics. Then $b_{k,d,t}$ could be a

[10] This is the decomposition for the individual and differs from both (1) and (2) because those are decompositions for aggregated expenditures.

[11] This is more difficult to show for $\omega = 1$. When this occurs, we get the Cobb Douglas form, through normalizing the $b_{k,d,t}$ coefficients by $\alpha_{k,d,t} = b_{k,d,t}/\sum_{k=1}^{K} b_{k,d,t}$. Then, $p_{h,t} = A_{h.t}\left[\prod_{k=1}^{K} p_{k,d,t}^{\alpha_{k,d,t}}\right]$, where $A_{h.t} = \left(\sum_{k=1}^{K} b_{k,d,t}\right)^{-1}$, and $\sum_{k=1}^{K}\alpha_{k,d,t} = 1$.

function of these characteristics, $b_{k,d,t} = b_{k,d,t}(c_{k,t})$, and it could be a change in $c_{k,t}$ that is changing $b_{k,d,t}$. One might ask why the statistical agency does not use Feenstra's (1995) or Rosen's (1974) hedonic methods to estimate $b_{k,d,t}(c_{k,t})$ and then plug these estimates into (10)? There are several impediments to hedonics. First, not all the $c_{k,t}$ are observable. For example, physician training might be an important characteristic, but as of this writing no government statistical agency collects this. Another example might be when an outpatient facility makes a large capital purchase such as a Da Vinci Surgical System. It is not possible for BLS data collectors to obtain this information from the outpatient billing office which is the venue where prices are collected. A second impediment is that most medical payments are third party reimbursements, and the total price, $p_{k,t}$, does not represent a patient's "willingness to pay," which is a crucial assumption for these hedonic methods.

Let there be a finite, D, number of diseases where π_d denotes the fraction of the population with disease d. Then a desired aggregate medical price index could be:[12]

$$I(\{p_{k,r}\}_{k=1,d=1,r=s}^{K,D,t}) = \frac{\sum_{d=1}^{D} \left(\sum_{k=1}^{K} [p_{k,t}/b_{k,d,t}]^{1-\omega} \right)^{1/(1-\omega)} \pi_d}{\sum_{d=1}^{D} \left(\sum_{k=1}^{K} [p_{k,s}/b_{k,d,s}]^{1-\omega} \right)^{1/(1-\omega)} \pi_d}. \tag{13}$$

This also cannot be measured by a superlative index. One must be able to estimate the changing parameters in (11), and at minimum one needs to be able to measure $h_{d,t}$ to do this.

Changes in $b_{k,d,t}$ are not the only challenge for computing a superlative index. There are other reasons that traditional superlative index theory as outlined in Diewert (1976) fails for medical goods. First, unlike other goods and services, health expenditures are financed in part by third party payments and not entirely from a consumer's disposable income. Second, many of the purchasing decisions made for $z_{d,t}$ are made by either physicians and/or health plans. It is not clear if either of these are perfect agents for the consumer. On the PPI (producer/provider) side, duality, which is often used for the economic approach, fails. The provider does not purchase and take complete ownership of the inputs $z_{d,t}$ and convert them according to the technology in (8) into $h_{d,t}$, before selling it as a final good to the consumer. Therefore, there is no produce/provider incentive for cost minimization and there is no cost function.[13] Since the traditional economic approach to price indexes for non medical goods and services is based on the cost function, it is then not possible to derive a medical price index using a traditional economic approach for non medical goods.

[12] This COL can be viewed as a nested CES. Let $p_{d,t} = \left(\sum_{k=1}^{K} b_{k,d,t}^{\omega} p_{k,d,t}^{1-\omega} \right)^{1/(1-\omega)}$, then $I(\{p_{k,d,r}\}_{d=1,r=s}^{D,t}) = \frac{\sum_{d=1}^{D} p_{d,t}\pi_d}{\sum_{d=1}^{D} p_{d,s}\pi_d}$. The disease "outer nest" is strictly Leontieff since d is not selected by the consumer. If the "outer nest" is not Leontieff, we could image a patient who would say, "This diabetes is getting expensive. I think that I will substitute to having asthma."

[13] This is a commonly heard complaint of the US fee for service system.

Because superlative index theory fails, when Cutler et al. (1998) derive their price index for heart attack treatments, they obviously do not compute a superlative index, nor do they estimate a cost function. Instead they impute $h_{d,t}$ for a heart attack patient by estimating the additions to life expectancy coming from the treatment's improvements. Since they cannot observe a market price for these life years, they assign three alternative values to an additional year of expected life expectancy, and compute three alternative Laspeyres indexes that adjust for the increased life expectancies. What they show, is that while nominal costs for heart surgery are rising, when one factors in the additional value coming from the increased life expectancy, the adjusted Laspeyres price indexes actually fall.[14]

4 The Committee on National Statistics Recommendation

In Chapter 6 of Schultze and Mackie ed. (2002) the Committee on National Statistics (CNSTAT) discusses the challenges and the special nature of constructing medical price indexes. Many of the issues discussed here are similar to the ones outlined in Section 2. However, CNSTAT's focuses on the studies such as Shapiro and Wilcox (1996) and Berndt et al. (1996,2001,2002) that showed for particular diseases a shift away from more expensive inputs toward less expensive ones. In particular, their recommendation 6-1 states:

> BLS should select between 15-40 diagnoses from the ICD (International Classification of Diseases), chosen randomly in proportion to their direct medical treatment expenditures and use information from retrospective claims databases to identify and quantify the inputs used in their treatment and to estimate their cost. On a monthly basis, the BLS could re-price the current set of specific items (e.g., anesthesia, surgery, and medications), keeping quantity weights temporarily fixed. Then, at appropriate intervals, perhaps every year or two, the BLS should reconstruct the medical price index by pricing the treatment episodes of the 15 to 40 diagnoses—including the effects of changed inputs on the overall cost of those treatments. The frequency with which these diagnosis adjustments should be made will depend in part on the cost to BLS of doing so. The resulting MCPI price indexes should initially be published on an experimental basis. The panel also recommends that the BLS appoint a study group to consider, among other things, the possibility that the index will 'jump' at the linkage points and whether a prospective smoothing technique should be used.[15]

[14] Additionally, Cutler et. al (1998) are working with a "right censored" data set where there are surviving patients at the end of the sample. They estimate life expectancy for the censored observations through the use of a hazard function.

[15] "MCPI" stands for Medical CPI.

After this recommendation was made, several studies computed disease based indexes for all diseases within a classification system rather than generating an index for just one disease. The first study is Song et al. (2009) which follows the CNSTAT recommendation for three US cities from 1999 to 2004. Bradley et. al. (2010) also follows the CNSTAT recommendation, but the use of expensive claims data is not consistent with BLS goals and instead, they use data from the Medical Expenditure Panel Survey (MEPS) in place of claims data. Aizcorbe and Nestoriak (2011) generate Medical Care Expenditure Indexes from a private insurance claims data base, and Aizcorbe et. al (2011) use MEPS but do not use BLS prices as recommended by CNSTAT. Finally, Bradley (2013) propose the use of both MEPS and BLS price data in a way that timely indexes can be put into production. In all these studies, the disease based price indexes grow less rapidly than the service based counterparts. Dunn et. al (2012) contribute another feature where they account for the "intra industry" substitutions and they find that over time there has been an increase in the number of procedures administered per encounter. While the across industry substitutions have lowered disease based price index within industry substitutions have done the opposite.

4.1 The Cost of Living Implications of the CNSTAT Proposal

The CNSTAT Price Index for disease d from period s to period t is:

$$\widetilde{L}_{d,s,t} = \frac{\sum_{k=1}^{K} p_{k,d,t} z_{k,d,y(t)}}{\sum_{k=1}^{K} p_{k,d,s} z_{k,d,y(t-1)}}. \tag{14}$$

CNSTAT calls for yearly updates on the quantities. Therefore, $y(t)$ is a yearly index function whose argument is a year-month. It returns a year that corresponds to a month-year, t. $y(t)$ is constant for 12 months and only changes at the yearly update of the inputs. Notice that only in January of a given year do the quantities in numerator and denominator differ for (14). It is in this month that the CNSTAT recommendation predicts that the "index will jump."

The following proposition outlines the conditions that make the CNSTAT recommended index is a Cost of Living Index:

Proposition 1 *If (i) $h_{d,t}$ has a Leontieff production function with coefficients, $b_{k,d,y(t)}$ that vary over yearly intervals, (ii) $h_{d,t} = h_{d,s}$ for all t and s, and $p_{d,k,t} = p_{k,t}$ for all d, then $\widetilde{L}_{d,s,t}$ is a Cost of Living Index.*
Proof. *The production function is*

$$h_{d,t} = \min\{b_{k,d,y(t)} z_{k,d,t}\}_{k=1}^{K}.$$

The cost function is

$$C_{d,t} = h_{d,t} \sum_{k=1}^{K} p_{k,d,t}/b_{k,d,y(t)}.$$

The true COLI is then:

$$\frac{C_{d,t}}{C_{d,t-1}} = \frac{h_{d,t} \sum_{k=1}^{K} p_{k,d,t}/b_{k,d,y(t)}}{h_{d,t-1} \sum_{k=1}^{K} p_{k,d,t-1}/b_{k,d,y(t-1)}}$$

By Shephard's Lemma, $z_{k,d,y(t)} = h_{d,t}/b_{k,d,y(t)}$ *and by condition (ii) of this proposition* $z_{k,d,y(t-1)} = h_{d,t}/b_{k,d,y(t-1)}$*, when both these are substituted for* $z_{k,d,y(t)}$ *and* $z_{k,d,y(t-1)}$ *in (14), we get this result.* ■

The Leontieff form often should be the correct production function. For example, one cannot get a pharmaceutical good without a physician prescription. However, the constant healing outcome assumption ($h_{d,t} = h_{d,s}$) is problematic, and we need a detailed survey on both the characteristics of the K medical goods and services as well as outcome measures for $h_{d,t}$ so that we can estimate the production parameters $b_{k,d,y(t)}$. The CNSTAT index does get us closer to a true index because it does allow us to update the utilizations for each disease.

A price index computed using a traditional Lowe Index for disease d from period s to period t is:

$$L_{d,s,t} = \frac{\sum\limits_{k=1}^{K} p_{k,d,t} z_{k,d,y(0)}}{\sum\limits_{k=1}^{K} p_{k,d,s} z_{k,d,y(0)}} \tag{15}$$

Notice that the quantities, $z_{k,d,y(0)}$, do not get updated. Thus, there is no accounting for the utilization changes or substitution across the K goods and services. The BLS price indexes for medical goods and services are currently constructed for the formula in (15).

4.2 Implementation of the CNSTAT Recommendation

We implement the CNSTAT recommendation with the blended use of BLS price indexes and MEPS. MEPS is an annual set of surveys conducted by the Agency for Healthcare Research and Quality. MEPS has three major surveys - the Consolidated Household Survey, the Medical Provider Survey, and the Insurance Component Survey in the Consolidated Household Survey, households are selected through a stratified random sample, and once one is selected, she or he is interviewed over a set of five rounds during two years. The survey asks these households to report any disease contracted for a fixed period of time, and what providers were contacted to treat these diseases. The survey gathers economic and demographic information such as age, gender and marital status. The medical providers mentioned by the household respondents are also surveyed to provide additional information on how the household was treated for its diseases. There is also an Insurance Component Survey (MEPS-IC) where employers are surveyed for the health plans that they sponsor for their employees. We do not use the MEPS-IC for disease based price indexes.

The MEPS data files are available on their website.[16] The results of survey are contained in a structured database with different files that can be easily linked. The first file, the Household File has a unique record for each individual in the survey and contains economic, demographic, and various health metrics. The second major file is the "Conditions File." Each time an individual reports a disease, a record is generated on the Conditions File. This record lists the disease's three digit ICD-9 code and its Clinical Classification Code (which MEPS recommends as a superior classification.) An additional variable in the Conditions file reports whether the disease was caused by an accident. The next set of files are "Event" files. There are event files for office based visits, outpatient visits, inpatient hospital visits, home health care visits, emergency room visits, and prescription fills. When a respondent reports, say, a visit to an emergency room, a record is created on the emergency room event file. The total payment for the visit is listed along with the amount financed by various third party sources, and out of pocket payments. We link the Conditions File with the Event files to get annual utilizations updates for each year.

MEPS is not a timely survey. It has a three year lag. So, using it alone does not allow us to generate timely indexes. Since the BLS indexes for medical goods and services is timely, we combine the MEPS utilization and initial prices with BLS indexes to generate a timely CNSTAT index as depicted in (14). Denote, $I_{k,t}$, as the BLS price index for service k in month t. Then the price, $p_{k,d,t}$, in (14) is imputed as:

$$p_{k,d,t} = p_{k,d,0} I_{k,t} / I_{k,0}.$$

Since MEPS has a three year lag, the $y(t)$ function in (14) is also lagged. t is a monthly index variable and for our implementation of the CNSTAT index, $y(t)$ must take the form

$$y(t) = year\ of\ t - 3.$$

For example, if t is March 2009 then $y(t)$ is 2006. This means that the utilizations, $z_{k,d,y(t)}$, in (14) has a three year lag.

To impute physician service prices, we use the Physician PPI instead of the Physician CPI because the Physician PPI includes Medicaid and the CPI does not. Likewise, we use the PPI for hospitals because the PPI for hospitals includes Medicare Part A and the CPI hospital index does not. We use the CPI Pharmaceutical Index to update pharmaceutical prices because PPI pharmaceuticals only covers domestically produced pharmaceuticals while the CPI pharmaceutical index covers all pharmaceuticals consumed in the United States.

Since the utilizations are updated yearly and the indexes are monthly, in January, when the $z_{k,d,y(t)}$ are updated, $z_{k,d,y(t)} \neq z_{k,d,y(t-1)}$. This change will make the index jump *if all the yearly quantity change is incorporated into the*

[16] http://meps.ahrq.gov/mepsweb/.

January index instead of being equally allocated across the 12 months. We calculate two sets of indexes. The first incorporates all the utilization update in January and the second allocates 1/12 of the yearly change to each month. The second method generates a smoother index and is the one that should be used for deflation purposes. The first index gives us a metric that measures the inflationary effect of the utilization update.

We also generate indexes that adjust and do not adjust for comorbidities. By comparing these two indexes we can get a measure of the effects of comorbidities in our index. We adjust for comorbidities using a simple pro rationing method. For example, if the average quantity of office visits to treat heart disease is 3 and the average quantity to treat diabetes is 2, then if an office visit treats both diabetes and heart disease, then 3/5 of the visit is allocated to heart disease and 2/5 is allocated to diabetes. It should be noted that under this allocation method, if comorbidities increase over time and there are an increasing number of visits treating more than one disease, this allocation method will increase physician productivity measures and it should reduce the price index because increasing comorbidities for a particular service will reduce the utilization per disease.

5 Results

Table 1 lists summary statistics from MEPS for year 2002 and 2012. This gives us measures of how aggregate demographics and health status has changed over a decade. This table also suggests that there are measures showing that the nation as a whole is not as healthy in 2012 as in 2002. The prevalence of obesity, diabetes, heart disease and hypertension have all increased. The nation on average has aged slightly and this slight aging might not explain the rapid rise in the incidence of so many diseases. Cawley and Meyerhoefer (2012), Chen (2012) and Baker and Bradley (2014) discuss the impact of obesity on healthcare costs. While the nation has a higher incidence of many chronic diseases, the fraction of Americans who perceive themselves in excellent or poor health has barely changed. It should not be surprising that the share of privately insured individuals has decreased and the share of publicly insured individuals has increased as the baby boom generation begins to retire in relatively large numbers. The smoking rate has dropped from 20% to 17%.

Table 2 compares the price indexes for all diseases that are disease based (computed according to equation (14)) to all disease traditional Lowe price indexes (computed according to equation (15)). The first two columns are computed without accounting for comorbidities and the last two are computed with accounting for comorbidities. From 1999 to 2014, the disease based price indexes in the second and fourth column have a cumulative growth rate that is 8.5% less than the traditional Lowe indexes. This represents a compounded annual difference of .5% per year. Comorbidities are increasing over time and as predicted in Section 4, price indexes that account for comorbidities will grow more slowly than indexes that do not when comorbidities are increasing.

Table 3 lists the same indexes as Table 2, but gives a disease breakdown from 1999 to 2014. The results vary by disease. While for all diseases, Table 2 shows that the disease based price indexes grow more slowly than the traditional Lowe indexes, the results vary on a disease by disease basis. For some diseases such as infections and parasitic diseases and diseases of the respiratory system, the disease based price index grows more rapidly than the Lowe index counterpart. There are 18 disease categories listed on Table 3. Nine have the disease based index growing less rapidly than their Lowe counterpart and the other nine have the disease based price index growing more rapidly. However, the disease categories where the Lowe is greater than the disease based index have a higher share of expenditures and this makes the "all-disease" index using formula (14) less than the Lowe index using formula (15). Table 4 provides the utilization changes that drive the index results in Table 3. For example, the disease based price indexes for infectious and parasitic diseases is 33% higher than the Lowe Index. Table 4 shows that utilizations for this disease have increased. Likewise, the disease based price index for neoplasms is 35% less than the Low Index. On Table 4 we can see that there are large drops for both inpatient hospital visits and emergency room visits. Changes in utilization levels are not the only factor that drives these results. Changes in utilization ratio can also play a role. For instance, there is a substitution toward emergency room visits that induces the disease based price index for diseases of the digestive system to grow more rapidly than its Lowe index.

Table 5 decomposes nominal health expenditures by disease as depicted in equation (1) for the base year 2002 and 2012. This tells us how inflation (price growth), prevalence growth and real per capita output growth affected nominal aggregate expenditure growth for each disease. These decompositions vary widely across disease. This table shows that the variation is so wide that the macro estimates that average across all diseases does not provide an accurate summary. We need to look at these decompositions on a disease by disease basis. Endrocrine and metabolic diseases includes diabetes. Aggregate nominal spending growth has more than doubled. The prevalence rate for this category has increased 70.6% while inflation (measured by the ratio of the price indexes) is up only by 14.9%. For this category, it is clear that prevalence is the key driver. However, our aggregate results have inflation as the major factor that drives nominal expenditure growth, and this is consistent with the results of Starr et. al (2014), Roehrig et. al (2010). Yet, like there are major categories like endrocrine and metabolic diseases where prevalence is the leading factor. Thus, the macro result that inflation is the major driver does not apply to all diseases.

Table 5 has results that are supported by other data. For example, US fertility rates were 2.03 in 2002 and 1.88 in 2012.[17] Table 5 shows a 5.2% drop in the prevalence of pregnancy complications but a 18.3% increase in the inflation rate for this category.

[17] Source: U.S. Census Bureau, American Community Survey, 2005-2013.

6 Conclusions

Reporting on a disease basis for the years 1999 to 2014 gives us different results from the indexes that are computed under traditional service oriented methods. Scitovsky (1967) almost 50 years ago found similar results. When reporting on a disease basis, over all medical inflation rises less rapidly than when reporting with traditional indexes. This means that real expenditure growth and output growth are growing more rapidly using a disease based approach. When reporting both expenditures and inflation on a disease basis, we find that for some diseases prevalence growth is a key driver and for other diseases, it is inflation. While inflation growth is the key driver in nominal expenditure growth, the rising prevalence of obesity, hypertension and diabetes are also contributing to the growth.

The disease based price index are still experimental. As we get more insight from these indexes improvements will be made. One necessary part that has yet to be completed is the quality adjustment for changes in outcomes when constructing these medical indexes. Outcome measurement is very difficult and may require changes in the ways that we survey medical care. The billing office may no longer be the appropriate venue to collect information since it does not have necessary data on procedure characteristics and patient outcomes. Finding the right data source is also problematic. Neither physicians or patients will necessarily be readily objective when disclosing the healing progress of their diseases.

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Table 1: Summary Health Statistics

Variable Name	Mean (Standard Error)	Mean (Standard Error)	% Change
Medical Cost per Person	$ 2,813.24	$ 4,308.66	53.156%
	(58.986)	(116.656)	
Age	35.744	37.443	4.739%
	(.228)	(.271)	
Child	27.587%	25.748%	-6.663%
	(.003)	(.004)	
Publicly Insured	17.054%	22.882%	34.174%
	(.005)	(.006)	
Privately Insured	71.193%	64.407%	-9.531%
	(.006)	(.009)	
Uninsured	11.753%	12.711%	8.147%
	(.003)	(.004)	
Married	41.631%	39.993%	-3.935%
	(.004)	(.005)	
Northeast	18.804%	17.621%	-6.293%
	(.007)	(.007)	
Midwest	22.432%	21.167%	-5.635%
	(.009)	(.008)	
South	35.236%	37.001%	5.009%
	(.010)	(.009)	
West	22.630%	23.394%	3.373%
	(.009)	(.007)	
White	81.036%	79.280%	-2.166%
	(.006)	(.009)	
Black	12.320%	12.449%	1.046%
	(.006)	(.006)	
Hispanic	13.764%	17.071%	24.030%
	(.006)	(.010)	
Perceived Poor Health	2.023%	1.959%	-3.151%
	(.001)	(.001)	
Perceived Excellent Health	12.686%	13.247%	4.427%
	(.003)	(.003)	
Obese	24.015%	29.436%	22.575%
	(.003)	(.005)	
Has Hypertention	24.613%	33.830%	37.444%
	(.004)	(.005)	
Is Disabled	1.786%	2.195%	22.944%
	(.001)	(.001)	
Has Primary Doctor	77.733%	74.561%	-4.081%
	(.005)	(.005)	
Smokes	20.420%	16.993%	-16.782%
	(.004)	(.004)	
Has Diabetes	4.837%	7.076%	46.303%
	(.002)	(.002)	
Has Heart Disease	2.371%	4.289%	80.932%
	(.001)	(.002)	

Table 2: All Disease Price Indexes

Year	Disease Based Price Index without Comorbidities	Lowe Index without Comorbidities	Disease Based Price Index with Comorbidities	Lowe Index with Commorbities
1999	1.0155	1.0155	1.0162	1.0162
2000	1.1088	1.0445	1.1029	1.0452
2001	1.0959	1.0789	1.0760	1.0802
2002	1.1198	1.1113	1.1182	1.1130
2003	1.1790	1.1562	1.1738	1.1588
2004	1.2467	1.2016	1.2330	1.2046
2005	1.2841	1.2390	1.2406	1.2427
2006	1.3046	1.2772	1.2569	1.2819
2007	1.3640	1.3213	1.3196	1.3263
2008	1.3607	1.3548	1.3193	1.3599
2009	1.3725	1.3937	1.3231	1.3995
2010	1.3752	1.4335	1.3463	1.4405
2011	1.3588	1.4639	1.3041	1.4725
2012	1.3897	1.4970	1.3441	1.5066
2013	1.3981	1.5189	1.3569	1.5288
2014	1.4240	1.5413	1.3482	1.5523

Table 3: Disease Based Price Indexes from 1999 to 2014

Period	Lowe Index without Comorbidities	Disease Based Price Index without Comorbidities	Lowe Index with Comorbidities	Disease Based Price Index with Comorbidities
Infectious and parasitic diseases	1.535253	2.040713	1.540434	2.096055
Neoplasms	1.550261	1.01474	1.55176	0.983863
Endocrine, nutritional, metabolic diseases and immunity disorders	1.541666	1.148554	1.57693	1.194142
Diseases of the blood and blood-forming organs	1.562202	0.764136	1.585384	0.799676
Mental disorders	1.478756	0.922715	1.484428	0.826289
Diseases of the nervous system and sense organs	1.46219	1.486762	1.477727	1.482008
Diseases of the circulatory system	1.554848	1.003742	1.573551	0.970491
Diseases of the respiratory system	1.547698	1.885904	1.558283	1.796676
Diseases of the digestive system	1.561487	1.600161	1.577627	1.607329
Diseases of the genitourinary system	1.526607	1.495045	1.530212	1.528959
Complications of pregnancy, childbirth and the puerperium	1.530988	1.293316	1.530751	1.260413
Diseases of the skin and subcutaneous tissue	1.489018	1.503757	1.499381	1.491093
Diseases of the musculoskeletal system and connective tissue	1.465533	1.340105	1.47472	1.204854
Congenital anomalies	1.532781	0.589359	1.535354	0.460634
Certain conditions originating in the perinatal period	1.640409	2.345117	1.640668	2.264331
Injury and poisoning	1.515745	1.697796	1.516295	1.643738
Other conditions	1.505321	1.697717	1.522338	1.67472
Residual codes and unclassified	1.534528	1.545316	1.536986	1.573709

Table 4: Utilization Changes from 1996 to 2011

Disease	Inpatient Hospital	Physicians	Emergency
1 Infectious and parasitic diseases	60%	10%	98%
2 Neoplasms	-51%	4%	-40%
3 Endocrine, nutritional, and metabolic diseases and immunity disorders	-54%	-31%	-27%
4 Diseases of the blood and blood-forming organs	-78%	1%	158%
5 Mental disorders	-65%	-50%	-27%
6 Diseases of the nervous system and sense organs	3%	1%	5%
7 Diseases of the circulatory system	-48%	-39%	-21%
8 Diseases of the respiratory system	23%	-4%	33%
9 Diseases of the digestive system	-13%	-10%	34%
10 Diseases of the genitourinary system	-15%	9%	58%
11 Complications of pregnancy, childbirth, and the puerperium	-20%	-14%	4%
12 Diseases of the skin and subcutaneous tissue	36%	12%	104%
13 Diseases of the musculoskeletal system and connective tissue	-1%	-7%	-35%
14 Congenital anomalies	-81%	-6%	-78%
15 Certain conditions originating in the perinatal period	64%	483%	61%
16 Injury and poisoning	23%	23%	10%
17 Other conditions	7%	-26%	9%
18 Residual codes and unclassified	17%	13%	-56%

Table 5: Decomposition of Nominal Expenditure Growth

Disease	Ratio of Total Expenditures 2012 to Total Expenditures 2002	Ratio of Price Index 2012 to Price Index 2002	Ratio of 2012 Population to 2002 Population	Ratio of 2012 Prevalence Rate to 2002 Prevalence Rate	Ratio of 2012 Real Per Capita Output to 2002 Real Per Capita Output
1 Infectious and parasitic diseases	1.425	1.481	1.091	0.987	0.893
2 Neoplasms	1.831	0.963	1.091	1.215	1.435
3 Endocrine, nutritional, and metabolic diseases and immunity disorders	2.182	1.149	1.091	1.706	1.020
4 Diseases of the blood and blood-forming organs	4.565	1.240	1.091	1.288	2.620
5 Mental disorders	1.829	0.958	1.091	1.336	1.310
6 Diseases of the nervous system and sense organs	1.469	1.292	1.091	1.052	0.991
7 Diseases of the circulatory system	1.492	0.996	1.091	1.411	0.973
8 Diseases of the respiratory system	1.657	1.307	1.091	1.025	1.133
9 Diseases of the digestive system	1.881	1.281	1.091	0.887	1.517
10 Diseases of the genitourinary system	1.497	1.322	1.091	0.915	1.134
11 Complications of pregnancy, childbirth, and the puerperium	1.683	1.183	1.091	0.948	1.376
12 Diseases of the skin and subcutaneous tissue	2.197	1.705	1.091	0.958	1.232
13 Diseases of the musculoskeletal system and connective tissue	2.391	1.044	1.091	1.372	1.530
14 Congenital anomalies	1.011	0.927	1.091	1.256	0.795
15 Certain conditions originating in the perinatal period	1.873	4.173	1.091	1.728	0.238
16 Injury and poisoning	2.004	1.347	1.091	0.899	1.517
17 Other conditions	1.568	1.359	1.091	1.103	0.958
18 Residual codes and unclassified	1.248	1.143	1.091	0.674	1.485
19 Dental diseases	1.324	1.485	1.091	0.950	0.860