# Do the CPI's Utilities Adjustments for OER Distort Inflation Measurement?

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## Abstract

The CPI uses an Owners' Equivalent Rent (OER) approach to measuring homeowner shelter-price inflation. Conceptually, OER inflation is inflation in the pure shelter component of rents. But most rental contracts include at least one utility. Unless the utilities component of the rent is removed, OER inflation estimates will be biased. Accordingly, the CPI performs a utilities adjustment prior to using rents in OER computations.

Between 1999 and 2006, there were two multi-year episodes during which OER and Rent inflation diverged. Critics believe that the CPI's utilities adjustment was responsible. This belief is false; I demonstrate below that the utilities adjustment was not the major determinant of these divergences, and does not distort inflation measurement in the long run.

Nonetheless, the BLS utilities adjustment does result in undesirable dynamic properties. In particular, BLS procedures implicitly assume that rents change every month, when in reality these typically remain unchanged for a year. Accordingly, the utilities adjustment is too aggressive, increasing the volatility of OER and driving it from its measurement goal in the short run.

This paper develops the theory of utilities adjustment, and outlines a straightforward improvement of BLS procedures which will eliminate its current undesirable properties. The impact on inflation measurement can be very sizable in the short run.

# 1 Introduction

Housing costs are a substantial part of most American's monthly outlays. As a result, these costs account for about one-third of the total weight of the Consumer Price Index (CPI). Given this large weight, accurate measurement of shelter costs is crucial to obtaining an accurate measurement of the overall inflation experienced by the average US consumer. Within the CPI, the Bureau of Labor Statistics (BLS) produces two shelter indexes: Rent, which covers the shelter expenditures of renters, and Owners' Equivalent Rent (OER), which covers owners. This latter index is constructed using the rental-equivalence method,[1] which equates the change in a homeowner's shelter cost to the change in the market rental price of that person's home. OER is thus a rent-of-shelter concept which does not include utilities, since utilities are measurable out-of-pocket expenses for homeowners (as they are for almost all renters of similar housing structures).[2]

How is OER produced? The exact market rent of an owned home is, of course, unobservable. However, a well-known and empirically valid rule of thumb in real estate pricing is "location, location, location." This carries over to rents: internal BLS research – most recently in Verbrugge et al., (2006) – has consistently supported the notion that, outside of location, it is difficult to find any reliable predictor of rent inflation. Hence, the BLS estimates inflation in homeowner rents using inflation in market rents of nearby rental units. (Furthermore, about one-quarter of the total BLS sample of rental units consists of detached units, so – even though there is only weak evidence that rents differ by shelter type – much of the rent sample that is used for measuring homeowner shelter cost inflation consists of the same structure type.) Ultimately, homeowner cost inflation is estimated by re-weighting inflation in market rents, as follows.

Monthly movements in the OER index, and the Rent index, are based upon ratios of weighted averages of rents. In particular, for a metropolitan area, the BLS constructs its index for Rent ($I_t^R$) or for OER ($I_t^O$) using a "rent relative" approach. That is, for index $j = \{Rent, OER\}$,

[1] This is a measure of the shelter cost itself, i.e. the cost of obtaining shelter services from this house, which abstracts from the highly-volatile, difficult-to-measure, financial-asset aspect of homeownership. Most of the academic research suggests that this method is the best of the available methods for estimating changes in homeowner shelter costs. See, e.g., the discussion in Diewert (2003), in Poole, Ptacek and Verbrugge (2005), and the recent findings of Verbrugge (2007).

[2] Both the Rent and OER series include the services of consumer durables like refrigerators, as these are typically included in all rental contracts.

$$I_t^j = I_{t-1}^j * R_t^j$$

where $R^j$ is the rent relative (defined below), and $t$ indexes months. The BLS reprices the housing units in their sample only every six months. Accordingly, the rent relative – which is used to move the index in the current month $t$ – is defined as

$$R_t^j = \left( \frac{\sum w_i^j rent_{i,t}^j}{\sum w_i^j rent_{i,t-6}^j e^{F_{i,t}^k}} \right)^{\frac{1}{6}} =: \left( \frac{\overline{rent}_t^j}{\overline{rent}_{t-s}^j} \right)^{\frac{1}{6}} \tag{1}$$

where $w_i^j$ is the expenditure weight for unit $i$ pertaining to index $j$, and $rent_{i,t}^j$ is the period-$t$ measure of rent from unit $i$ that is applicable to the construction of index $j$.[3] Regional or national Rent and OER indexes are constructed via weighted-averages of area-indexes, with weights again differing across the two indexes.

Notice in (1) that the rent measure from unit $i$ differs across indexes; in particular, observed market rents must be adjusted for utilities prior to use in OER index construction. Homeowners almost always pay for their own utilities directly, so these expenses are almost entirely excluded from OER, and are considered separately in the CPI. But in the US, rent contracts are rarely pure shelter prices; instead, around two-thirds of rental contracts include at least one utility (that is, the renter does not pay a separate bill for that utility); see the American Housing Survey, 2002 Metropolitan area survey. Heat, in particular, is included in about one quarter of all US rental apartments, and this matches the proportion in BLS data (see Appendix 4 for details). The prevalence of utilities-included contracts varies regionally, and also by building structure, size, and age. (See Levinson and Niemann, 2004, for details.) Hence, if the market rent on unit $i$, $rent_{i,t}^{Rent}$, includes utilities, the BLS must apply a utilities adjustment in order to transform it into a pure-shelter rent measure admissible for use in constructing OER, $rent_{i,t}^{OER}$. It would be inappropriate to equate the imputed shelter costs of a homeowner – i.e., what a hypothetical landlord would charge to rent the unit *without utilities* – to the *utilities-included* rent of an otherwise identical unit.[4] A utilities adjustment is necessary; the only question is whether the BLS is doing it properly.

[3] As is evident in (1), period-$t$ rent-measures are quality-adjusted via an age-bias factor $F_{i,t}^k$ (which is common across Rent and OER) to ensure that the index is measuring inflation in constant-quality units. The age-bias adjustment is studied in Gallin and Verbrugge (2007a). This factor is common across Rent and OER and is of second-order size; thus it is henceforth ignored. For more details on BLS procedures, see Ptacek and Baskin (1996).

[4] Putting this somewhat differently, if utilities from a utilities-included rent were not removed, then utilities

Between 1999 and 2007:5, rent inflation and OER inflation diverged markedly several times; see Figure 1, which plots 12-month changes in these indexes.

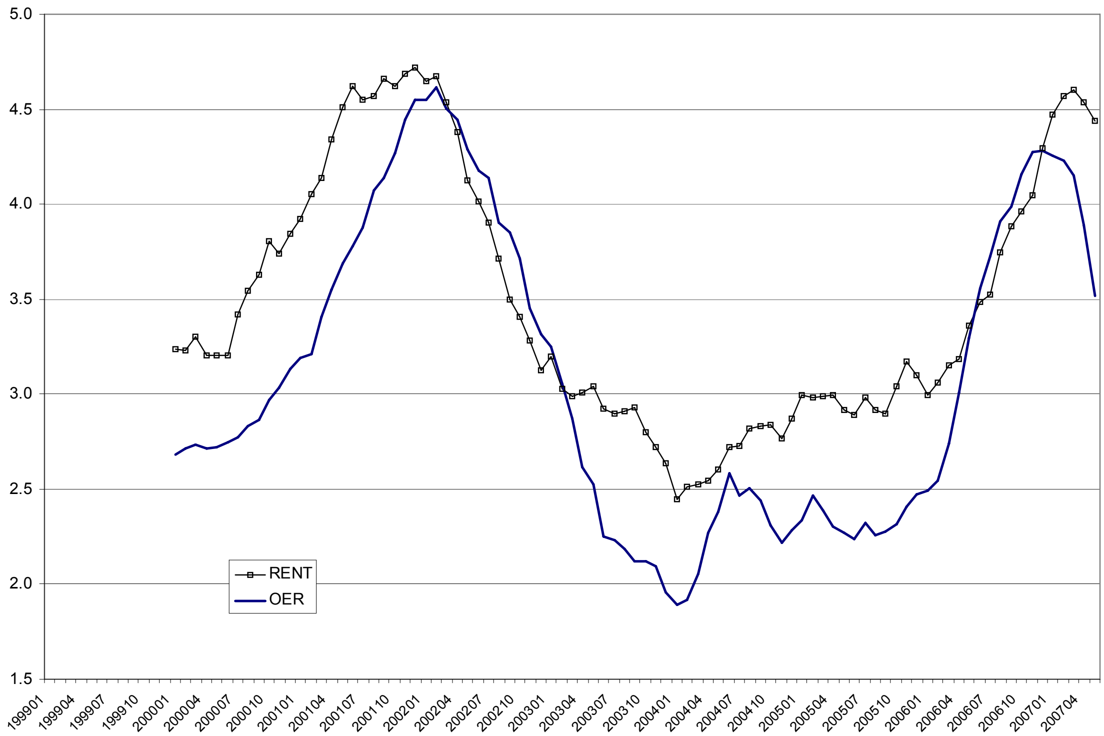



Figure 1: Rent and Owner's Equivalent Rent

Such divergence often causes many analysts and commentators to speculate that the BLS has been doing something wrong with the utilities adjustment. Buttressing this claim are two other facts. First, over the past decade, utilities price inflation has been correlated with divergences between Rent inflation and OER inflation. In regions where rental contracts typically include energy utilities, such as the Northeast, the impact of utilities prices on measured OER inflation is particularly noticeable. The following figure depicts 12-month inflation in OER and 12-month inflation in heating oil; the relationship between these series is striking.

expenditures would be double-counted for homeowners – counted first as a consequence of the resultant inflation in the rents of utilities-included units, and counted again as a consequence of the resultant increase in their out-of-pocket expenses on utilities.

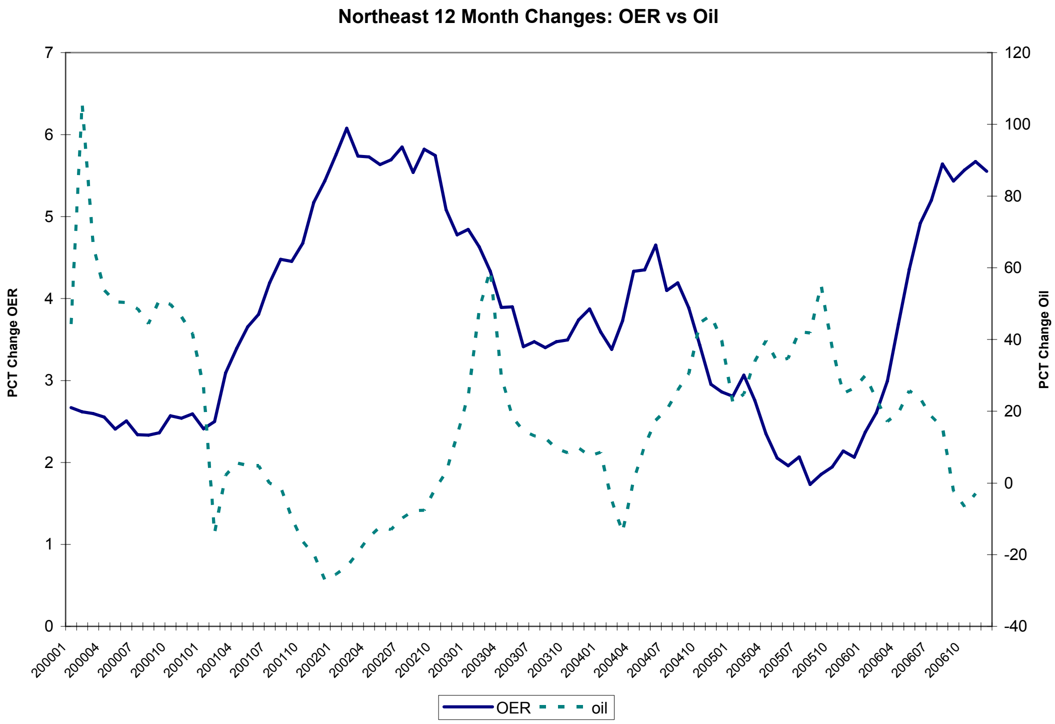



Figure 2: OER and Oil in the Northeast

The correlation between these series equals -0.70. (This finding is not new; the BLS has noted this correlation in public.) The seemingly inescapable conclusion is that divergence between OER and Rent inflation will occur when heating fuel inflation changes markedly. Second, there is Crucini's anomaly[5]: changes in the relative prices of various energy series induce immediate changes in the relative prices of shelter across PSU's which predominately use different primary heating fuels.

The argument that an improper BLS utilities adjustment caused an improper divergence of Rent and OER inflation rests upon two conditions: First, that the BLS utilities adjustment actually caused these divergences; and second, that a divergence would not have happened if the BLS had used a *correct* utilities adjustment.

Neither condition holds.

[5] I term it thus because this anamoly was noted by Mario Crucini in 2006 (private communication).

In this paper, I develop a simple theory of utilities adjustment. I demonstrate that the utilities adjustment is not the "smoking gun" responsible for the divergence between OER and Rent inflation. However, I also demonstrate that the BLS utilities adjustment procedures do suffer from theoretical deficiencies that result in undesirable dynamic properties. Finally, I demonstrate that the deficiencies in BLS procedures can be eliminated via a straightforward and simple adjustment. I reconstruct the OER index over the 1999-2007:5 period using this new procedure in order to demonstrate the impact of the adjustment on measured inflation, and this turns out to be quite sizable during some time periods.

The outline of the remainder of the paper is as follows. Sections 2-4 focus on the theory of utilities adjustment: Section 2 lays out the fundamental intuition, and presents a stylized example; Section 3 develops the theory of utilities adjustment; and Section 4 outlines a theoretically-valid utilities adjustment. Section 5 uses the theory to critique BLS procedures, and to propose an improvement. Section 6 then studies the impact of the original, and proposed, utilities adjustment procedures on measured inflation. Section 7 concludes, and the Appendix treats several generalizations to the theory.

## 2 Intuition: BLS Procedures and Rent Stickiness

BLS procedural deficiencies ultimately stem from implicitly ignoring stickiness in rents.

Theoretically, OER inflation is based upon inflation in the *shelter* component of rental prices; as noted above, the hypothetical rent of a owner's detached home does not include a utilities component. But there is no observable market transaction, hence one must estimate the hypothetical rent using observed rents on similar properties, and – if those rental contracts include utilities – using estimates of the utilities components of those rents. If rents changed monthly, this would be straightforward. But rents are sticky; most rent adjustments occur annually when the lease is changed (e.g., Crone, Nakamura and Voith, 2006).[6] This means that, if energy prices unexpect-

[6] Data from the US Census Bureau's Property Owners and Managers Survey in 1995 showed that 44% of all units had annual leases, 4% had leases longer than one year, 36% had leases shorter than one year, and 16% had no lease. Thus, the annual lease is modal but not universal. Still, most rent adjustments occur at roughly annual intervals.

edly rise in the middle of the rental contract period, renters with such contracts enjoy an implicit subsidy: the *cost* of *providing* shelter-services-plus-utilities has risen, but the *price* they pay as consumers for this bundled commodity has not changed.[7] Note that such renters face no inflation; instead, landlord profits fall. Conversely, *new* one-year rental contracts which include utilities *will* be adjusted to reflect the utility costs which are expected over the next year.

But extant BLS utilities adjustments are computed under the implicit assumption that the utilities component of all existing rental contracts are repriced every month. How so? The BLS procedure subtracts the current utilities costs from each current market rent to obtain an estimate of the current shelter component price. On the face of it, this seems reasonable: if utilities prices unexpectedly rise, the renter is receiving a subsidy, so shouldn't this be reflected somehow? But moving the shelter component price is erroneous, since – as noted above – *both the utilities component price and the shelter component price are fixed*. The fact that landlord profits are affected is irrelevant. And notice the impact of the adjustment procedure: if the rent level for a particular rental unit is currently fixed, every time the estimated utilities cost of that rental unit changes, the estimate of the price of the shelter component moves in an equal and opposite direction. Thus, innovations to utilities prices in a given period are introduced immediately into the estimate of the shelter component price – as if the rental contract were actually being repriced immediately – rather than when the rental contract actually *is* repriced. This causes estimated OER to deviate from its measurement goal, which is the current – fixed – shelter price of that unit. Thus, a permanent utilities price increase will shift OER down immediately, and OER will only gradually converge to its measurement goal as rental contracts gradually expire and then adjust to the new utilities price.

To further sharpen intuition, consider the following hypothetical example. Suppose one wished to construct Rent and OER measures for an apartment complex with 4 identical units. Each has an annual (4-quarter) lease, which includes utilities. Unit 1 is a quarter I lease; unit 2 is a quarter II lease; and so on. The ideal Rent measure equals the average *rent* over time; the ideal OER measure equals the average *rent-of-shelter* over time. (As noted in the introduction, the BLS actually constructs indexes; but it is helpful to initially fix ideas using simple averages, rather than relatives of averages.)

[7] And, of course, the opposite happens if utilities costs fall.

*The CPI's Utilities Adjustment for OER*

For simplicity, assume that the shelter part of rent is fixed at \$1000; i.e., this price is stable and expected to remain stable. Each unit's rent equals \$1000 *plus* the expected utilities cost over the next year. Suppose that up until the end of quarter I, utilities have been stable at \$200; thus the lease on unit 1 was renewed at \$1200 = \$1000 + \$200. But suppose that right at the end of quarter I, utilities costs rise to \$400, and are expected to stay there for some years.

On impact, only the unit 2 lease changes, to \$1400. All other leases are still fixed at \$1200.

Thus, the (correct) Rent measure in quarter II is given by

$$\overline{Rent} = \left(\frac{1}{4}\right)(3\,(1200) + 1400) = 1000 + \left(\frac{1}{4}\right)(3\,(200) + 400) = 1250$$

The correct OER measure does not include utilities, and is still \$1000. Conversely, the Rent measure correctly includes part of the increase in utilities costs, and starts to diverge from the true OER measure.

However, the OER measure must be estimated, since the shelter part of rent is unobservable. The observables are the four market rents, and the current and new utilities costs.

To compute OER, the current BLS utilities-adjustment procedure would subtract the current utilities cost from each current rent, yielding as the current-period OER value

$$\overline{OER}^{BLS} = \left(\frac{1}{4}\right)(3\,(1200 - 400) + (1400 - 400)) = 850$$

Over the next 3 quarters, *as rents adjust to the new higher utilities costs*, the BLS measure would converge to the theoretical ideal. (Conversely, given an unexpected utilities cost decrease, OER would rise above the correct measure of OER.)

Suppose that instead of subtracting the current utilities costs from each current rent, the BLS instead subtracted a 4-quarter moving average of utilities costs, i.e. subtracted 250 from each rent. Then OER in the current period would equal

$$\overline{OER}^{MA(4)} = \left(\frac{1}{4}\right)(3\,(1200 - 250) + (1400 - 250)) = 1000,$$

and in each of the successive months, OER would continue to be correctly measured.

This procedure works because this MA(4) of costs matches the frequency of rent price changes;

this is the basic insight. The next two Sections develop the theory of utilities adjustment rigorously. Section 5 discusses BLS procedures in more detail, and outlines a proposed improvement.

## 3 A Theory of Utilities Adjustment

In the housing research literature, it is fairly standard practice to characterize individual house prices as arising from a stochastic process in which the *average* rate of change or drift in housing values is represented by a market index, and the dispersion and volatility of values around the market average are modeled as a log normal diffusion process.[8] In this approach, one assumes that the price of an individual house $i$ at time $t$ can be expressed in terms of a market price index plus a Gaussian random walk plus white noise.

A similar set of assumptions is made here.

Assume that all agents are risk-neutral and that there is perfect competition in the rental market, so that landlords are price-takers. Assume that there are two types of rental contracts (perhaps based upon structure type): contracts with utilities included, and contracts without utilities included. Contract-type is unit-specific, so that the type of contract associated with unit $i$ does not vary over time. Consider a unit $i$ which is associated with contracts which include utilities. Its rent is assumed to be based upon five underlying stochastic processes: $P_t$, the overall price level, and four relative price processes:

1. $B_t$, a flex-price "equilibrium 'market' rent (without utilities)"
2. $H_{it}$, an idiosyncratic independent persistent process
   (capturing the value of locational amenities)
3. $e_{it}$, an idiosyncratic independent noise process
   (capturing purely transient impacts on a unit's rental value)
4. $u_t$, an aggregate utilities process, defined below

The $B_t$ process is an equilibrium process which captures all non-idiosyncratic influences on the relative price of shelter: supply and demand, the stochastic process governing user costs of owned

[8] Calhoun (1996) cites five prominent studies in the literature as examples.

homes (including interest rates and expected appreciation of housing capital), the vacancy rate, and so on. Its dynamics need not be specified; the only assumption made here is that landlords are able to form expectations about its evolution over the next four quarters.

### 3.1 Landlord Behavior: Flex-price rents

Landlords are price-takers, so if they were able to change the rental price on each unit every period, the period-$t$ utilities-included rent for unit $i$ (i.e., $rent_{it}^{*,u}$) would be given by[9,10]

$$rent_{it}^{*,u} = P_t \left(\varphi_{it}^* + u_t\right) \tag{2}$$

where $P_t$, the independent price level process, governs overall inflation, $u_t$ is the utilities price process,[11] and

$$\varphi_{it}^* = \left(B_t + H_{it}\right) v_{it}.$$

The term $\varphi_{it}^*$ captures the notion of the "equilibrium market rent-of-shelter on unit $i$." Its first component, $B_t$, reflects such influences on average market rents such as overall demand and supply conditions, and its second component, $H_{it}$, reflects unit-$i$-specific influences which are persistent (such as overall quality of the neighborhood). In contrast, the term $v_{it}$ captures any idiosyncratic influences on unit-$i$-rent which are purely transitory. Note that $\varphi_{it}$ and $u_t$ are both relative price processes, namely "pure rent" relative to inflation, and utilities relative to inflation; their dynamics are specified below. Equation (2) will be referred to as the "flex-price" rent (for units with utilities included). The flex-price rent for units *without* utilities included is identical, except that it does not contain the utilities term $u_t$:

$$rent_{it}^{*,no} = P_t \varphi_{it}^*$$

[9] In dynamic analysis, it is both customary and generally convenient to model all variables in logs. While this is true in the present case as well, this assumption leads to a utilities adjustment which involves unobservables – namely, $u_t$, the relative price of utilities, and $P_t$, the price level. In principle, these could be estimated from data, but it is preferable to avoid such complications by making alternative (and basically equivalent) modeling choices.

[10] In Appendix 1, I relax the assumption that $\varphi$ and $u$ enter with equal weight for all units. As this assumption turns out to be inconsequential, I maintain the simpler formulation (2) in the text.

[11] Evidence from Levinson and Niemann (2004) suggests that landlords do not recover the full costs of utilities from their tenants. This rules out one set of explanations for utilities-included contracts, namely "demand-side" explanations (such as the desire to avoid utilities price risk). However, the paper does not attempt to distinguish between the various "supply-side" explanations that are consistent with this evidence. Unfortunately, it is impossible to obtain a reliable estimate of the percentage cost-saving passed to consumers. As discussed below, it is not obvious whether current BLS procedures would overstate or understate the utilities portion of the rent.

Since $P_t$ evolves independently, $E_t P_{t+j}\left(\varphi_{t+j}+u_{t+j}\right)=E_t P_{t+j}\cdot E_t\left(\varphi_{t+j}+u_{t+j}\right)\equiv \widehat{P}_{t+j}E_t\left(\varphi_{t+j}+u_{t+j}\right)$.

## 3.2 Stochastic processes for $P_t$, $u_t$, $H_{it}$, and $e_{it}$, and the log bias issue

### 3.2.1 Desirable properties

To ensure that nominal rents remain nonnegative, it suffices to make assumptions which ensure that the processes $P_t$, $B_t$, $u_t$, $H_{it}$, and $e_{it}$ each remain nonnegative. As noted above, we need not specify the dynamics of $B_t$. But since it solves an equilibrium price problem, we will assume that it remains nonnegative.

As for the other processes, additional properties are desirable. In particular, it is desirable that $H_{it}$ and $u_t$ display "random-walk" behavior, i.e., that $E_t H_{it+1}=H_{it}$ and that $E_t u_{t+1}=u_t$. As noted above, the former assumption is frequently made in other studies of real estate dynamics (e.g., Calhoun, 1996), and the latter assumption is a reasonable description of the dynamics of energy prices. It is desirable that $E_t e_{it+1}=1$. And since $P_t$ grows over time, "random-walk-with-drift" behavior is desirable, i.e., $E_t P_{t+1}=a_t P_t$.

### 3.2.2 Assumptions

The following assumptions ensure that these properties hold.

1. The overall inflation process $P_t$ is assumed to evolve as

$$P_{t+1}=\kappa^P a_t P_t \exp\left(\varepsilon_t^p\right)$$

where $\varepsilon_t^p$ is an iid Normal random variable, and $a_t\geq 1$ is a jump process, with jumps corresponding to "permanent" changes in the rate of inflation. The constant $\kappa^P$, and other similar constants appearing in assumptions 2-4, are discussed in conjunction with assumption 5.

2. The utilities process is assumed to evolve as

$$u_{t+1}=\kappa^u u_t \exp\left(\varepsilon_t^u\right) \tag{3}$$

3. The $H_{it}$ process is assumed to evolve as

$$H_{it+1} = \kappa^H H_{it} \exp\left(\varepsilon_{it}^H\right) \tag{4}$$

4. The noise process $e_{it}$ is assumed to evolve as

$$v_{it} = \kappa^v \exp\left(\varepsilon_{it}^v\right), \tag{5}$$

where $\varepsilon_t^u$, $\varepsilon_{it}^H$ and $\varepsilon_{it}^v$ are iid Normal random variables.

5. The constants $\kappa^P$, $\kappa^u$, $\kappa^v$ and $\kappa^H$ are chosen to satisfy the desired random walk (or white noise) properties described above. This is not as straightforward as it first appears, as discussed in the next subsection.

#### 3.2.3 Log-bias and typical drift

The "obvious" choice for the constants above – namely, $\kappa^l = 1\ \forall l$ – is theoretically invalid. This is due to Jensen's inequality: given a Normal random variable $\epsilon$, the expectation of its log is not equal to the log of its expectation; that is,

$$E\left(\ln\left(\epsilon\right)\right) \neq \ln\left(E\left(\epsilon\right)\right) = 1$$

Instead, there is a "log-bias" term, namely

$$E\left(\ln\left(\epsilon\right)\right) = e^{\frac{1}{2}\sigma_\epsilon^2}$$

Thus, if $\kappa^j = e^{-\frac{1}{2}\sigma_j^2}$, for $j = (u, H, e)$, then $E\left(x_{t+1}^j\right) = x_t^j$. (A similar choice ensures that $E_t P_{t+1} = a_t P_t$.)

However, in practice, correcting these constants for this log-bias might be unsuitable: Since a lognormal random variable is positively skewed, then these choices of $\kappa^j$ will imply that, with high probability, the processes $u_t$ and $H_{it}$ will drift toward zero. To see why this is the case, consider an independently-distributed discrete random variable $X$ which takes on two values, 0.99 and 1.99, with probability 0.99 and 0.01, respectively. Notice that $E\left(X\right) = 1$. We consider $\prod_{j=1}^{10{,}000} x_j$, the product of

10,000 independent trials. Note that, given independence, $E\left(\prod_{j=1}^{10,000} x_j\right) = \prod_{j=1}^{10,000} Ex_j = 1$. However, consider an "ideal" simulation such that $x_j = 0.99$ for exactly 99% of these 10,000 trials. Note that $\frac{1}{10,000}\sum_{j=1}^{10,000} x_j = 1$; for this "ideal" set of draws, the sample mean is exactly 1. However, for this "ideal" set of draws, $\prod_{j=1}^{10,000} x_j = (0.99)^{9900}(1.99)^{100} \approx 0$.[12]

Conversely, consider $\kappa^j = 1$, which here corresponds to the median of the random variable. With this choice for $\kappa^u$ and $\kappa^H$, the processes $u_t$ and $H_{it}$ typically display no drift. Choosing $\kappa^l = 1$ $\forall l$ is therefore sensible – at least in a simulation context – even though this choice theoretically invalidates the desired "random walk" properties noted above.

Readers are cordially invited to select values for $\kappa$ which are, to their tastes, most palatable. In any case, the desired random walk properties are assumed below.

## 3.3 Landlord behavior: Rents if contracts are annual

While BLS indexes are constructed on a monthly basis, it is conceptually and notationally simpler to assume a quarterly frequency for modeling purposes. Unlike the complete price flexibility case discussed above, most rents in the US are fixed for 4 quarters. To better approximate the dynamics of aggregate rents, assume that all rental contracts are 4-quarter contracts. Also, assume for convenience that contract initiation dates are distributed uniformly across the four quarters. In this section, we assume that $a_t$ is fixed, at least between the periods $t-3$ and $t+3$. Under the certainty-equivalence assumption that landlords set their prices as close as possible to the optimal prices, this implies that rents which change in period $t$ will be set equal to

[12] Tim Erickson (private communication) points out two issues related to this phenomenon. First, if we consider repeating the proposed "experiment" – i.e., computing the product of 10,000 draws of this random variable – and examining the distribution of resultant products, there will be a large probability mass at zero, and small mass extending to very large numbers.
Second, note that this issue will arise in chained price indexes as well.

$$
\begin{aligned}
rent_{it}^{u} &= \frac{1}{4}\left[\begin{array}{c} P_t\left(\varphi_t^* + u_t\right) + \widehat{P}_{t+1}E_t\left(\varphi_{t+1}^* + u_{t+1}\right) \\ +\widehat{P}_{t+2}E_t\left(\varphi_{t+2}^* + u_{t+2}\right) + \widehat{P}_{t+3}E_t\left(\varphi_{t+3}^* + u_{t+3}\right) \end{array}\right] \\
&= \frac{1}{4}\left[\begin{array}{c} P_t\left(\left(B_t + H_{it}\right)v_{it} + u_t\right) + a_t P_t E_t\left(B_{t+1} + H_{it+1} + u_{t+1}\right) \\ +a_t^2 P_t E_t\left(B_{t+2} + H_{it+2} + u_{t+2}\right) + a_t^3 P_t E_t\left(B_{t+3} + H_{it+3} + u_{t+3}\right) \end{array}\right] \\
&= \frac{1}{4}P_t\left[B_t + a_t E_t B_{t+1} + a_t^2 E_t B_{t+2} + a_t^3 E_t B_{t+3}\right] + \frac{1}{4}P_t B_t\left(e_{it} - 1\right) \\
&\quad + \frac{1}{4}P_t H_{it}\left[1 + a_t + a_t^2 + a_t^3\right] + \frac{1}{4}P_t H_{it}\left(e_{it} - 1\right) \\
&\quad + \frac{1}{4}P_t u_t\left[1 + a_t + a_t^2 + a_t^3\right] \\
&\equiv b_t' P_t + H_{it}P_t\xi_t + U_t\xi_t + \frac{1}{4}P_t\left(B_t + H_{it}\right)\left(v_{it} - 1\right)
\end{aligned}
$$

where

$$
\begin{aligned}
b_t' &\equiv \frac{1}{4}\left[B_t + a_t E_t B_{t+1} + a_t^2 E_t B_{t+2} + a_t^3 E_t B_{t+3}\right], \\
\xi_t &\equiv \frac{1}{4}\left[1 + a_t + a_t^2 + a_t^3\right],
\end{aligned}
$$

and

$$U_t \equiv P_t u_t \text{ (i.e., } U_t \text{ is the current } \textit{nominal} \text{ utilities price)}$$

Notice that, besides the final term involving $e_{it}$, each term in this expression incorporates inflation expectations. In other words, the nominal counterpart to each relative price is expected to grow at the rate of inflation. (Or to focus on a particular example, if the portion of the rental price attributable to utilities did *not* increase at the rate of inflation, then this would correspond to a *decrease* in the utilities portion of the rent.) Also notice that there are no backward-looking terms in this expression; by assumption, the previous rental price of a unit has no impact on its current rental price.[13] As the utilities price process possesses the random walk property noted above, the entire current innovation in the utilities price enters (immediately) into the rental offer price.[14]

[13] Conversely, suppose that unit-level rents are sluggish in this respect, i.e. that landlords are constrained somehow by the previous annual rent level. Or alternatively, consider the case in which landlords myopically set the expected utilities costs on unit $i$ to be the average costs experienced by unit $i$ over the past year. In either case, average rents in the economy would end up being even longer moving averages of past fundamentals – see below.

[14] If the utilities process were stationary (perhaps with infrequent mean shifts), then the current innovation would be downweighted, incorporating expected mean-reversion. However, a very persistent relative utilities process – which is a reasonable description of reality – would lead to only very modest downweighting. Furthermore, if the mean of the process shifted, the entire mean-shift would be included. Thus, the "random-walk" assumption is likely to be a reasonable approximate description of behavior in any case. I explore an alternative in the Appendix.

Note also that the corresponding price for a unit without utilities is identical, save that it does not contain the utilities term $U_t \xi_t$.

The average nominal rent of utilities-included units in the economy (averaging over units whose contracts changed this period, last period, two periods ago, and three periods ago) is then given by[15]

$$\begin{aligned}
\overline{rent}_t^u &= \frac{1}{4}\left(b_t' P_t + P_t \xi_t + U_t \xi_t\right) \\
&+ \frac{1}{4}\left(b_{t-1}' P_{t-1} + P_{t-1} \xi_{t-1} + U_{t-1} \xi_{t-1}\right) \\
&+ \frac{1}{4}\left(b_{t-2}' P_{t-2} + P_{t-2} \xi_{t-2} + U_{t-2} \xi_{t-2}\right) \\
&+ \frac{1}{4}\left(b_{t-3}' P_{t-3} + P_{t-3} \xi_{t-3} + U_{t-3} \xi_{t-3}\right) \\
&= \frac{1}{4}\left[P_t b_t' + P_{t-1} b_{t-1}' + P_{t-2} b_{t-2}' + P_{t-3} b_{t-3}'\right] \\
&+ \frac{\xi_t}{4}\left[P_t + P_{t-1} + P_{t-2} + P_{t-3}\right] \\
&+ \frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right]
\end{aligned} \tag{6}$$

where the last equality follows from the fact that $a_t$ is fixed. Average rents, then, are a kind of four-quarter moving average of the rent fundamentals. Notice that today's average utilities-included rent still includes "the effects of" utilities prices from three quarters ago, since rental contracts are assumed to be annual. Recalling the definition of $b_t'$, note that rents on utilities-included units move in response both to actual changes in $B_t$ *and* to changes in *expectations* about future $B_t$, as well as in response to utilities prices.

The corresponding expression for units without utilities included is

$$\begin{aligned}
\overline{rent}_t^{no} &= \frac{1}{4}\left[P_t b_t' + P_{t-1} b_{t-1}' + P_{t-2} b_{t-2}' + P_{t-3} b_{t-3}'\right] \\
&+ \frac{\xi_t}{4}\left[P_t + P_{t-1} + P_{t-2} + P_{t-3}\right]
\end{aligned} \tag{7}$$

[15] For a fixed $t$, the cross-section average of the $H_{it} P_t \xi_t$ terms equals a constant $P_t \xi_t$ multiplied by the average of $N$ independent random variables with a mean of 1. Similarly, since the $e_{it}$ are independent and have a mean equal to 1, the final term vanishes upon averaging. All averages assume equal weights, for simplicity in exposition.

# 4 Implied Utilities Adjustment

Shelter price inflation estimation is based upon equation (1); in this model, the 6-month change corresponds to 2 quarters. But as noted above, the measurement goal for OER inflation is inflation in the "pure shelter" part of rents. Thus, the BLS must perform a utilities adjustment in order to transform a contract rent which *includes* utilities into an associated rent-of-shelter component which does *not* include utilities – in effect, transforming $\overline{rent}_t^u$ into $\overline{rent}_t^{no}$. Equations (6) and (7) imply the following relationship:

$$\frac{\overline{rent}_t^{no}}{\overline{rent}_{t-2}^{no}} = \frac{\overline{rent}_t^u - \frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right]}{\overline{rent}_{t-2}^u - \frac{\xi_t}{4}\left[U_{t-2} + U_{t-3} + U_{t-4} + U_{t-5}\right]} \tag{8}$$

Note that the average utilities "adjustment" or correction term for period $t$ is given by $\frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right]$, which is the average nominal utilities cost over the preceding year, *scaled upwards* by a factor $\frac{\xi_t}{4}$. As detailed above, this scaling factor derives from the fact that landlords project that nominal utilities prices will grow at the rate of inflation, and build this inflation estimate into their contracts. BLS utilities adjustment is actually done on a unit-by-unit basis; implications of this theory for such a unit-by-unit adjustment are detailed below.

Different utilities processes might imply different utilities adjustments. The implications of alternative utilities processes for utilities adjustment are examined in Appendix 2 and 3. Appendix 2 examines the implications of seasonality in the utilities process. This makes little difference. Appendix 3 examines the implications of a richer utilities process, namely one which includes a transitory component. This would require the BLS to undertake a Kalman filtering exercise, to avoid overly-aggressive utilities adjustment.

# 5 Improving BLS Procedures

## 5.1 Current BLS practice and theoretical implications

### 5.1.1 Current practice

Existing BLS utilities-adjustment practice differs somewhat from (8), as follows. The BLS collects information on the type of heating and cooling equipment for the rental units in its sample, and estimates a unit-specific current utilities price using CPI price data and utilities-use estimates from the Residential Energy Consumption Survey (RECS) of the Department of Energy. In particular, the RECS provides estimates of the annual quantities consumed of three utilities: electricity, natural gas, and fuel oil. The BLS then estimates the monthly utilities expenditure by unit $i$ in time $t$ as[16]

$$\widehat{U}_{i,t} = p_t^e \frac{\overline{q}_i^e}{12} + p_t^{ng} \frac{\overline{q}_i^{ng}}{12} + p_t^{fo} \frac{\overline{q}_i^{fo}}{12} \tag{9}$$

where $p_t^e$, $p_t^{ng}$, and $p_t^{fo}$ are the *current* (local) prices of electricity, natural gas, and fuel oil, respectively, and $\overline{q}_i^e$, $\overline{q}_i^{ng}$, and $\overline{q}_i^{fo}$ are the *annual-average* estimated unit-$i$-specific consumed quantities of electricity, natural gas, and fuel oil, respectively. Subtracting this unit-$i$-level adjustment from the current rent is the major part of the transformation of the "economic rent" (or contract rent) of the unit into its "pure rent" (the "pure shelter" part of rent). In estimating OER inflation, the BLS uses weighted averages of the inflation in pure rents. While electricity prices are quite stable, natural gas and fuel oil prices are quite volatile, and thus these unit-level adjustments are correspondingly volatile.

As noted above, evidence from Levinson and Niemann (2004) suggests that landlords do not recover the full costs of utilities from their tenants. However, this same study finds that tenants with utilities-included rental contracts also consume more energy than do tenants who pay for utilities separately. RECS collection of fuel use information from apartments in which tenants pay utilities is incomplete, and it thus *estimates* the fuel use for many such units. It is unclear whether these regression-based estimates capture the increased energy use by tenants in utilities-included

[16] This equation is a simplification of the adjustment procedures actually used by the BLS. For the present purposes, I abstract from other adjustments undertaken by the BLS, such as structural change adjustments, aging bias, other utilities such as water and sewer, and the like. Finally, since current-month prices are unavailable, last-month prices are used.

rental units. Hence, given that these two effects pull in opposite directions, it is unclear a priori whether estimates such as those in (9) will overestimate or underestimate the portion of rent that is attributable to utilities.

Upon converting (9) to the quarterly frequency, BLS practice is approximated by computing the price relative for no-utilities-rent as

$$\left(\frac{\overline{rent}_t^{no}}{\overline{rent}_{t-2}^{no}}\right)_{BLS} = \frac{\overline{rent}_t^{u} - \widehat{U}_t}{\overline{rent}_{t-2}^{u} - \widehat{U}_{t-2}} \approx \frac{\overline{rent}_t^{u} - U_t}{\overline{rent}_{t-2}^{u} - U_{t-2}} \tag{10}$$

where $\widehat{U}_t = \sum_i \widehat{U}_{i,t}$, and we assume identical units and perfect utilities measurement.

Notice that since 6-month (2-quarter) changes in rent are used to move the BLS indexes, accordingly it is 6-month changes in utilities which will distinguish the rent relatives of OER and Rent. However, there is no simple linear relationship, for two reasons. First, notice the functional form: growth in $\overline{rent}_t^{no}$ cannot be decomposed into growth in $\overline{rent}_t^{u}$ minus growth in $U_t$. Relative levels will matter, as will relative growth rates.[17] Second, the aggregation weights applied to construct Rent differ from those applied to construct OER, and this difference can matter a great deal in practice; see Poole and Verbrugge (2007).

If rents changed every period, they would immediately adjust to account for any change in the cost of utilities. Hence, $\overline{rent}_t^{no}$ would be accurately captured by subtracting the *current* utilities cost, and (10) would be the theoretically appropriate utilities-adjustment. However, if rents only change annually, then – see (8) – the adjustment in (10) is incorrect: $\left(\frac{\overline{rent}_t^{no}}{\overline{rent}_{t-2}^{no}}\right)_{BLS} \neq \frac{\overline{rent}_t^{no}}{\overline{rent}_{t-2}^{no}}$. As is described next, current BLS practice *induces seasonality* into the OER index, and additionally induces persistent deviations of the OER index from its measurement goal (i.e., it increases the variance of the OER index).

### 5.1.2 Implications

The BLS adjustment (10) introduces **seasonality** into the OER indexes, since $p_t^j$ is seasonal. (Note, though, that $\widehat{U}_t$ will likely display less seasonality than does $U_t$, since the seasonality of $p \cdot q$

[17] Growth in $(rent_t^u - U_t)$ will exceed growth in $rent_t^u$ if $\left(rent_t^u / rent_{t-2}^u\right) > (U_t/U_{t-2})$; thus, even the *sign* of "the utilities adjustment" does not follow directly from the sign of $(U_t/U_{t-2})$.

is greater if one uses the actually-consumed quantities $q_t^j$ rather than averages). Conversely, as discussed in Appendix 2, even if $U_t$ possesses strong seasonality, the OER rent relative in (8) will be approximately non-seasonal. Induced seasonality is probably not a major problem in practice, since BLS seasonal adjustment procedures subsequently remove seasonality from the index.

A more serious implication is that the **variance** of the OER indexes is increased, as OER departs from its measurement goal. This is because innovations in utilities prices – which shift $\widehat{U}_t$ immediately – are applied to *all* existing rental contracts, rather than only to the fraction of contracts which actually change in response to these utilities innovations. This distorts the estimate of the price of the pure shelter component of rent on non-renewal units: *these* renters have not experienced a price change at all, and there is no reason to believe that the price of *shelter* responds appreciably to a change in utilities prices. (Along the same lines, the hypothetical landlord of the owned property would be unable to charge her "renter" any more for utilities right away; rather, she would have to wait until the hypothetical contract expired.) Note that the OER index moves *opposite to* the innovation in utilities, then slowly converges to its theoretical ideal over the next year (so that the impact on inflation measurement is confined to the short run). More precise estimates are given below, but a back-of-the-envelope calculation suggests that the short-run impact could well be far from trivial, particularly since BLS indexes are monthly rather than quarterly (hence less than 10% of the rental prices will actually respond to a utilities innovation immediately). In particular, if utilities comprise about 10% of the total rent on utilities-included units, a 10% increase in utilities costs will result in a 1% reduction in *estimated* rent-minus-utilities on each *non*-adjusting utilities-included unit. If such units comprise a large portion of the sample – as they do in most Northeast PSU's, for example – this will have a noticeable impact on OER indexes. (Actual impacts are estimated in Section 6.)

A suggestion for adjusting BLS practice to address the issue is described next.

## 5.2 A Suggested Improvement

As noted in the previous subsection, the BLS applies a unit-specific utilities adjustment in order to obtain "pure" rents, which in turn are used in OER computations. But if most rents change only annually, what is the appropriate unit-level adjustment?

Ideally, if the rental contract on unit $i$ was put into place six months ago at time $s$, then the BLS should use $U_s \xi_s$; alternatively and equivalently, it should use the information available in period $s$ to estimate $rent_{js}^{no}$, and then carry this information forward as the price-of-shelter for unit $j$ until unit $j$'s contract is renewed again. After all, the reason that the moving-average term $\frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right]$ appears in the adjustment (8) is that this expression has averaged over units whose rents changed at $t-3$, at $t-2$, at $t-1$, and at $t$.

However, the BLS does not collect data on the month during which a particular unit last experienced a rent change. Since this information is unavailable in almost all cases, and since averaging similar to that which give rise to equation (6) occurs in each "panel" in each PSU as well, the BLS monthly unit-level utilities adjustment (9) should be replaced by

$$\frac{\xi}{12}\sum_{j=0}^{11} U_{i,t-j} = \frac{\xi}{12}\left(\overline{q}_i^{e}\sum_{j=0}^{11} p_{t-j}^{e} + \overline{q}_i^{ng}\sum_{j=0}^{11} p_{t-j}^{ng} + \overline{q}_i^{fo}\sum_{j=0}^{11} p_{t-j}^{fo}\right)$$

which basically amounts to applying moving-average (rather than current) prices in the utilities adjustment. Even if a unit has changed its utilities status over the past six months (from utilities-not-included to utilities-included), this annual-average would still be an appropriate adjustment for that unit – since the BLS operates in ignorance regarding contract renewal dates over the *other* units in the panel.

Since $\xi$ is likely to be small, since it must be estimated (with error), and and since landlords probably do not recover the full costs of utilities in any case (see Levinson and Niemann, 2004), using a simple 12-month moving average is defensible.

An alternative approach, which would allow one to posit *any* utilities price process (and avoid the issue of the $\xi$ adjustment), would be to produce annual forecasts of electricity, natural gas, and fuel oil prices on a monthly basis. Denote the time-$t$ forecasts by $\widehat{\overline{p}}_t^{e}, \widehat{\overline{p}}_t^{ng}$, and $\widehat{\overline{p}}_t^{fo}$, respectively. Then the estimated utilities adjustment term would be given by

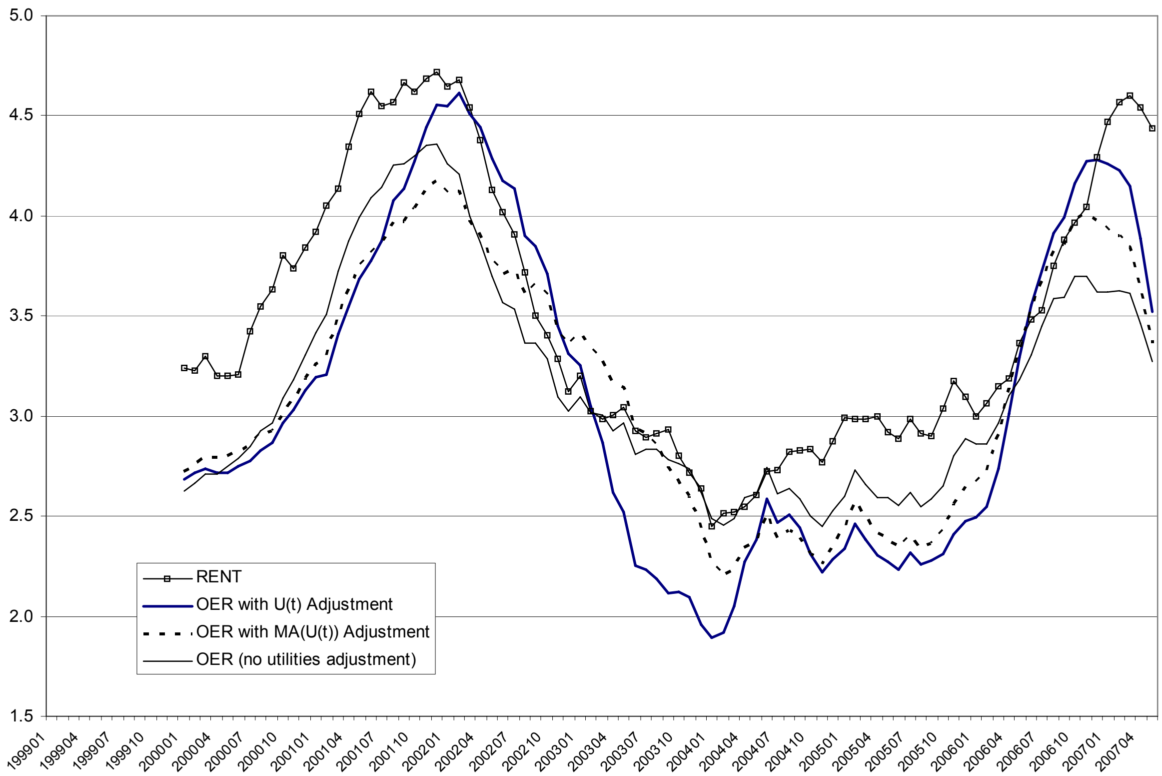
$$\sum_{j=0}^{11} U_{i,t-j} = \left(\overline{q}_i^{e}\sum_{j=0}^{11} \widehat{\overline{p}}_{t-j}^{e} + \overline{q}_i^{ng}\sum_{j=0}^{11} \widehat{\overline{p}}_{t-j}^{ng} + \overline{q}_i^{fo}\sum_{j=0}^{11} \widehat{\overline{p}}_{t-j}^{fo}\right)$$

Of course, this implicitly assumes more sophistication on the part of the average landlord.

## 6 The Impact of Utilities Adjustment on Inflation

How important is the BLS utilities adjustment, and what is the impact of the proposed alternative adjustment procedure? These questions are answered by reconstructing CPI indexes under alternative utilities-adjustment procedures. Plotted below are four series, all constructed via a CPI housing index simulator (written especially for this task)[18] which estimates official CPI shelter indexes to a high degree of accuracy. This simulator reconstructed the official BLS utilities adjustment, as well as an alternative adjustment built upon 12-month moving-average prices. Finally, it constructed a hypothetical series which produces an OER-type index, with OER weights, but *without any utilities adjustment*; this series is not a valid measure of homeowner shelter costs, but is informative as to the impact of the utilities adjustment on OER. Plotted below are these series, in addition to the BLS Rent index, which – as is hopefully now clear – is *not* a pure shelter series, since it also includes utilities. The series "OER with U(t) Adjustment" refers to OER as it is currently constructed, namely with a utilities adjustment that uses current-month utilities prices. The series "OER with MA(U(t)) adjustment" refers to OER constructed with a utilities adjustment that uses 12-month moving-average utilities prices. The series "OER (no utilities adjustment)" refers to the research series noted above, i.e. OER constructed using rents which include utilities.

[18] Special thanks go to Rob Poole and the Statistical Methods Division.




# Figure 3: Impact of Utilities Adjustment Procedures

The answers to two questions are evident. First, does the utilities adjustment explain the OER-Rent inflation divergence? No. Outside of one clear episode (2003:I-2004:II) – a period during which the BLS implemented a modest water/sewer adjustment improvement which influenced almost every OER rent[19] – the utilities adjustment does not "explain" the observed divergences between OER and Rent inflation. Indeed, during 2002 and after mid-2006, the utilities adjustment actually *reduced* the divergence between OER and Rent inflation. (Thus, the early 2007 OER-Rent inflation divergence is even more striking.) The utilities adjustment – while sometimes quantitatively significant, as it should be – rarely accounts for even half of the divergence between OER and Rent inflation. (However, exploring alternative explanations for this divergence lies beyond the scope of the present work, and is the focus of Poole and Verbrugge (2007). Note that, as those

[19] This improvement was retroactively applied to the "OER with MA(U(t)) adjustment" series. Retroactively applying this to the either OER series has little effect outside of eliminating the implementation dip.

authors discuss, it is easy to misinterpret such graphs: plotted are 12-month changes in indexes which are themselves constructed on the basis of 6-month changes, and one implication is that the timing of utilities price movements need not match the timing of divergent movements.)

Second, what is the impact of the suggested improvement? There are three things to note. First, it has the anticipated effects: the new OER series is less volatile (the standard deviation for 12-month inflation rates is 17% smaller), and its response to sharp changes in utilities prices is more subdued. Second, its impact can be quite sizable. Over this period (and abstracting from the water/sewer episode), the maximum deviation between the new and official OER series occurs during the first half of 2002, when for six months straight, the 12-month inflation rate of the new OER series lay 0.5% below that of the official index. Since OER is a major component of the CPI, then for each of these months, *overall* 12-month CPI inflation would have been reduced by an average of more than 0.1% (at annual rates). One-month divergences can be even greater. Between 2001:7-12, monthly OER inflation would have been reduced by an average of 0.8% (at annual rates), which would have led to a 0.2% reduction in overall CPI inflation (at annual rates) each month. Divergence of this sort is nontrivial. Furthermore, OER's contribution to the oft-cited CPI-less-food-and-energy is even larger,[20] and *regional* divergences can be even more pronounced. For example, in the Northeast, the divergence in 12-month OER inflation rates between March-September of 2003 averaged +0.75% (new vs. official); in the Midwest, the divergence over the period December 2001-July 2002 averaged -0.85%. But the final thing to note is that such divergences are a short-term phenomenon: the inflation rate of the new OER series agrees with the official series over longer horizons. (The suggested change in treatment of utilities could thus be viewed as essentially a smoothing issue.) For instance, over the eight-year period between 1999:01 and 2006:12, both underlying indexes grew by 27.4%.

Finally, I return to the correlation between OER inflation and fuel oil inflation in the Northeast which was noted in the Introduction. Once again, the CPI utilities adjustment procedure is not a smoking gun: the alternative procedure does reduce the correlation, but a significant negative correlation remains even if one completely *removes* the utilities adjustment. In the Northeast, fuel

[20] This observation is due to John Greenlees, who further noted that the current utilities adjustment embeds short-run (high-frequency) utilities price movements into OER. Thus, energy enters the CPI-less-food-and-energy through OER, as well as through Rent and other items such as airline fares.

oil inflation turns out to be negatively correlated with rent inflation over this period.

## 7 Conclusion

For contracts which include utilities, annual rental contracts fix the price of both the shelter component and the utilities component of the rent for one year. If landlords itemized these in the contract, a statistical agency could collect the shelter component of the price upon contract renewal, and then use inflation in *this* price – i.e., the year-on-year change of this shelter component – to estimate OER inflation. Since these prices are not itemized in a contract, statistical agencies must estimate the utilities component in order to obtain an estimate of the shelter component by subtraction. Still, given an annual contract, the shelter component price corresponding to this rental contract would remain unchanged for one year. And thus, inflation in this shelter component estimate should be used to estimate OER inflation.

However, current BLS methods implicitly assume that in all rental contracts which include utilities, the utilities component is repriced every month (despite the fact that the *total* rental price – the sum of these two components – remains unchanged). Implicitly, then, the shelter component is also repriced every month, and obtained by subtracting utilities from the (unchanged) total. Thus, using these methods causes a period of rapid utilities price inflation to translate into a period of rapid price-of-shelter deflation.

Contrary to the belief of critics, utilities adjustment is rarely the main driver of divergences between OER and Rent inflation. (For a study focused on that question, see Poole and Verbrugge, 2007.)

However, the theory developed in this paper implies that current BLS methods for adjusting rental units for utilities imparts both seasonality and additional variance into OER indexes – in that the current utilities adjustment procedure induces a (short-run) divergence between the estimated series and the measurement goal. This divergence can be non-trivial. A simple remedy is to alter the BLS utilities-adjustment procedure by using a moving average of present and past utilities prices rather than current utilities prices. This will reduce the volatility of the OER series, and make its response to sharp changes in utilities prices is more subdued, while retaining unbiasedness over the long run. (Sluggishness in rent-inflation at the individual unit level – which appears to be likely (see Genesove (2003) and Gallin and Verbrugge (2007b)) – will only reinforce the suggestion of this paper: use moving-average prices.) But current procedures impart no long-term impact on the magnitude of inflation.

# 8 Appendix

## 8.1 Appendix 1: Additional idiosyncrasy

Assume that $rent_{it}^{*,u}$ is instead given by

$$rent_{it}^{*,u} = P_t \left( k_i^{\varphi} \varphi_{it}^{*} + k_i^{u} u_t \right)$$

where $k_i^{\varphi}$ and $k_i^{u}$ are random variables with mean 1, variance-covariance matrix $\Sigma$, and iid across units. (Their presence reflects the fact that some units are larger than others, and that some units have greater energy requirements than others.) As before,

$$\varphi_{it}^{*} = \left( B_t + H_{it} \right) e_{it}.$$

Then the annual rent on utilities-included unit $i$ will be given by

$$\begin{aligned}
rent_{it}^{u} &= \frac{1}{4} \left[ \begin{array}{c} P_t \left( k_i^{\varphi} \varphi_{it}^{*} + k_i^{u} u_t \right) + \widehat{P}_{t+1} E_t \left( k_i^{\varphi} \varphi_{it+1}^{*} + k_i^{u} u_{t+1} \right) \\ + \widehat{P}_{t+2} E_t \left( k_i^{\varphi} \varphi_{it+2}^{*} + k_i^{u} u_{t+2} \right) + \widehat{P}_{t+3} E_t \left( k_i^{\varphi} \varphi_{it+3}^{*} + k_i^{u} u_{t+3} \right) \end{array} \right] \\
&= \frac{1}{4} \left[ \begin{array}{c} P_t \left( k_i^{\varphi} \left( B_t + H_{it} \right) e_{it} + k_i^{u} u_t \right) + a_t P_t E_t \left( k_i^{\varphi} B_{t+1} + k_i^{\varphi} H_{it+1} + k_i^{u} u_{t+1} \right) \\ + a_t^2 P_t E_t \left( k_i^{\varphi} B_{t+2} + k_i^{\varphi} H_{it+2} + k_i^{u} u_{t+2} \right) + a_t^3 P_t E_t \left( k_i^{\varphi} B_{t+3} + k_i^{\varphi} H_{it+3} + k_i^{u} u_{t+3} \right) \end{array} \right] \\
&= \frac{k_i^{\varphi}}{4} P_t \left[ B_t + a_t E_t B_{t+1} + a_t^2 E_t B_{t+2} + a_t^3 E_t B_{t+3} \right] + \frac{k_i^{\varphi}}{4} P_t B_t \left( e_{it} - 1 \right) \\
&\quad + \frac{k_i^{\varphi}}{4} P_t H_t \left[ 1 + a_t + a_t^2 + a_t^3 \right] + \frac{k_i^{\varphi}}{4} P_t H_t \left( e_{it} - 1 \right) \\
&\quad + \frac{k_i^{u}}{4} P_t u_t \left[ 1 + a_t + a_t^2 + a_t^3 \right] \\
&\equiv k_i^{\varphi} b_t' P_t + k_i^{\varphi} H_t P_t \xi_t + k_i^{u} U_t \xi_t + \frac{k_i^{\varphi}}{4} P_t \left( B_t + H_{it} \right) \left( e_{it} - 1 \right)
\end{aligned}$$

Upon averaging over units, one obtains the same expression as before:

$$\begin{aligned}
\overline{rent}_t^u &= \frac{1}{4}\left(b_t' P_t + P_t \xi_t + U_t \xi_t\right) \\
&+ \frac{1}{4}\left(b_{t-1}' P_{t-1} + P_{t-1} \xi_{t-1} + U_{t-1} \xi_{t-1}\right) \\
&+ \frac{1}{4}\left(b_{t-2}' P_{t-2} + P_{t-2} \xi_{t-2} + U_{t-2} \xi_{t-2}\right) \\
&+ \frac{1}{4}\left(b_{t-3}' P_{t-3} + P_{t-3} \xi_{t-3} + U_{t-3} \xi_{t-3}\right) \\
&= \frac{1}{4}\left[P_t b_t' + P_{t-1} b_{t-1}' + P_{t-2} b_{t-2}' + P_{t-3} b_{t-3}'\right] \\
&+ \frac{\xi_t}{4}\left[P_t + P_{t-1} + P_{t-2} + P_{t-3}\right] \\
&+ \frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right]
\end{aligned}$$

## 8.2 Appendix 2: Seasonal utilities process

Consider an alternative to assumption 2, namely assume that the utilities process has a multiplicative deterministic seasonal, i.e.,

$$\widetilde{u}_t = u_t S_t$$

where, as before,

$$u_{t+1} = \kappa^u u_t \exp\left(\varepsilon_t^u\right)$$

and

$$S_t = \left\{ \begin{array}{cc} s_1 & t \in quarter\ I \\ s_2 & t \in quarter\ II \\ s_3 & t \in quarter\ III \\ \frac{1}{s_1 s_2 s_3} & t \in quarter\ IV \end{array} \right\}$$

In this case, $u_t \equiv \widetilde{u}_t / S_t$ is identical to the process in (3). If one undertakes the utilities adjustment (8), what difference does such seasonality make? The rent on unit $i$ is now given by

$$
\begin{aligned}
rent_{it}^{u} &= \frac{1}{4}\left[\begin{array}{c} P_t\left(\left(B_t + H_{it}\right)e_{it} + u_t S_t\right) + a_t P_t E_t\left(B_{t+1} + H_{it+1} + u_{t+1}S_{t+1}\right) \\ +a_t^2 P_t E_t\left(B_{t+2} + H_{it+2} + u_{t+2}S_{t+2}\right) + a_t^3 P_t E_t\left(B_{t+3} + H_{it+3} + u_{t+3}S_{t+3}\right) \end{array}\right] \\
&= \frac{1}{4}P_t\left[B_t + a_t E_t B_{t+1} + a_t^2 E_t B_{t+2} + a_t^3 E_t B_{t+3}\right] + \frac{1}{4}P_t\left(e_{it} - 1\right) \\
&\quad + \frac{1}{4}P_t H_t\left[1 + a_t + a_t^2 + a_t^3\right] + \frac{1}{4}P_t H_t\left(e_{it} - 1\right) \\
&\quad + \frac{1}{4}P_t u_t\left[S_t + a_t S_{t+1} + a_t^2 S_{t+2} + a_t^3 S_{t+3}\right] \\
&\equiv b_t' P_t + H_t P_t \xi_t + U_t \xi_t^S + \frac{1}{4}P_t\left(1 + H_{it}\right)\left(e_{it} - 1\right)
\end{aligned}
$$

where

$$\xi_t^S := \frac{1}{4}\left[S_t + a_t S_{t+1} + a_t^2 S_{t+2} + a_t^3 S_{t+3}\right]$$

This differs from $\xi_t$ via the inclusion of seasonal factors which are multiplied by the powers of $a_t$, and this implies that $\xi_t^S$ is at least mildly seasonal. It could be strongly seasonal, if the seasonal factors are large and $a_t$ is large, and this in turn could potentially induce seasonality in $\overline{rent}_t^u$.

However, even for rather significant seasonals, the implied variation in $\xi_t^S$ is likely to be fairly modest. For example, consider the seasonal factors $(s_1, s_2, s_3, s_4) = (1.15, 1.03, 0.96, 0.86)$, which implies over 30% average seasonal variation in the price of utilities over a year. (In many localities, this is a vast overstatement of the degree of seasonal variation in the relevant utilities prices, since – due to regulation – these typically change rather infrequently.) With inflation at 3% a year, $\xi_t^S$ varies between 1.0103 and 1.0117, a difference of about 0.1%. (Furthermore, at this rate of inflation, $\xi_t$ =1.0113, so the maximum divergence between $\xi_t^S$ and $\xi_t$ is again about 0.1%.)

Since the level of seasonality attributable to utilities price movements is likely rather modest, I recommend against attempting to adjust for seasonality in the utilities adjustment; model and estimation error will likely preclude any improvement.

### 8.3 Appendix 3: Adding noise to the utilities process

Consider an alternative to assumption 2, namely assume that the utilities process has an additional transitory term, i.e.,

$$\widetilde{u}_t = u_t + \varrho_t$$

where $\varrho_t$ is an iid mean-zero process and, as before,

$$u_{t+1} = \kappa^u u_t \exp\left(\varepsilon_t^u\right)$$

(One could make the case that this process better approximates the stochastic process of fuel oil prices, for example.) If landlords can observe $u_t$ and $\varrho_t$,[21] then the rent on utilities-included unit $i$ is given by

$$\begin{aligned}
rent_{it}^u &= \frac{1}{4}\left[\begin{array}{c} P_t\left(\left(B_t + H_{it}\right)e_{it} + u_t + \varrho_t\right) + a_t P_t E_t\left(B_{t+1} + H_{it+1} + u_{t+1} + \varrho_{t+1}\right) \\ +a_t^2 P_t E_t\left(B_{t+2} + H_{it+2} + u_{t+2} + \varrho_{t+2}\right) + a_t^3 P_t E_t\left(B_{t+3} + H_{it+3} + u_{t+3} + \varrho_{t+3}\right) \end{array}\right] \\
&= \frac{1}{4}P_t\left[B_t + a_t E_t B_{t+1} + a_t^2 E_t B_{t+2} + a_t^3 E_t B_{t+3}\right] + \frac{1}{4}P_t\left(e_{it} - 1\right) \\
&\quad +\frac{1}{4}P_t H_t\left[1 + a_t + a_t^2 + a_t^3\right] + \frac{1}{4}P_t H_t\left(e_{it} - 1\right) \\
&\quad +\frac{1}{4}P_t u_t\left[1 + a_t + a_t^2 + a_t^3\right] + \frac{1}{4}P_t \varrho_t \\
&\equiv b_t' P_t + H_t P_t \xi_t + U_t \xi_t^S + \frac{1}{4}P_t\left(1 + H_{it}\right)\left(e_{it} - 1\right) + \frac{1}{4}P_t \varrho_t
\end{aligned}$$

where, as before, $U_t \equiv P_t u_t$. Now, upon averaging over units (and defining the "deviation" term $D_t \equiv P_t \varrho_t$), one obtains:

[21] Regardless of the actual data-generating process for utilities, as long as the landlords operate under the assumptions in Section 3, then the utilities adjustment procedures in Section 4 are valid.

$$
\begin{aligned}
\overline{rent}_t^u &= \frac{1}{4}\left(b_t' P_t + P_t \xi_t + U_t \xi_t\right) + \frac{1}{16} D_t \\
&\quad + \frac{1}{4}\left(b_{t-1}' P_{t-1} + P_{t-1}\xi_{t-1} + U_{t-1}\xi_{t-1}\right) + \frac{1}{16} D_{t-1} \\
&\quad + \frac{1}{4}\left(b_{t-2}' P_{t-2} + P_{t-2}\xi_{t-2} + U_{t-2}\xi_{t-2}\right) + \frac{1}{16} D_{t-2} \\
&\quad + \frac{1}{4}\left(b_{t-3}' P_{t-3} + P_{t-3}\xi_{t-3} + U_{t-3}\xi_{t-3}\right) + \frac{1}{16} D_{t-3} \\
&= \frac{1}{4}\left[P_t b_t' + P_{t-1} b_{t-1}' + P_{t-2} b_{t-2}' + P_{t-3} b_{t-3}'\right] \\
&\quad + \frac{\xi_t}{4}\left[P_t + P_{t-1} + P_{t-2} + P_{t-3}\right] \\
&\quad + \frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right] \\
&\quad + \frac{1}{16}\left[D_t + D_{t-1} + D_{t-2} + D_{t-3}\right]
\end{aligned}
$$

This expression differs from (6) only by the last term, $\frac{1}{16}\left[D_t + D_{t-1} + D_{t-2} + D_{t-3}\right]$, which equals $\frac{1}{4}$ times the average "temporary deviation" term over the previous four quarters. The implied utilities adjustment term is then given by

$$
\frac{\overline{rent}_t^{no}}{\overline{rent}_{t-2}^{no}} = \frac{\overline{rent}_t^u - \left\{\frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right] + \frac{1}{16}\left[D_t + D_{t-1} + D_{t-2} + D_{t-3}\right]\right\}}{\overline{rent}_{t-2}^u - \left\{\frac{\xi_t}{4}\left[U_{t-2} + U_{t-3} + U_{t-4} + U_{t-5}\right] + \frac{1}{16}\left[D_{t-2} + D_{t-3} + D_{t-4} + D_{t-5}\right]\right\}} \tag{11}
$$

If both $U_t$ and $D_t$ were observable, this would be a straightforward adjustment. However, if the BLS only observed the sum $Util_t \equiv (U_t + D_t)$, then it would have to perform a signal-extraction exercise in order to estimate these terms separately. A failure to do so – assuming that landlords could observe these terms separately – would imply an overly-aggressive utilities adjustment. To see this, consider the following thought experiment. Suppose that $u_t$ is essentially fixed, that $\varrho_t$ is zero both prior to and after period $t$, but that $\varrho_t$ is large and positive. The correct utilities adjustment in this period (and for the next three periods) would be $\frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right] + \frac{1}{16} D_t$; but a failure to identify this as a temporary deviation would result, over these same four periods, in the larger adjustment $\frac{\xi_t}{4}\left[U_t + U_{t-1} + U_{t-2} + U_{t-3}\right] + \frac{1}{4} D_t$.

As noted above, in reality the BLS series are monthly rather than quarterly, so – if the recommendations in this paper were implemented – highly transitory influences on utilities prices would be associated with a far smaller deviation from the ideal adjustment.

## 8.4 Appendix 4: Utilities in BLS data

Percentage of units with utility included, 2004-2006 data

| | All types | Single, detached | Single, attached | Multi-unit w/elevator | Multi-unit w/o elevator | Mobile home | Other |
|---|---|---|---|---|---|---|---|
| Any utility | 68 | 35 | 57 | 92 | 82 | 71 | 59 |
| Besides water/sewer | 22 | 5 | 7 | 60 | 29 | 9 | 27 |
| Hot water: *electricity* | 2 | 1 | 1 | 5 | 2 | 5 | 0 |
| Hot water: *gas* | 16 | 3 | 5 | 38 | 22 | 4 | 25 |
| Hot water: *fuel oil* | 3 | 0 | 1 | 14 | 2 | 0 | 2 |
| Hot water: *alternate* | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Heat: *electricity* | 2 | 1 | 1 | 7 | 2 | 2 | 0 |
| Heat: *gas* | 13 | 3 | 4 | 29 | 18 | 4 | 25 |
| Heat: *fuel oil* | 3 | 1 | 1 | 14 | 3 | 1 | 2 |
| Heat: *alternate* | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Electricity | 7 | 3 | 3 | 19 | 7 | 8 | 10 |

As would be expected, these percentages vary over time. Schiro (1954) provides a fascinating glimpse of utilities and the rental market across cities in the early 1950s. There was considerable variation across cities. For example, the vast majority of rented units included water in the rent; but at the same time, only about 20% of dwellings in Mobile and Savannah even had running water inside the unit. Only 36% of units in Birmingham had a private bathroom with both a flush toilet and a shower or bath; and this proportion fell below 90% even for large cities in nearly all cases. Heat was included for 92% of all New York City units, for 63% for all Buffalo units, and for 5% of all Miami units. About 1 in 3 occupied units still used fuels like wood, kerosene or gasoline for cooking in cities such as Birmingham, Portland (Maine), and Scranton.

The inclusion of utilities also varies across regions. For example, heating oil is used in about one-quarter of all rental units in the Northeast, and in that region the inclusion of heating oil in rent is nearly as common as the inclusion of natural gas. However, this heating type is virtually unused in the rental units in other regions. In the Midwest, natural gas heat is included in the rent contract in nearly one-quarter of cases – only slightly more frequently than in the Northeast, but far more frequently than in the South and West, where it is only present in about 4-6% of the contracts. (In contrast, electricity inclusion only varies 1-2% across regions.)

## 9 References

Calhoun, Charles A. (1996) "OFHEO House Price Indexes: HPI Technical Description." Manuscript, OFHEO.

Crone, Theodore, Leonard Nakamura and Richard Voith. (2006) "Rents have been rising, not falling, in the postwar period." Manuscript, Federal Reserve Bank of Philadelphia.

Diewert, Erwin (2003) "The Treatment of Owner Occupied Housing and Other Durables in a Consumer Price Index." Manuscript, University of British Columbia.

Genesove, David (2003) "The Nominal Rigidity Of Apartment Rents," *Review of Economics and Statistics*, 85.4, 844-853.

Gallin, Joshua, and Randal Verbrugge (2007a) "Improving the CPI's Age-Bias Adjustment: Leverage, Disaggregation and Model-Averaging." Manuscript, BLS.

Gallin, Joshua, and Randal Verbrugge (2007b) "Features of Rent Changes that You Want to Know About." (working title) Manuscript in preparation, BLS.

Levinson, Arik, and Scott Niemann (2004) "Energy Use By Apartment Tenants When Landlords Pay For Utilities," Resource and Energy Economics, 26.1, 51-75.

Poole, Robert, and Randal Verbrugge (2007). "Explaining Rent-OER Inflation Divergence, 1999-2006." Manuscript, BLS.

Ptacek, Frank, and Robert M. Baskin (1996) "Revision of the CPI Housing Sample and Estimators." Monthly Labor Review (December), 31-39.

Schiro, Bruno A. (1954) "Housing Surveys in 75 Cities, 1950 and 1952." Monthly Labor Review (July).

Verbrugge, Randal (2007) "The Puzzling Divergence of Rents and User Costs, 1980-2004." Manuscript, BLS.

Verbrugge, Randal, Alan Dorfman, William Johnson, Fred Marsh III, Robert Poole, and Owen Shoemaker (2006) "Determinants of rent changes: location, location, location?" Manuscript, BLS.