

Methodology for Regional Price Parities, Real Personal Consumption Expenditures, and Real Personal Income

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Regional price parities (RPPs) are price indexes that measure geographic price level differences for one period in time within the United States. For example, if the RPP for Washington, DC, is 120, prices in Washington are on average 20 percent higher than the U.S. average. An RPP is a weighted average of the price level of goods and services for the average consumer in one geographic region compared to all other regions in the United States. The U.S. Bureau of Economic Analysis (BEA) estimates of real personal consumption and real personal income consist of their respective current-dollar estimates adjusted by the RPPs and converted to constant dollars using the U.S. personal consumption expenditures (PCE) price index.

Limitations

The RPPs use mainly price- and expenditure-related survey data that are collected or published by U.S. federal agencies. These include the Consumer Price Index (CPI) survey data from the U.S. Bureau of Labor Statistics (BLS) and the Public Use Microdata Sample (PUMS) from the American Community Survey (ACS) published by the U.S. Census Bureau. As of 2021, they also include BEA's PCE by state series. These distinct data sources are estimated at different geographic scales and must be reconciled to a common unit. We allocate each series down to the county level using either housing unit or income shares as the distributional assumption.

The CPI survey was not designed for place-to-place comparisons, which can lead to volatility in the results, especially across areas that have few observations or where sampling sizes are unevenly distributed. In past estimates, the CPI results were averaged over 5 years, but as of 2021, the RPPs use annual results. Regional price levels for selected CPI items with extreme volatility, particularly in medical and education services, will be substituted with national price levels.¹ Both BEA and BLS are looking for alternative data sources for these categories.

1. The areas are assigned a national price level, that is, they do not vary by region, but their expenditures remain in the RPPs.

History

BEA, in a joint project with BLS, first estimated RPPs for consumption goods and services for 38 metropolitan and urban areas of the United States for 2003 and 2004 (Aten 2005, 2006). These areas, for which BLS produces the CPI, represent about 93 percent of the total population. The method was expanded to cover the remaining rural portions of each state. Prototype estimates for 2005 and 2006 were reported in the *Survey of Current Business* in November 2008 (Aten 2008; Aten and D’Souza 2008). Experimental estimates for 2007 incorporate the multiyear ACS from the U.S. Census Bureau, as do official estimates for 2008 forward. In 2020, BEA produced another set of experimental estimates using PCE-based weights instead of CPI cost weights (Figueroa 2020).² These were adopted for the official RPP estimates in 2021. In that year, BEA also standardized its methodology for estimating housing rent expenditures at the national and regional levels. The estimates use ACS PUMS data and include a new method for imputing owner-occupied rent expenditures (Rassier and others 2021; Aten and Heston 2020).

Methods

The CPI data are price observations classified into item strata consisting of detailed goods and services categories within broad expenditure classes such as food, apparel, transport, housing, education, recreation, medical, and other. They are sampled throughout the year in 32 index areas.³ For strata with a high relative importance, that is, with larger expenditure weights in the average U.S. consumption basket, such as motor vehicles and gasoline, we estimate index area means that control for detailed characteristics of the item strata. For strata with smaller weights, we use a shortcut method controlling for broader characteristics. The ACS PUMS data are individual housing unit observations sampled annually for Public Use Microdata Areas (PUMAs).⁴ Tenant rents are observed directly, and area means are stratified by structure type, number of rooms, number of bedrooms, and age of the unit.

The RPPs are derived using a multilateral price aggregation index that combines the CPI price relatives for goods and services, the ACS PUMS price relatives for housing rents and utilities, and expenditure weights from the PCE by state series.

The following sections describe in more detail the methods: the estimation of price levels and of housing expenditures and how the final RPP indexes are computed.

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2. Expenditure weights used in the CPI are known as cost weights and are derived from BLS Consumer Expenditure Surveys data. See [“Consumer Price Index”](#) in the BLS *Handbook of Methods*.
 3. The CPI revised its geographic sample in 2018. For more information, see the [“Consumer Price Index Geographic Revision for 2018.”](#)
 4. A PUMA is a Census Bureau statistical geographic area defined for the dissemination of PUMS data, including the ACS. PUMAs are built on census tracts and counties, contain at least 100,000 people, cover the entirety of the United States, and do not span more than one state.

1. CPI Price Levels

CPI price data cover an array of consumer goods and services, ranging from high-expenditure goods, such as new automobiles, to low-expenditure services, such as haircuts. Over a million price quotes are collected each year and are classified into more than 200 item strata, each consisting of detailed entry-level items (ELIs), which may be further divided into clusters. The item strata can be combined into nine expenditure groups: apparel, education, food, housing, medical, recreation, rents, transportation, and other goods and services.⁵

Because the CPI was not designed to measure geographic price level differences, items with identical characteristics are not always priced in all areas. Therefore, for the ELIs and clusters in the 68 highest item strata (accounting for roughly 75 percent of expenditure weights), we estimate hedonic regressions that account for the variation in the characteristics of the sampled items.

For the cluster women's tops excluding active and outerwear, for example, we use a hedonic price model to adjust for the type of clothing (jacket, sweater, or blouse), the fiber content, the length of the sleeves, the closure type, the size range, the brand category (exclusive/luxury, national, or private), country of origin, and the type of outlet where it was sold. An example of an item-specific hedonic regression may be found in Aten (2006).

For the remaining item strata, we use a shortcut approach consisting of a weighted regression with only areas and ELIs (and clusters when available) as independent variables. Overall results do not differ greatly whether detailed hedonic regressions are run on all item strata or only on the top 68 in combination with this shortcut approach (Aten 2006).

After the ELI price levels are estimated, they are aggregated to yield item strata price levels using a weighted country product dummy (CPD-W) approach, with weights corresponding to the importance of the ELIs within the item strata.⁶ Both the ELI and the item strata price levels undergo an outlier checking process described in detail in Aten, Figueroa, and Martin (2011). Briefly, it is modeled after the Quaranta tables.⁷ We flag observations that are (1) either very large or small relative to the mean in that area and ELI, (2) either large or small relative to the variance of the ELI observations, or (3) either large or small once they have been adjusted for the relative price level of the area. It is an iterative process that looks at the raw price data as well as the relative prices after the hedonic adjustment.⁸

5. See "[Consumer Price Index](#)" in the BLS *Handbook of Methods*.

6. The CPD-W is the weighted geometric mean when there are no missing observations. For a complete description, see Rao (2004).

7. The process is modeled after the Quaranta method used by the Organisation for Economic Co-operation and Development, Eurostat, and the International Comparison Program of the World Bank.

8. Beginning in 2022, BEA plans to reduce the number of ELI clusters estimated using the hedonic approach and simplify the Quaranta outlier review.

The outcome of this process—hedonic and CPD-W regressions—is a matrix of 32 by approximately 200 area-item price levels, with the weighted geometric average of the 32 areas in each item strata indexed to 1. These are *relative* prices, not actual prices, for each area-item combination. Any of the 32 areas could be the numeraire, but their geometric average provides a more neutral interpretation.

The CPI price levels are matched to state PCE categories following selections used for national PCE.⁹ These include one-to-one and one-to-many matches. For example, expenditures on new motor vehicles are matched to a single CPI series for new vehicles (TA01); however, expenditures on motor vehicle parts and accessories are matched to two CPI series—tires (TC01) and parts and equipment other than tires (TC02). Where a PCE category is matched to multiple price series, CPI relative importance data are used to estimate weighted average price levels for each area.

Some PCE categories, such as life insurance or gambling, are excluded from the CPI and cannot be matched to a price level. For these categories, a national price level is assigned that is uniform across all regions. National price levels have also been assigned to three medical categories (hospitals, physician services, and prescription drugs) with high relative importance.¹⁰ This is in part because BEA's PCE series uses the Producer Price Index (PPI) for these categories instead of the CPI and because BLS is transitioning to alternative sources of price data for these categories. Now that the RPPs use annual estimates of the relative prices for these items, instead of 5-year moving averages, their volatility and standard errors have proven problematic. For the same reasons, the RPPs do not use CPI price relatives for three education categories (college tuition, elementary and high school tuition, and child care and nursery school fees) and one recreation category (club membership for shopping clubs, fraternal, or other organizations).¹¹

The price levels for the remaining PCE categories are allocated from each of the CPI areas to their component counties. Price levels for each county are assumed to be those of the CPI sampling area in which the county is located. For example, counties in Pennsylvania are assigned price levels from either the Philadelphia or Pittsburgh areas or from the CPI Middle Atlantic region. Rural counties are not included in any of the urban sampling areas for which stage-one price levels are estimated; therefore, these counties are assigned price levels of the CPI regional index area in which they are located.

9. See "[How are personal consumption expenditures \(PCE\) prices and quantities derived?](#)" for descriptions of CPI and PCE concordances across categories.

10. In 2020, the relative importance of these three categories in the CPI, which only includes out-of-pocket expenditures by households, was 5.3 percent. In PCE, which also includes expenditures made on behalf of households, their share of the U.S. total was 15.0 percent.

11. In the CPI, the combined relative importance for these four categories was 3.5 percent. In PCE, their share of the U.S. total was 2.8 percent.

2. ACS Housing Rent and Utility Price Levels

Beginning in 2021, we use the ACS PUMS files from the U.S. Census Bureau to estimate the relative price levels of housing rents and of utilities.¹² The rent price levels are estimated at the PUMA level from the monthly rent variable for each housing unit that is tenant occupied. Each observation includes the unit's monthly rent, the monthly cost of electricity, gas, or other fuel for heating, and the annual cost of water and sewage services if they are not included in the rent. It also includes broad characteristics of the unit, such as type of structure, number of bedrooms, total number of rooms, and the age, as well as a housing weight associated with the sampled unit. If utilities are included in the rent, we subtract an estimate of the average cost of utilities for homes with similar characteristics.¹³

Weighted average price levels of the tenant-occupied units are estimated for each PUMA, stratified by the broad characteristics listed above and allocated to counties.¹⁴ If a county contains more than one PUMA, its price level is estimated as the weighted average of the PUMA price levels with housing units as weights. No imputation of owner-occupied rents is used in the price levels; instead, we use rent price levels for both renters and owners.¹⁵ Research is underway to publish owner-imputed rent price levels in future estimates, using the concept of owner-premium rents described below (*Survey of Current Business (SCB)* 2020).

Beginning in 2022, the price levels for Electricity and Gas are from the annual state tables published by the U.S. Energy Information Administration (EIA).¹⁶

12. In prior years, we used a combination of CPI and ACS microdata for housing rents and CPI data for utility price levels. Details can be found in Aten, Figueroa, and Martin 2011.

13. Beginning in December 2022, expenditures were estimated separately for gas, electricity, other fuels and water. Units where any one or more of these utilities are included in the rent make just under 40 percent of the total of tenant-occupied units. We use the units where all utilities are excluded to obtain the average cost of each utility, stratifying by characteristics of the units and by PUMA, and then we subtract that cost estimate from the rents of the units where utilities are included.

14. In 2020, data were allocated from 2,351 PUMAs to 3,143 counties using information obtained from the [U.S. Census Bureau](#) and the [Missouri Census Data Center](#).

15. In Aten and D'Souza (2008), the imputation for county-level owner-occupied rent levels used owner's monthly housing cost data from the 5-year ACS housing file, together with the annual CPI Housing Survey from BLS. In more recent work (Aten, Figueroa, and Martin 2011, 2012), only observed rent price levels from the ACS were used, making no imputations for the owner-occupied rent levels.

16. These EIA data are used for the utility RPPs beginning in 2017. ACS-based estimates for the prior years will be replaced by EIA data in an upcoming comprehensive revision.

3. Expenditure Weights

Expenditures on housing rents are obtained from the same source as for the housing rent price levels—the ACS PUMS. The expenditures for tenants are observed directly as monthly contract rents, while expenditures on owner-occupied homes must be imputed. In 2021, BEA implemented an update to the National Income and Product Accounts (NIPA) housing expenditures that included a new rental equivalence method for owner-imputed rents (SCB 2020; Aten 2017). They are estimated at the PUMA level and allocated to counties using the population-weighted concordance described earlier. The national total is equal to the sum of all the PUMAs. One of the main advantages of the housing update is consistency in the estimation of housing rents expenditures across all BEA accounts and geographies.¹⁷ These imputed owner-occupied rent expenditures, plus the observed tenant-occupied rents, are the weights for the housing rents category in the RPPs.

All other expenditure weights used in the RPPs are taken from BEA’s PCE series for states.¹⁸ The state-level expenditures, exclusive of housing rents, are allocated to PUMAs using the ACS distribution of household income.¹⁹ That is, the same factor is used across the various PCE categories to distribute expenditures from states to PUMAs and then to counties, with the exception of tenant- and imputed owner-occupied rent expenditures.

17. The expenditures on housing rents for some states have been modified by BEA’s Regional Economic Accounts PCE Branch and do not exactly match the state totals in the publicly available ACS data. They have been adjusted to reflect population and income trends and to smooth out the volatility in the year-to-year estimates. The revisions were largest (between 10 percent and up to 40 percent) in states with small populations. For example, Alaska, Maine, Montana, North Dakota, and Wyoming for imputed owner rents and Alaska, Montana, Wyoming, and the District of Columbia for tenants. The national totals in the NIPA accounts equal the national totals from the public data.

18. For an overview of state estimates of PCE, see “[Personal Spending by State](#)” on the BEA website.

19. The allocation uses PUMA household income. It is defined as money income received on a regular basis (exclusive of certain money receipts such as capital gains) before payments for personal income taxes, social security, union dues, Medicare deductions, and others. Therefore, money income does not reflect the fact that some families receive part of their income in the form of noncash benefits. For more information, see “[About Income](#)” on the Census website. In past papers, population was used to distribute the weights; for a comparison, see Figueroa, Aten, and Martin (2014).

4. Regional Price Parities

Prior to 2021, we estimated the RPPs in several stages to reconcile CPI price data and weights at the BLS area level with PCE weights at the national level. This is no longer necessary because BEA began publishing state-level PCE data in 2015 and because the ACS housing and utility data are at the PUMA level. We now first allocate CPI, ACS, and PCE data to the county level and build up to other geographic levels directly from the price-adjusted expenditures that are estimated in the Geary system.

The price levels and expenditure weights consist of approximately 170 PCE categories for more than 3,000 counties for a given year. They are aggregated to an overall index and to four components using the Geary multilateral formula (Balk 2009). One of the advantages of the Geary index is that it is additive at any level of aggregation, making it possible to simultaneously create subnational tables with different components. Previous research on the RPPs (Aten and Marshall 2010) has shown that other methods, such as the EKS-Törnqvist and Fisher indexes, the CPD-W approach, and a GAIA index, tend not to deviate greatly from the Geary.²⁰

The Geary multilateral price level index, P_{Geary} , is given by:

$$P_{Geary}^i = \frac{\sum_{j=1}^N (pq)_j^i}{\sum_{j=1}^N \pi_j q_j^i} \quad \text{Equation (1)}$$

$$\pi_j = \sum_{i=1}^M \frac{(pq)_j^i}{P_{Geary}^i \sum_{j=1}^M q_j^i} \quad \text{Equation (2)}$$

Where: p is the relative price of the PCE category in each county,

(pq) are expenditures in current dollars (nominal PCE),

q is the notional quantity, equal to $(pq)/p$,

π is the national average price relative of the PCE category,

P is the aggregate county price relative, or spatial price index,

superscript i denotes counties, from 1 through M,

subscript j denotes the individual PCE categories, from 1 through N.

In practice, the system is solved simultaneously by iteration, that is, until the solution to each of the equations converges. The Geary index, P_{Geary} , is generally summed over all N categories to obtain a single all items price index, but it can also be summed over a smaller subset of categories. The RPP is simply the Geary index multiplied by 100. In 2021, we published RPPs for goods, housing rents, utilities, and other services. By construction, the Geary index for the United States is equal to 1, that is, the all items RPP for the United States is 100. For a given year t , the RPP can be written as:

$$RPP^{i,t} = 100 * P_{Geary}^{i,t} = \left(\frac{P^{i,t}}{P^{US,t}} \right) \quad \text{Equation (3)}$$

20. The Geary formula is solved simultaneously for the area RPPs and the expenditure categories (notation and formulas follow Deaton and Heston 2010).

5. Real PCE

The RPPs are regional price indexes for one point in time, relative to the United States. In equation 3, the superscript t is added to make the transition from current to constant dollars more explicit. Real regional PCE for year t is defined as current-dollar (nominal) expenditures that are adjusted for regional prices and expressed in constant dollars relative to a base year. The first adjustment, converting current-dollar expenditures to regionally price-adjusted PCE, falls out of the Geary estimation. That is, the price-adjusted PCE for each year is the current-dollar PCE divided by the Geary price index:

$$\text{price adjusted } PCE^{i,t} = \frac{PCE^{i,t}}{P_{Geary}^{i,t}} = \frac{\sum_{j=1}^N (pq)_j^{i,t}}{P_{Geary}^{i,t}} \quad \text{Equation (4)}$$

The left-hand term is the regionally price-adjusted expenditure in county i across all j categories for a particular year t . The numerator on the right-hand side is the current-dollar expenditure (for year t), and the denominator is the Geary price index for that county. Rearranging terms in equation 1, we see this left-hand term is exactly the denominator estimated in equation 1:

$$\text{price adjusted } PCE^{i,t} = \sum_{j=1}^N \pi_j q_j^{i,t} = \frac{\sum_{j=1}^N (pq)_j^{i,t}}{P_{Geary}^{i,t}} \quad \text{Equation (5)}$$

The Geary system of equations estimates the multilateral price index and the price-adjusted expenditures simultaneously.

The second step is to convert these RPP-adjusted PCE values in each year to constant dollars. This is done by dividing the left-hand term by the U.S. PCE price index, currently expressed in 2012 dollars.²¹ The result equals real PCE in constant 2012 dollars:

$$\text{Real } PCE^{i,t} = \frac{\text{price adjusted } PCE^{i,t}}{\left(\frac{P^{US,t}}{P^{US,2012}} \right)} \quad \text{Equation (6)}$$

Although we estimate the Geary at the county level, we only publish RPPs at higher levels of aggregation, such as states and metropolitan areas.²²

21. The U.S. PCE price index is a chained-dollar estimate. In previous versions, we used the term “chained” when converting current-dollar incomes to constant dollars, but our geographic estimates themselves are not individually chained, so we will refer to them only as “constant-dollar” estimates.

22. More research is needed to verify the reliability of the county-level estimates on an annual basis.

6. Real Personal Income

We can apply the all items RPPs to other aggregated economic indicators, such as total personal income (PI), to get an indirect estimate of the indicator's price-adjusted value.²³ For example, substituting PCE by PI in equation 4:

$$\text{price adjusted } PI^{i,t} = \frac{PI^{i,t}}{P_{Geary}^{i,t}} \quad \text{Equation (7)}$$

The sum of price-adjusted PI across the United States and that of nominal PI across the United States will vary by a small factor, k , which is used to rebalance the individual price-adjusted PIs.²⁴

Dividing the left-hand term in equation 7 by the U.S. PCE price index results in an estimate of real PI in constant 2012 dollars:

$$\text{Real } PI^{i,t} = \frac{\text{price adjusted } PI^{i,t}}{\left(\frac{P_{US,t}}{P_{US,2012}}\right)} \quad \text{Equation (8)}$$

The implicit regional price growth rate is the change in RPPs between 2 years times the change in the U.S. PCE price index (see “Implicit Price Growth Rates”).

Implicit Price Growth Rates

The RPP indexes express a region's average price relative to the U.S. average, that is,

$RPP_{i,t} = (P_i / P_{US})_t$ where i is the region and t is the time period.

The implicit price growth or implicit regional inflation may be calculated as:

$$(P_{i,t} / P_{i,t-1}) = (RPP_{i,t} / RPP_{i,t-1}) * (P_{US,t} / P_{US,t-1})$$

Where: U.S. price change is measured by the national PCE price index.

23. Personal income is defined as the income received by all persons from all sources. It is the sum of net earnings by place of residence, property income, and personal current transfer receipts. For more information, see [BEA's Regional Economic Accounts](#).

24. k usually differs from 1 by 0.05 or less.

Publication Schedule

Estimates of real PCE, real PI, and RPPs are published annually. Starting in 2020, the regular release of data has been in December, 12 months after the end of the reference year.

The PCE estimates are published only at the state level, while the RPP and PI estimates are published for three sets of geographies: states (including the District of Columbia), state metropolitan and nonmetropolitan portions, and metropolitan statistical areas. RPPs for metropolitan areas include the nonmetropolitan portion of the United States to provide complete coverage of all U.S. counties.

The estimates are regularly revised, in part to reflect revisions in current-dollar personal income (see methodologies for state and local area personal income on the BEA website) and because of geographic revisions, such as the changes to the boundaries of metropolitan areas.

In December 2021, previously published estimates for 2008 through 2019 were revised to reflect methodology revisions described above. These include the introduction of PCE-based weights for estimating RPPs, the adoption of a new methodology for housing rent expenditures using annual ACS PUMS data, the replacement of 5-year moving averages for CPI relative prices with annual estimates, and the exclusion of CPI relative prices for some highly variable items. In December 2022, we revised utility expenditures to include Other Fuels and Water, and price levels for Electricity and Gas were sourced from the annual EIA state level tables for residential electricity and gas prices.

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Disclaimer

The BEA RPP statistics are based in part on restricted access CPI data from BLS. The BEA statistics expressed herein are products of BEA and not BLS.

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