# A Distributional PCE Price Index From Aggregate Data

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## Abstract

This paper proposes a method to measure individual and aggregate changes in the cost of living when consumer behavior is nonhomothetic and microdata on consumption expenditures are not available. Aggregate prices and expenditure shares together with a single cross-sectional distribution of expenditures are sufficient to create a distribution of nonhomothetic cost-of-living indices with this approach. The cost-of-living indices derive from PIGL preferences, generalize the Törnqvist price index, and only contain one unknown parameter. Because PIGL preferences aggregate consistently, this parameter can be identified from aggregate data. Using US Personal Consumption Expenditure (PCE) data, we apply the method to obtain a nonhomothetic PCE price index covering 71 product groups for the period 1959 to 2023. This index reveals a 0.39 percentage point gap in average annual inflation rates between the poorest and richest ten percent since 1959 and a 1.9 percentage point gap throughout 2022, thus suggesting that poorer households are hit harder both in the long run and in the recent inflation surge.

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# 1 Introduction

Over 160 years of empirical research, following the early work of Engel (1857), suggests that consumption patterns vary systematically with income. Because households consume different bundles, it is widely acknowledged that price movements generate heterogeneous changes in the cost of living at the individual level. Yet, despite a growing interest in distributional questions related to national income and monetary policy, most national accounts-based deflators and inflation measures still rely on aggregate cost-of-living indices that are assumed to apply to everyone. The reason is mainly practical: estimating similar cost-of-living indices for individual households or even subgroups of households generally requires detailed microdata on consumer expenditures that are rarely available to national income accountants. This paper presents a method to overcome this limitation, and uses it to document inflation disparities in US Personal Consumption Expenditure (PCE) data.

The approach considered here is a generalization of the Törnqvist (1936) cost-of-living index that (i) allows consumer behavior to differ with the consumption expenditure level, (ii) can be implemented using publicly available macroeconomic data on prices and expenditure shares only, and (iii) nests the standard Törnqvist index as a limit case. While all other commonly used cost-of-living indices also satisfy (ii), they do so under the assumption of homothetic preferences, in which consumer behavior is independent of the expenditure level. These indices therefore only describe cost-of-living changes for an average household. By contrast, in the framework considered here a single cross-sectional distribution of household consumption expenditures is sufficient to generate a full distribution of cost-of-living indices at the household level in addition to the aggregate-level index.

Like the closely related paper by Hochmuth, Pettersson and Weissert (2023), the cost-of-living index relies on a theoretical foundation with utility-maximizing households whose preferences are of the "price independent generalized linearity" (PIGL) form originally defined by Muellbauer (1975, 1976).[1] These preferences are nonhomothetic, meaning that rich consumers allocate a larger budget share to luxuries than poor consumers, but nevertheless maintain tractable aggregation properties that allow us to consistently estimate any preference parameters from aggregate expenditure data. As shown by Hochmuth, Pettersson and Weissert, PIGL preferences generalize all common homothetic cost-of-living indices, including the Törnqvist index, and allow straightforward decompositions to identify the commodities that drive any overall changes in the cost of living.

The implementation of the PIGL cost-of-living index rests upon a separable preference structure in which commodities are bundled into three intermediate baskets: necessities, luxuries, and homothetic goods. In doing so, the cost-of-living index of any individual person or group of people becomes a function of four components:

   (i)   their total expenditure share allocated to necessities in some chosen *base period*;

  (ii)   the aggregate expenditure share allocated to the homothetic bundle in *every period*;

 (iii)   the prices of each basket; and

 (iv)   a preference parameter that governs the elasticity of demand for necessities.

Behavior within each intermediate basket is homothetic, so the prices of these are captured by standard Törnqvist indices that can be computed from aggregate time series. Thus, given an observed base-period

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[1] These preferences have become popular in the structural change literature; see Boppart (2014), Alder, Boppart and Müller (2022), Cravino, Levchenko and Rojas (2022), and Fan, Peters and Zilibotti (2023).

distribution of household expenditures and aggregate time series on prices and expenditure shares, this approach requires the estimation of only one parameter, thereby keeping econometric concerns to a minimum.

The empirical analysis focuses on US PCE data, which we use to construct nonhomothetic PCE price indices covering 71 separate commodity groups over the 65-year period between January 1959 and December 2023. The official PCE price index is the consumption deflator in the US national accounts and the main inflation measure for US monetary policy. Yet, the PCE data only covers aggregate consumption expenditures, so distributional inflation analyses with these data have not been possible before. We overcome that limitation through recent attempts by Garner *et al.* (2022) to distribute PCEs across US households between 2017 and 2021. Since the proposed approach here only needs a single cross-sectional distribution of household expenditures, these estimates are sufficient to characterize a full distribution of PCE inflation rates.

Our empirical results suggest that consumption-poor households face considerably higher PCE inflation than consumption-rich households both in the long run and in the recent episode of high inflation. When we consider the full 65-year sample from 1959 to 2023, the gap in annual inflation rates between the top and bottom deciles of the 2019 expenditure distribution amounts to 0.39 percentage points on average. This difference adds up to a cumulative 30 percent larger increase in the cost of living for the bottom decile over the same period. These long-run findings corroborate much of what Jaravel and Lashkari (2024) find for the 1955–2019 period with Consumer Expenditure Survey data.

The differences between the top and bottom of the expenditure distribution is even more pronounced during the recent inflation surge. Specifically, the bottom decile faced an annual inflation rate which was 1.9 percentage points larger on average than that of the top decile during 2022, peaking at 2.9 percentage points in June of the same year. A decomposition of this gap identifies price increases for food consumed at home, energy, and motor vehicles as major drivers of the higher inflation of poor households. These are partially offset by increasing costs for restaurant meals and accommodations, transportation services, and financial services, which are consumed proportionately more by the rich.

Our findings contrast with our own previous results in Hochmuth, Pettersson and Weissert (2023), a paper which suggest that differences between the top and bottom of the expenditure distribution occur in the short run but finds no significant long-run divergence in the cost of living. Using Consumer Expenditure Survey data, Hochmuth, Pettersson and Weissert consider a coarse set of 21 nondurable consumption categories, and to shed light on these diverging conclusions we also bring our paper closer to this setting. Excluding durable goods lowers the inflation rate gap between the top and bottom deciles of the distribution from 0.39 to 0.17 percentage points overall and from 0.54 to 0.18 percentage points over the same years as in Hochmuth, Pettersson and Weissert. Calculating PCE indices at a higher level of aggregation with only 15 consumption categories similarly lowers the inflation gap by a similar amount, thus reiterating Jaravel's (2019, 2021) concerns about aggregation bias when measuring inflation inequality. These two changes combined explain almost all of the difference to Hochmuth, Pettersson and Weissert's results.

Overall, the contribution of this paper is threefold. First, the cost-of-living index presented here extends Hochmuth, Pettersson and Weissert's (2023) nonhomothetic generalization of the Törnqvist price index, allowing commodities to be not only luxuries or necessities but also homothetic. The paper thereby adds to the literature on the economic approach to price index theory following, among many others, Konüs

(1939), Samuelson and Swamy (1974), Diewert (1976, 1978), Feenstra (1994), Feenstra and Reinsdorf (2000), Barnett and Choi (2008), and Redding and Weinstein (2020).

Second, to the best of our knowledge this paper obtains the first-ever distribution of PCE inflation rates across households with different levels of consumption expenditures. This adds to the growing efforts by for instance Fixler *et al.* (2017), Piketty, Saez and Zucman (2018), Fixler, Gindelsky and Johnson (2020), and Garner *et al.* (2022) to construct distributional measures of income, consumption, and wealth in the national accounts. Up until now, the primary focus has been on nominal variables, with the deflators of real variables receiving limited attention. Two exceptions are Baqaee, Burstein and Koike-Mori (2024), and Jaravel and Lashkari (2024), who propose nonparametric algorithms to construct nonhomothetic real-consumption deflators. These methods require cross-sectional consumption data for every period of consideration, however, and are thus not applicable to the PCE data.

Lastly, by showing that consumption-poor households in the United States face significantly higher inflation rates than the consumption-rich, both during the current inflation surge and in the long run, this paper contributes to the ever-growing literature on the measurement of inflation inequality that was recently surveyed by Jaravel (2021). Previous studies primarily use detailed microdata such as the Consumer Expenditure Survey or the Kilts-Nielsen Consumer Panel to construct separate homothetic price indices for different consumer groups.[2] By contrast, this paper uses a theoretically consistent framework and is the first to consider PCE data.

## 2  PIGL-Törnqvist Model

This section outlines the theoretical model of nonhomothetic consumer demand and derives the corresponding cost-of-living index. The material draws closely on Hochmuth, Pettersson and Weissert (2023), who consider a framework in which goods must be either necessities or luxuries. Our innovation here is to extend that framework to also include homothetic goods, which allows us to deal with product categories that cannot clearly be classified as necessities or luxuries in the data.

### 2.1  Preferences

Following Boppart (2014), suppose a household with consumption expenditure $e$ who is faced with a price vector $\boldsymbol{p}$ has an indirect utility function of Muellbauer's (1975, 1976) PIGL form:

$$V(e, \boldsymbol{p}) = \frac{1}{\varepsilon}\left[ \left( \frac{e}{F(H(\boldsymbol{p}), B(\boldsymbol{p}))} \right)^{\varepsilon} - 1 \right] - \frac{\nu}{\varepsilon}\left[ \left( \frac{D(\boldsymbol{p})}{B(\boldsymbol{p})} \right)^{\varepsilon} - 1 \right], \tag{1}$$

where $\varepsilon \in (0, 1]$ governs the expenditure elasticity of demand for necessity goods and $\nu > 0$ is a scale parameter. The functions $B(\boldsymbol{p})$, $D(\boldsymbol{p})$, and $H(\boldsymbol{p})$ are linearly homogenous and are treated throughout as unit cost functions of some intermediate homothetic consumption bundles (which are similarly referred to as the $B$, $D$, and $H$ baskets). The function $F$ is a CES composite of $H(\boldsymbol{p})$ and $B(\boldsymbol{p})$:

$$F\left(H(\boldsymbol{p}), B(\boldsymbol{p})\right) = \left[ \theta H(\boldsymbol{p})^{1-\sigma} + (1-\theta)B(\boldsymbol{p})^{1-\sigma} \right]^{\frac{1}{1-\sigma}}, \tag{2}$$

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[2] Examples include Hobijn and Lagakos (2005), McGranahan and Paulson (2005), Broda and Romalis (2009), Kaplan and Schulhofer-Wohl (2017), Jaravel (2019), Argente and Lee (2021), Klick and Stockburger (2021), Lauper and Mangiante (2021), and Orchard (2022).

where $\sigma > 0$ denotes the asymptotic elasticity of substitution between the $B$ and $H$ baskets as $e \rightarrow \infty$ and $\theta \in (0, 1)$ is a taste parameter for the $H$ basket.

To add some structure that makes the demand system empirically tractable, a key separability restriction is imposed on preferences:

**Assumption 1.** Preferences are quasi-separable between $B(\boldsymbol{p})$, $D(\boldsymbol{p})$, and $H(\boldsymbol{p})$.[3]  ◄

Under Assumption 1, the price of an individual commodity occurs in one and only one of the three price functions $B$, $D$, and $H$. This permits two-stage budgeting in which households first allocate expenditures between the three bundles, and subsequently make within-basket decisions conditional on the first-stage allocation. The expenditure share of bundle $C \in \{B, D, H\}$, defined as $w_C \equiv \sum_{j \in J_C} p_j q_j \, / \, e$ with $J_C$ denoting the set of goods in $C$ and $p_j$ and $q_j$ denoting the price and quantity of commodity $j$, is given by Roy's identity as

$$w_D \;=\; \nu \left( \frac{F\big(H(\boldsymbol{p}), B(\boldsymbol{p})\big)}{e} \cdot \frac{D(\boldsymbol{p})}{B(\boldsymbol{p})} \right)^{\varepsilon}, \tag{3}$$

$$w_H \;=\; \theta \left( \frac{H(\boldsymbol{p})}{F\big(H(\boldsymbol{p}), B(\boldsymbol{p})\big)} \right)^{1-\sigma}, \tag{4}$$

$$w_B \;=\; (1 - \theta) \left( \frac{B(\boldsymbol{p})}{F\big(H(\boldsymbol{p}), B(\boldsymbol{p})\big)} \right)^{1-\sigma} - \nu \left( \frac{F\big(H(\boldsymbol{p}), B(\boldsymbol{p})\big)}{e} \cdot \frac{D(\boldsymbol{p})}{B(\boldsymbol{p})} \right)^{\varepsilon}. \tag{5}$$

Since $\varepsilon$ is positive, Equations (3) to (5) highlight that as the expenditure level increases, the budget share for $D$ declines, the share for $H$ remains unchanged, and the share for $B$ increases. Since within-basket behavior is homothetic, it follows that $D$ is a bundle of *necessities*, $H$ is a bundle of *homothetic goods*, and $B$ is a bundle of *luxuries*.

Our demand system closely follows the Boppart (2014) preferences that we also use for cost-of-living index purposes in Hochmuth, Pettersson and Weissert (2023), but differs in two respects. First, the inclusion of homothetic goods in Equation (2) generalizes the Boppart specification, which only considers luxuries and necessities (the special case where $F(H(\boldsymbol{p}), B(\boldsymbol{p})) = B(\boldsymbol{p})$). Second, we consider a single elasticity parameter ($\varepsilon$) for both isoelastic terms on the right-hand side of Equation (1). Boppart specifies separate parameters for these terms to allow for both relative price effects and income effects on consumption patterns, and to separate the elasticity of substitution between $B$ and $D$ from the expenditure elasticity of demand for $D$ (which are otherwise equal). Here, the presence of the homothetic basket generates similar properties: Equations (3) and (5) include both expenditure and relative price changes while the Allen-Uzawa elasticity of substitution between $B$ and $D$ and the expenditure elasticity of demand for $D$ are, respectively, $1 - \frac{1 - w_D}{w_B} \varepsilon$ and $1 - \varepsilon$. Our simplification of the parameter set is therefore not a restriction in this regard.[4]

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[3] Following Gorman's (1996) definition, quasi-separability groups *prices* of goods in the *expenditure function*, in contrast to direct separability which groups *quantities* of goods in the *utility function*.

[4] A separate elasticity parameter for $\frac{D(\boldsymbol{p})}{B(\boldsymbol{p})}$ is also somewhat difficult to pin down empirically. Alder, Boppart and Müller (2022) for instance estimate a similar demand system on aggregate data for the US, the UK, Canada, and Australia and fails to find estimates in the interior of their theoretically imposed bounds. In our empirical implementation, we obtained similar results when we tried to estimate this parameter.

## 2.2 Cost-of-Living Index

To briefly review known results, let the minimum consumption expenditure needed to reach some utility level $u$ when faced by a price vector $\boldsymbol{p}$ be given by the expenditure function $e = c(u, \boldsymbol{p})$. Konüs (1939) defines a cost-of-living index to be the change in minimum expenditures needed to maintain a fixed utility level as prices change from some base-period price vector $\boldsymbol{p}_s$ to a period-$t$ price vector $\boldsymbol{p}_t$:

$$P(u, \boldsymbol{p}_t, \boldsymbol{p}_s) \equiv \frac{c(u, \boldsymbol{p}_t)}{c(u, \boldsymbol{p}_s)}. \tag{6}$$

The Konüs index (6) is independent of the reference utility level if and only if preferences are homothetic, in which case the index becomes a ratio of unit cost functions.[5] The prices of the three intermediate bundles are therefore simply

$$P_{Bt} = \frac{B(\boldsymbol{p}_t)}{B(\boldsymbol{p}_s)}, \qquad P_{Dt} = \frac{D(\boldsymbol{p}_t)}{D(\boldsymbol{p}_s)}, \qquad \text{and} \qquad P_{Ht} = \frac{H(\boldsymbol{p}_t)}{H(\boldsymbol{p}_s)}, \tag{7}$$

where the function arguments on the left-hand sides are left implicit to simplify notation. Moreover, $F(H(\boldsymbol{p}), B(\boldsymbol{p}))$ is a CES composite. Following Sato (1976) and Vartia (1976), its value in period $t$ relative to any other period $k$ can be written as a function of the expenditure share on $H$ in these periods and the price changes of $B$ and $H$: using Equations (3) to (5) it can be shown that

$$\frac{P_{Ft}}{P_{Fk}} = \frac{F(H(\boldsymbol{p}_t), B(\boldsymbol{p}_t))}{F(H(\boldsymbol{p}_k), B(\boldsymbol{p}_k))} = \left(\frac{P_{Bt}}{P_{Bk}}\right)^{1-\rho_{t,k}} \left(\frac{P_{Ht}}{P_{Hk}}\right)^{\rho_{t,k}}, \tag{8a}$$

where the weight on the $H$ basket is given by

$$\rho_{t,k} = \frac{L(w_{Ht}, w_{Hk})}{L(w_{Ht}, w_{Hk}) + L(1 - w_{Ht}, 1 - w_{Hk})}. \tag{8b}$$

In (8b), $L(\cdot, \cdot)$ denotes the logarithmic mean, defined for positive values $x$ and $y$ as

$$L(x, y) = \begin{cases} \dfrac{x - y}{\ln x - \ln y} & \text{if } x \neq y, \\ x & \text{if } x = y. \end{cases} \tag{9}$$

Equation (8) is convenient because it implies that we do not need to know the two parameters $\sigma$ and $\theta$ in empirical applications as long as we directly observe the expenditure shares for the $H$ bundle.[6]

Having established the necessary foundations, we now turn to the cost-of-living index that corresponds to the indirect utility function (1). First, inverting the indirect utility function yields an expenditure function of the form

$$c(u, \boldsymbol{p}) = \left[(1 - v + \varepsilon u) B(\boldsymbol{p})^\varepsilon + v D(\boldsymbol{p})^\varepsilon\right]^{\frac{1}{\varepsilon}} \frac{F(H(\boldsymbol{p}), B(\boldsymbol{p}))}{B(\boldsymbol{p})}.$$

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[5] See for instance the *Homogeneity Price Theorem* in Samuelson and Swamy (1974).

[6] A quick derivation starts from the identity $0 = w_{Ht} - w_{Hk} + [(1 - w_{Ht}) - (1 - w_{Hk})] = L(w_{Ht}, w_{Hk}) \ln\left(\frac{w_{Ht}}{w_{Hk}}\right) + L(1 - w_{Ht}, 1 - w_{Hk}) \ln\left(\frac{1 - w_{Ht}}{1 - w_{Hk}}\right)$. Since Equations (3) to (5) imply that $w_H = \theta\left(\frac{H(\boldsymbol{p})}{F(H(\boldsymbol{p}), B(\boldsymbol{p}))}\right)^{1-\sigma}$ and $1 - w_H = (1 - \theta)\left(\frac{B(\boldsymbol{p})}{F(H(\boldsymbol{p}), B(\boldsymbol{p}))}\right)^{1-\sigma}$, we can plug these into the logarithms and solve for $F(H(\boldsymbol{p}_t), B(\boldsymbol{p}_t)) / F(H(\boldsymbol{p}_k), B(\boldsymbol{p}_k))$ to get Equation (8).

As shown by Hochmuth, Pettersson and Weissert (2023, Proposition 1), it is possible to pin down the reference utility level $u$ in the expenditure function with the base-period expenditure share on necessities, $w_{Ds}$. Specifically, take the indirect utility function (1) in the base period $s$, substitute for $u$ in any period-$t$ expenditure function, and apply Equation (3). Together with the Konüs definition (6) and the price indices (7) and (8), we then obtain the PIGL cost-of-living index

$$P(u, \boldsymbol{p}_t, \boldsymbol{p}_s) = \left[(1 - w_{Ds})P_{Bt}^{\varepsilon} + w_{Ds}P_{Dt}^{\varepsilon}\right]^{\frac{1}{\varepsilon}} \left(\frac{P_{Ht}}{P_{Bt}}\right)^{\rho_{t,s}}. \tag{10}$$

The cost-of-living index (10) is what is taken to the data and, to reiterate the introduction, it is a function of four components:

   (i)   the expenditure share $w_D$ allocated to necessities in the *base period s*;
  (ii)   the expenditure share $w_H$ allocated to homothetic goods in *both periods s and t*;
 (iii)   the prices of each basket; and
 (iv)   the single preference parameter $\varepsilon$.

Heterogeneity in the cost of living occurs because the expenditure share for necessities varies with the expenditure level, so richer individuals allocate a lower weight to price changes of necessities, as captured by $P_{Dt}$. Yet, this nonhomotheticity only shows up explicitly in the price index formula through the base-period allocation. Consequently, knowledge about the expenditure distribution for periods other than the base period is not needed. Expenditure shares for the $H$ bundle are required for all periods considered, but these shares are homothetic and thus identical for everyone. They can therefore be obtained from aggregate time series in the data. This makes the PIGL cost-of-living index ideal for the present analysis. Moreover, while Equation (10) is derived for an individual household, an identical formula also holds for any group of households, in which $P_{Dt}$ is weighted by the group's aggregate expenditure share on necessities.

The cost-of-living index (10) gives the total change in the cost of living, but it is also possible to decompose this change into individual contributions of each basket. Following Hochmuth, Pettersson and Weissert (2023, Lemma 1), the period-to-period change in the cost of living for someone with a base-period allocation $w_{Ds}$ can be written as

$$\frac{P(u, \boldsymbol{p}_t, \boldsymbol{p}_s)}{P(u, \boldsymbol{p}_{t-1}, \boldsymbol{p}_s)} = \left(\frac{P_{Dt}}{P_{Dt-1}}\right)^{\phi_{t,t-1}(u)} \left(\frac{P_{Bt}}{P_{Bt-1}}\right)^{1 - \phi_{t,t-1}(u) - \rho_{t,t-1}} \left(\frac{P_{Ht}}{P_{Ht-1}}\right)^{\rho_{t,t-1}}, \tag{11}$$

where the weight $\phi_{t,t-1}(u)$ on necessities, which varies across households, is defined as

$$\phi_{t,t-1}(u) = \frac{L\big(w_{Dt}^h, w_{Dt-1}^h\big)}{L\big(w_{Dt}^h, w_{Dt-1}^h\big) + L\big(1 - w_{Dt}^h, 1 - w_{Dt-1}^h\big)}. \tag{12}$$

In Equation (12), $L(\cdot, \cdot)$ is again the logarithmic mean (9) while $w_{Dt}^h$ and $w_{Dt-1}^h$ are *Hicksian* expenditure shares. That is, $w_{Dt}^h$ and $w_{Dt-1}^h$ are the necessity expenditure shares that prevail under period-$t$ and period-$t-1$ prices along the indifference curve associated with the observed base-period allocation $w_{Ds}$. Though not directly observable, Hicksian expenditure shares are straightforward to construct for decomposition purposes: apply Shephard's lemma on the expenditure function in period $k \in \{t, t-1\}$

and use Equations (3) and (10) to get

$$w_{Dk}^h = \frac{w_{Ds}P_{Dk}^{\varepsilon}}{(1 - w_{Ds})P_{Bk}^{\varepsilon} + w_{Ds}P_{Dk}^{\varepsilon}}. \tag{13}$$

## 2.3 A Nonhomothetic Törnqvist Index

It remains to parametrize the price indices for the three intermediate baskets. To that end, let $B(\boldsymbol{p})$, $D(\boldsymbol{p})$, and $H(\boldsymbol{p})$ be homogeneous translog expenditure functions. As shown by Diewert (1976), this implies that the corresponding price indices are of the Törnqvist (1936) form. That is, for each bundle $C \in \{B, D, H\}$, we have

$$\frac{P_{Ct}}{P_{Ct-1}} = \prod_{j \in J_C} \left(\frac{p_{jt}}{p_{jt-1}}\right)^{\delta_{j,t,t-1}^C}, \qquad \delta_{j,t,t-1}^C = \frac{w_{jt}^C + w_{jt-1}^C}{2}, \tag{14}$$

where $w_j^C \equiv p_j q_j / \sum_{j \in J_C} p_j q_j$ is the within-basket expenditure share. Since within-basket behavior is homothetic, these within-shares are identical across agents. The Törnqvist weights can therefore be constructed from aggregate data, just like the weight on the $H$ basket in Equation (10).

The geometric-mean representation of Equations (11) and (14) makes it straightforward to decompose the overall change in the cost of living into contributions of individual commodities, which is useful in applications. While the same is true for any other homothetic geometric-mean parametrization of $P_{Ct}/P_{Ct-1}$, the Törnqvist index is particularly neat because Equations (11) and (14) then nest the standard Törnqvist index as a limit case. We finish the section by stating this as a formal result, since it generalizes Proposition 4 in Hochmuth, Pettersson and Weissert (2023) to include the homothetic bundle $H$.

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**Proposition 1.** *Let $B(\boldsymbol{p})$, $D(\boldsymbol{p})$, and $H(\boldsymbol{p})$ be homogeneous translog expenditure functions. If $\varepsilon \to 0$ and $\sigma \to 1$, then the PIGL cost-of-living index (11) becomes the standard Törnqvist index:*

$$\frac{P(u, \boldsymbol{p}_t, \boldsymbol{p}_s)}{P(u, \boldsymbol{p}_{t-1}, \boldsymbol{p}_s)} = \prod_{j \in J} \left(\frac{p_{jt}}{p_{jt-1}}\right)^{\delta_{j,t,t-1}}, \qquad \delta_{j,t,t-1} = \frac{w_{jt} + w_{jt-1}}{2},$$

*where $J = J_D \cup J_B \cup J_H$ is the full set of commodities available and $w_j = p_j q_j / e$ is the total expenditure share of commodity $j$.*

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*Proof.* If $\varepsilon \to 0$ and $\sigma \to 1$, the indirect utility function (1) becomes Cobb-Douglas: $V(e, \boldsymbol{p}) = \ln e - \ln\left[D(\boldsymbol{p})^\nu B(\boldsymbol{p})^{1-\theta-\nu} H(\boldsymbol{p})^\theta\right]$. The cost-of-living index between periods $t$ and $t-1$ is then given by $\left(P_{Dt}/P_{Dt-1}\right)^\nu \left(P_{Bt}/P_{Bt-1}\right)^{1-\theta-\nu} \left(P_{Ht}/P_{Ht-1}\right)^\theta$, where the weights are time-invariant expenditure shares: $\nu = w_D$, $1 - \theta - \nu = w_B$, and $\theta = w_H$. Substituting in (14), the weight on good $j$ in bundle $C$ becomes $w_C \delta_{j,t,t-1}^C = (w_{jt} + w_{jt-1})/2$, since $w_j = w_C w_j^C$ holds by definition under Assumption 1. $\qquad \square$

# 3   Data and Empirical Implementation

This section applies the theory above to aggregate US data on consumption expenditures and prices. The goal is to construct a nonhomothetic version of the PCE price index, which is the consumption deflator in the US national accounts and the main inflation measure for US monetary policy. All in all, the analysis requires no more than six publicly available tables from the US Bureau of Economic Analysis (BEA), three from the National Income and Product Accounts (NIPA) and another three from the Regional Economic Accounts (REA), which we combine with distributional PCE estimates from Garner *et al.* (2022).

The implementation strategy exploits the separability structure of the theoretical model, in which a good belongs to one and only one of the three commodity bundles. Under such separability, the overall basket expenditure shares ($w_C$) and the individual within-basket expenditure shares ($w_j^C$) can be inferred directly from the observed expenditure shares on individual goods ($w_j$) once we know the sets of goods that belong to each basket. These sets of goods can be identified via the fact that one basket is a bundle of necessities, one is a bundle of luxuries, and one is a bundle of homothetic goods: simply investigate the Engel curves of individual goods and classify them as necessity, luxury, or homothetic based on the slopes of the Engel curves. Following Hochmuth, Pettersson and Weissert (2023), the empirical procedure can then be summarized by the following steps:

  (i)   classify each individual good considered as "necessity", "luxury", or "homothetic";
 (ii)   construct the Törnqvist price index (14) for each of the three baskets using within-basket expenditure shares for the sets of commodities identified in (i);
(iii)   estimate $\varepsilon$ using the expenditure share equation (3); and
 (iv)   for a given base-period expenditure distribution, construct the corresponding PIGL cost-of-living indices using (ii) and (iii).

The subsections below cover these steps in turn and provide additional detail on the data used in this regard.

## 3.1   Data on US Personal Consumption Expenditures and Prices

The classification of goods and the parameter estimation relies on annual PCE data by US state, which are available from 1997 onward in REA Table SAPCE3 and include details on over 70 separate consumption categories at the lowest level of product aggregation. These exercises also make adjustments for price differences across states with the regional price parities (RPPs) reported in REA Table SARPP, which are available at an annual frequency starting in 2008 for four broad expenditure groups (goods, housing, utilities, and other services). We construct the cost-of-living indices themselves over a 65-year period from January 1959 to December 2023 using monthly time series on aggregate US expenditures and prices for each consumption category. These data are provided in the underlying detail tables, NIPA Tables 2.4.4U and 2.4.5U. All expenditures in these sources are converted into per-capita terms using the population estimates reported in REA Table SAINC1 and NIPA Table 2.6.

We exclude four consumption categories from the analysis and subtract these from the expenditure totals: net expenditures abroad by US residents, net foreign travel, internet access, and final consumption expenditures of nonprofit institutions serving households. The first two are dropped because their expenditures are not guaranteed to be positive and because the BEA does not provide any corresponding price indices to use. We remove internet access because the Törnqvist index does not easily deal with entering and exiting

products, and this consumption category only exists in the BEA data from 1988 on. The last category is excluded from the distributional PCE estimates by Garner *et al.* (2022), and is consequently also dropped here. These restrictions result in a data set with 71 distinct product groups that cover between 96 and 98 percent of total US personal consumption expenditures during our sample period.

## 3.2  Classification of Goods and Basket Price Indices

The classification of a good is implemented by investigating the slope of budget-share Engel curves implied from the cross-sectional variation in consumption expenditures across US states. As in for instance Wachter and Yogo (2010), Orchard (2022), and Hochmuth, Pettersson and Weissert (2023), the classification relies on a simple allocation rule: a good is classified as a necessity if the slope of its estimated Engel curve is negative and statistically significant at the 5 percent level, as a luxury if the slope is positive and similarly significant, and otherwise considered a homothetic good.

The Engel curve of a product $j$ is estimated across states $g$ and years $t$ by regressing the state-level aggregate expenditure share $\overline{w}_{jgt}$ on the corresponding per-capita consumption expenditure $\overline{e}_{gt}$, according to a reduced-form model

$$\overline{w}_{jgt} \; = \; \alpha_{jr} + \alpha_{jt} + \beta_{je} \ln \overline{e}_{gt} + \beta_{jp} \ln RPP_{jgt} + u_{jgt}. \tag{15}$$

In this regression, $\alpha_{jr}$ is a dummy for the BEA region in which a state is located, $\alpha_{jt}$ is a good-$j$ time fixed effect, $RPP_{jgt}$ is a price parity adjustment across states, and $u_{jgt}$ is an error term. We also weigh states by population size in each year.

In Equation (15), the regional fixed effects control for permanent differences in consumption patterns across regions that are unrelated to nonhomotheticity. It would for instance be bold to claim that nonhomothetic preferences alone explain why a landlocked region such as the Rocky Mountain Region exhibits lower expenditure shares on water transportation than, say, the Great Lakes Region, and the regional dummies mitigate these concerns while still allowing us to exploit the cross-sectional variation in the state data. The time-fixed effects control for aggregate changes in relative prices between goods and for any other common macro shocks, while the regional price parities similarly control for differences in relative prices across states and their evolution over time. These controls are also important, because all else equal we expect the expenditure share of a good to vary across years and states for which its relative price is different, even in the absence of nonhomothetic behavior.

Table 1 reports the 71 expenditure categories that we consider and their corresponding Engel slope estimate and resulting classification. The table also includes the average expenditure share of each good at the aggregate US level for our 2008–2022 classification sample. In total we obtain 30 necessities, 34 luxuries, and 7 homothetic goods, and most of these are highly intuitive.[7] Goods (especially nondurables) are generally classified as necessities while services are luxuries broadly speaking. This pattern is consistent with the macro evidence on structural transformation.[8] For comparable individual categories, Table 1 aligns with classifications in similar analyses such as Wachter and Yogo (2010) and Orchard (2022) as well. As a sensitivity check, we also consider the same expenditure categories as in Hochmuth, Pettersson and Weissert (2023) and construct per-capita averages across states and years using identical Consumer

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[7] Figure A.1 and Table A.1 in Appendix A show that our classification is largely unchanged if we consider the full 1997–2022 state sample without RPP adjustments or if we include additional demographic controls. The former primarily moves housing (rented as well as owned) into luxuries, arguably because it does not control for the geographic variation in housing costs, while the latter mainly increases standard errors and thus classifies more categories as homothetic.

[8] See for instance Boppart (2014), Herrendorf, Rogerson and Valentinyi (2014), Comin, Lashkari and Mestieri (2021), and Alder, Boppart and Müller (2022).

**Table 1.** Engel curve classification from 2008–2022 state PCE data.

| PCE category | PCE share (in percent) | Engel slope | | Classification |
|---|---|---|---|---|
| | | Coefficient | Std. Error | |
| **Motor vehicles and parts** | | | | |
| New motor vehicles | 2.13 | −0.008*** | (0.001) | Necessity |
| Net purchases of used motor vehicles | 1.18 | −0.013*** | (0.001) | Necessity |
| Motor vehicle parts and accessories | 0.62 | −0.005*** | (0.001) | Necessity |
| **Furnishings and durable household equipment** | | | | |
| Furniture and furnishings | 1.47 | 0.006*** | (0.001) | Luxury |
| Household appliances | 0.47 | −0.002*** | (0.000) | Necessity |
| Glassware, tableware, and household utensils | 0.33 | 0.003*** | (0.000) | Luxury |
| Tools and equipment for house and garden | 0.28 | −0.003*** | (0.000) | Necessity |
| **Recreational goods and vehicles** | | | | |
| Video, audio, photographic, and information processing equipment and media | 1.89 | 0.033*** | (0.002) | Luxury |
| Sporting equipment, supplies, guns, and ammunition | 0.58 | −0.005*** | (0.001) | Necessity |
| Sports and recreational vehicles | 0.50 | 0.000 | (0.002) | Homothetic |
| Recreational books | 0.19 | 0.001 | (0.001) | Homothetic |
| Musical instruments | 0.05 | 0.001*** | (0.000) | Luxury |
| **Other durable goods** | | | | |
| Jewelry and watches | 0.58 | 0.006*** | (0.001) | Luxury |
| Therapeutic appliances and equipment | 0.50 | −0.006*** | (0.000) | Necessity |
| Educational books | 0.07 | 0.001*** | (0.000) | Luxury |
| Luggage and similar personal items | 0.24 | 0.003*** | (0.000) | Luxury |
| Telephone and related communication equipment | 0.20 | 0.001** | (0.000) | Luxury |
| **Food and beverages purchased for off-premises consumption** | | | | |
| Food and nonalcoholic beverages purchased for off-premises consumption | 6.86 | −0.035*** | (0.003) | Necessity |
| Alcoholic beverages purchased for off-premises consumption | 1.15 | 0.002*** | (0.001) | Luxury |
| Food produced and consumed on farms | 0.00 | 0.000*** | (0.000) | Necessity |
| **Clothing and footwear** | | | | |
| Women's and girls' clothing | 1.42 | −0.002 | (0.001) | Homothetic |
| Men's and boys' clothing | 0.83 | −0.004*** | (0.001) | Necessity |
| Children's and infants' clothing | 0.17 | −0.001*** | (0.000) | Necessity |
| Other clothing materials and footwear | 0.68 | −0.002*** | (0.001) | Necessity |
| **Gasoline and other energy goods** | | | | |
| Motor vehicle fuels, lubricants, and fluids | 2.83 | −0.049*** | (0.003) | Necessity |
| Fuel oil and other fuels | 0.20 | −0.003*** | (0.001) | Necessity |
| **Other nondurable goods** | | | | |
| Pharmaceutical and other medical products | 3.41 | −0.042*** | (0.003) | Necessity |
| Recreational items | 1.44 | −0.011*** | (0.001) | Necessity |
| Household supplies | 1.06 | −0.003*** | (0.000) | Necessity |
| Personal care products | 1.05 | 0.004*** | (0.001) | Luxury |
| Tobacco | 0.87 | −0.009*** | (0.001) | Necessity |
| Magazines, newspapers, and stationery | 0.53 | 0.002** | (0.001) | Luxury |
| **Housing** | | | | |
| Rental of tenant-occupied nonfarm housing | 3.66 | −0.034*** | (0.005) | Necessity |
| Imputed rental of owner-occupied nonfarm housing | 12.23 | −0.009 | (0.010) | Homothetic |
| Rental value of farm dwellings | 0.17 | 0.002* | (0.001) | Luxury |
| Group housing | 0.02 | 0.001*** | (0.000) | Luxury |
| **Household utilities** | | | | |
| Water supply and sanitation | 0.77 | −0.006*** | (0.000) | Necessity |
| Electricity | 1.48 | −0.018*** | (0.001) | Necessity |
| Natural gas | 0.45 | −0.009*** | (0.001) | Necessity |

**Table 1.** Engel curve classification from 2008–2022 state PCE data. (Cont.)

| PCE category | PCE share (in percent) | Engel slope | | Classification |
|---|---|---|---|---|
| | | Coefficient | Std. Error | |
| **Health care** | | | | |
| Physician services | 4.13 | 0.001 | (0.002) | Homothetic |
| Dental services | 0.99 | −0.003*** | (0.001) | Necessity |
| Paramedical services | 2.71 | 0.007*** | (0.002) | Luxury |
| Hospitals | 7.80 | −0.085*** | (0.004) | Necessity |
| Nursing homes | 1.43 | −0.012*** | (0.001) | Necessity |
| **Transportation services** | | | | |
| Motor vehicle maintenance and repair | 1.36 | −0.002 | (0.001) | Homothetic |
| Other motor vehicle services | 0.71 | 0.005*** | (0.001) | Luxury |
| Ground transportation | 0.37 | 0.004*** | (0.001) | Luxury |
| Air transportation | 0.75 | 0.020*** | (0.002) | Luxury |
| Water transportation | 0.03 | 0.000** | (0.000) | Necessity |
| **Recreation services** | | | | |
| Membership clubs, sports centers, parks, theaters, and museums | 1.45 | 0.016*** | (0.002) | Luxury |
| Audio-video, photographic, and information processing equipment services | 1.05 | 0.008*** | (0.001) | Luxury |
| Gambling | 1.07 | 0.005* | (0.002) | Luxury |
| Other recreational services | 0.47 | 0.005*** | (0.001) | Luxury |
| **Food services and accommodations** | | | | |
| Purchased meals and beverages | 5.60 | 0.010*** | (0.002) | Luxury |
| Food furnished to employees (including military) | 0.17 | −0.001*** | (0.000) | Necessity |
| Accommodations | 1.04 | 0.012*** | (0.002) | Luxury |
| **Financial services and insurance** | | | | |
| Financial services furnished without payment | 2.40 | 0.012*** | (0.002) | Luxury |
| Financial service charges, fees, and commissions | 2.63 | 0.027*** | (0.002) | Luxury |
| Life insurance | 0.72 | 0.002*** | (0.001) | Luxury |
| Net household insurance | 0.09 | 0.000** | (0.000) | Luxury |
| Net health insurance | 1.52 | 0.014*** | (0.003) | Luxury |
| Net motor vehicle and other transportation insurance | 0.59 | 0.004** | (0.001) | Luxury |
| **Communication** | | | | |
| Telecommunication services | 1.31 | 0.008*** | (0.001) | Luxury |
| Postal and delivery services | 0.12 | 0.000** | (0.000) | Necessity |
| **Education services** | | | | |
| Higher education | 1.40 | −0.010*** | (0.002) | Necessity |
| Nursery, elementary, and secondary schools | 0.35 | 0.000 | (0.000) | Homothetic |
| Commercial and vocational schools | 0.39 | 0.007*** | (0.000) | Luxury |
| **Other services** | | | | |
| Professional and other services | 1.54 | −0.004* | (0.002) | Necessity |
| Personal care and clothing services | 1.13 | 0.022*** | (0.002) | Luxury |
| Social services and religious activities | 1.50 | 0.021*** | (0.005) | Luxury |
| Household maintenance | 0.64 | 0.005*** | (0.000) | Luxury |

*Notes.* The "PCE share" column shows the 2008–2022 average of each good's share of total US personal consumption expenditures on the 71 categories we include. The remaining columns report the slope coefficients from regressing state-level expenditure shares on the corresponding level of logarithmized personal consumption expenditures per capita (with state-by-year clustered standard errors in parentheses) and the resulting classification as necessity, luxury, or homothetic. Each estimation controls for year fixed effects, BEA region fixed effects, and interstate price differences through BEA's regional price parities. States are weighted by population size. *, **, and *** denote statistical significance at the 5 percent, 1 percent, and 0.1 percent.

Expenditure Survey (CEX) data. Applying the regression model (15) on these state averages, we then obtain a near identical luxury-necessity split as Hochmuth, Pettersson and Weissert obtains from the CEX microdata; only the category "other vehicle expenditures" differs (see Table A.2 in Appendix A). Overall, these observations suggest that our approach works well on the state PCE data.

The classification in Table 1 yields basket expenditure shares at the aggregate US level that are shown in Figure 1a. As expected under sustained economic growth, the expenditure share on homothetic goods remains stable while the necessity share trends downwards. Over the full sample period, the necessity share declines by around 10 percentage points. Dividing individual expenditure shares by these basket shares generates the within-basket shares needed to compute the Törnqvist index (14) for each bundle. The resulting price indices are shown in Figure 1b together with the official PCE price index for reference. These indices reveal that the price of necessities relative to luxuries has increased by about 50 percent since 1959, which likely explains the flat trend in both necessity and luxury shares since the late 1990s.
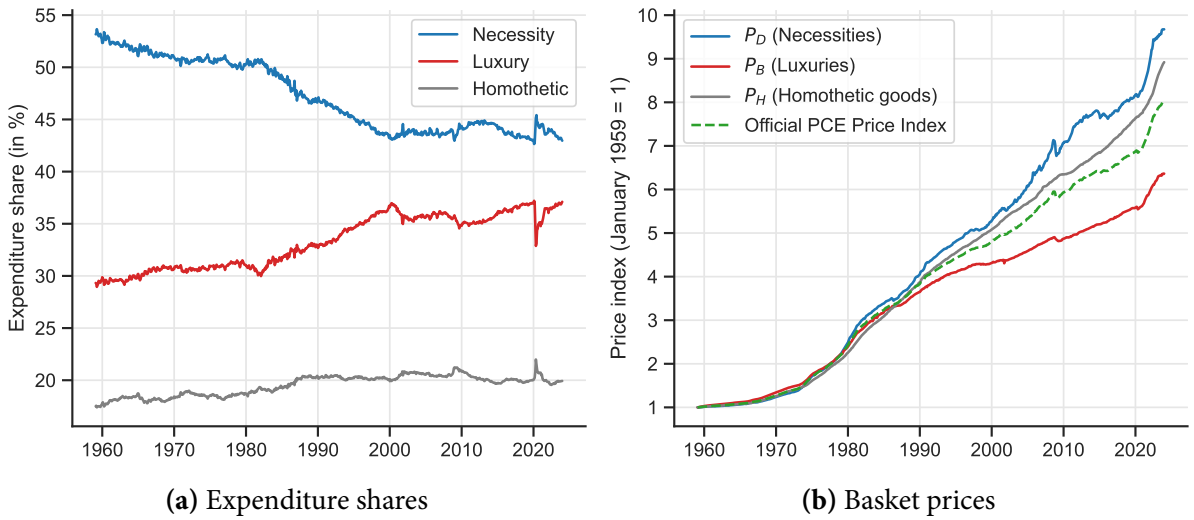


**(a)** Expenditure shares        **(b)** Basket prices

**Figure 1.** Constructed US time series, Jan 1959 to Dec 2023.

## 3.3 Estimation of Preference Parameters

We estimate the preference parameter $\varepsilon$ using the same cross-state variation as for the classification. In doing so, we exploit that PIGL preferences consistently aggregate individual-level expenditure shares into market-level expenditure shares as functions of per-capita expenditures. Specifically, for any measure $N$ of consumers (indexed by $h$ below) facing the same prices, the corresponding aggregate necessity share $\overline{w}_D$ is defined as the expenditure-weighted average of individual-level expenditure shares. This definition together with Equations (3), (7) and (8) generates an aggregate expenditure share in some implicit time period of the form

$$\overline{w}_D \equiv \frac{1}{N} \int_0^N \frac{e_h}{\overline{e}} w_{Dh} \, dh = \widetilde{v} \kappa^{-\varepsilon} \left( \frac{P_F}{\overline{e}} \cdot \frac{P_D}{P_B} \right)^{\varepsilon}, \tag{16}$$

where $\overline{e}$ is the expenditure level per person within the group, $\widetilde{v} \equiv v\left[F\big(H(\boldsymbol{p}_s), B(\boldsymbol{p}_s)\big)D(\boldsymbol{p}_s)/B(\boldsymbol{p}_s)\right]^{\varepsilon}$ is a scale parameter, and the aggregation factor

$$\kappa = \left[ \frac{1}{N} \int_0^N \left( \frac{e_h}{\overline{e}} \right)^{1-\varepsilon} dh \right]^{-\frac{1}{\varepsilon}} \tag{17}$$

is a scale-invariant inequality measure. It is therefore possible to estimate $\varepsilon$ from macro data without aggregation bias.

Taking logs of Equation (16) consequently allows us to run a linear fixed-effects regression on state-level necessity shares, per-capita expenditures, and prices.[9] Assuming that the aggregation factors (17) are uncorrelated with expenditures and prices beyond what is captured by any fixed effects,[10] we obtain the estimating equation

$$\ln \overline{w}_{Dgt} \;=\; \alpha_r + \alpha_t + \varepsilon \ln \left[ \frac{P_{Fgt}}{\overline{e}_{gt}} \cdot \frac{P_{Dgt}}{P_{Bgt}} \right] + u_{gt}, \tag{18}$$

where $\alpha_r$ and $\alpha_t$ again denote region and time fixed effects and where $P_{Fgt}$, $P_{Dgt}$, and $P_{Bgt}$ are basket price indices for state $g$ in year $t$. To construct the latter three, we first compute state and category-specific prices by adjusting the PCE price indices for all 71 product categories with the corresponding RPP adjustment factors and then apply the formulas in Section 2 on these prices together with the state-level expenditure shares.

**Table 2.** Preference parameters estimated from US state-level data.

|  | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| $\varepsilon$ | 0.702*** | 0.726*** | 0.791*** | 0.512*** |
|  | (0.061) | (0.062) | (0.018) | (0.038) |
| Durable goods[a] | ✓ |  | ✓ | ✓ |
| RPP controls | ✓ | ✓ |  | ✓ |
| Age controls |  |  |  | ✓ |
| Observations | 765 | 765 | 1,326 | 765 |
| RMSE | 0.053 | 0.053 | 0.038 | 0.039 |
| Adjusted $R^2$ | 0.290 | 0.286 | 0.708 | 0.536 |

*Notes.* RMSE denotes the root mean square error. Robust standard errors in parentheses. *, **, and *** denote statistical significance at the 5 percent, 1 percent, and 0.1 percent levels. Columns (3) and (4) use the classification without RPPs and with age controls, respectively.
[a] Motor vehicles and parts, furnishings and durable household equipment, recreational goods and vehicles, and other durable goods.

Table 2 reports the results of estimating Equation (18) on state PCE data. The first column shows our preferred estimate of $\varepsilon$, which we use when constructing the nonhomothetic PCE price indices. The remaining columns report how this estimate changes under various adjustments: column (2) excludes durable goods, which is a useful consideration as these categories include investment-good properties that may interfere with our notion of consumption; column (3) removes all RPP adjustments to assess how crucial our constructed state-level prices are for the estimation; and column (4) includes additional controls for the age composition in each state, as reported by the US Census Bureau. This last alternative is motivated by Cravino, Levchenko and Rojas (2022), who identify population aging as an important driver of aggregate US structural transformation from goods to services (and consequently, from necessities to luxuries).

We find an $\varepsilon$ of 0.702 in our benchmark regression, with homothetic preferences ($\varepsilon = 0$) being clearly rejected. This estimate lies close to previous work: considering virtually identical PIGL demand systems,

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[9] Obvious caveats here include a potential simultaneous equation bias between expenditure shares and prices, and potential measurement errors on expenditures and prices. Fully addressing these issues is beyond the scope of the paper, though the final part of the paper includes a sensitivity analysis on the value for $\varepsilon$.

[10] Figure A.6 in Appendix A plots estimates of $\kappa$ at the US state level using $\varepsilon = 0.702$ and the same CEX data as in Hochmuth, Pettersson and Weissert (2023), and shows little variation across states, with $\kappa$ ranging between 0.96 and 1 with an average 0.98.

Alder, Boppart and Müller (2022) estimate $\varepsilon$ to 0.71 using twentieth-century macro data for the US whereas Hochmuth, Pettersson and Weissert (2023) find a value of 0.677 with CEX microdata. As in Boppart (2014), excluding durables marginally increases $\varepsilon$. Removing RPP adjustments could shift $\varepsilon$ in either direction depending on how it affects relative prices; we find that it too increases $\varepsilon$, to 0.791. Nevertheless, columns (2) and (3) both produce point estimates that remain within the confidence interval of the benchmark estimation. Consistent with Cravino, Levchenko and Rojas (2022), controlling for age lowers the degree of nonhomotheticity, thus suggesting that age-specific tastes explain some of the observed consumption patterns. The estimate for $\varepsilon$ remains significantly different from zero though, and in a similar ballpark as our benchmark. Taken together, these econometric results point to a value for $\varepsilon$ somewhere between 0.5 and 0.8, with our benchmark being close to the midpoint of this range.

## 3.4 Base-Period Distribution of US Personal Consumption Expenditures

The basket prices and the parameter value for $\varepsilon$ allow us to compute the PIGL cost-of-living index for a given base-period expenditure share on necessities. This, in turn, is sufficient to analyze aggregate changes in the cost of living using the expenditure shares in Figure 1, or to answer questions about cost-of-living changes for hypothetical groups or individuals with some given expenditure levels. To obtain empirically relevant estimates of cost-of-living inequality, however, we need information about the distribution of base-period expenditures. Until recently, no such PCE data existed, but a recent paper by Garner *et al.* (2022) bridges this gap by distributing PCE spending in 2019 across US households, which we consequently use as base year here.[11] These estimates divide aggregate spending by decile in the expenditure distribution, both for total expenditures and for 15 broad commodity groups. The former also includes expenditure shares for the top 1 and 5 percent of the distribution.
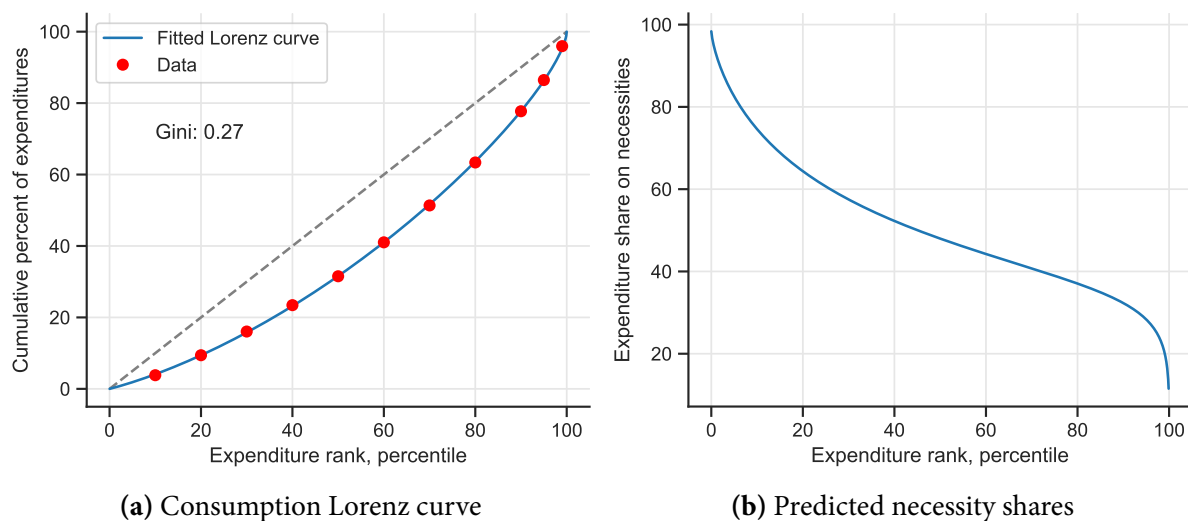


**(a)** Consumption Lorenz curve        **(b)** Predicted necessity shares

**Figure 2.** Estimated US consumption profiles for the base year 2019.

Garner *et al.*'s (2022) breakdown into deciles and into 15 commodity groups is too coarse to directly infer household-level expenditure shares on the necessity basket identified in Figure A.1. Fortunately, the theoretical model predicts a direct link between expenditure shares at the household level, the corresponding aggregate expenditure share, and the overall distribution of consumption expenditures. Denote the Lorenz curve associated with the expenditure distribution by $\ell(x)$, where $x$ is the expenditure rank, and its derivative with respect to the rank by $\ell'(x)$. Evaluated at the rank $x_h$ of household $h$, this derivative must

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satisfy $\ell'(x_h) = e_h / \bar{e}$. Using the individual expenditure share (3) and the aggregate expenditure share (16) then yields

$$w_{Dh} = \frac{w_{Dh}}{\bar{w}_D} \bar{w}_D = \left(\frac{e_h}{\bar{e}\kappa}\right)^{-\varepsilon} \bar{w}_D = \left(\frac{\ell'(x_h)}{\kappa}\right)^{-\varepsilon} \bar{w}_D. \qquad (19)$$

Similarly, by Equation (17), the aggregation factor $\kappa$ in (19) can be written

$$\kappa = \left[\int_0^1 \ell'(x)^{1-\varepsilon}\, dx\right]^{-\frac{1}{\varepsilon}}. \qquad (20)$$

Thus, the Lorenz curve $\ell(x)$, an empirically observed aggregate expenditure share $\bar{w}_D$ and a parameter value for $\varepsilon$ are sufficient to impute all base-period expenditure shares at the individual level.[12]

We therefore use the estimates by Garner *et al.* (2022) to construct a consumption Lorenz curve. To that end, we follow Sitthiyot and Holasut's (2021) suggestion and parameterize $\ell(x)$ as a weighted average between an exponential function and the functional form implied by the Pareto distribution: $\ell(x) = (1 - \omega)x^\eta + \omega\big(1 - (1 - x)^{1/\eta}\big)$, where $\omega$ and $\eta$ are parameters to estimate. Fitting this function to the distributional PCE data yields the Lorenz curve shown in Figure 2a, which exhibits an $R^2$ of 0.9999. Figure 2b shows the corresponding expenditure share predictions from Equations (19) and (20). Together with the basket prices in Figure 1b and the parameter value for $\varepsilon$, these shares yield the nonhomothetic PCE price indices that underlie the results explored in the next section.

# 4  PCE Inflation Across the Expenditure Distribution

Unlike most other approaches to measuring inflation inequality, a key benefit of the PIGL cost-of-living index is that it can be implemented without requiring detailed microdata for every period of consideration. Once constructed, the nonhomothetic PCE price index therefore easily sheds light on the very latest inflation developments as well as on long-run changes. In this section, we discuss these two cases in turn.

## 4.1  Long-Run Inflation Inequality

Starting with the full sample period from 1959 to 2023, we find larger increases in the cost of living for consumption-poor households over the last 65 years. Figure 3 summarizes this empirical long-run result. Qualitatively, this comes as no surprise in light of the increasing relative price of necessities shown in Figure 1b, since poorer households attach higher weights to necessities than the rich do. Quantitatively, Figure 3b displays average annual inflation rates that decrease monotonically with the base-period expenditure level from more than 3.6 percent per year at the very bottom of the distribution to less than 3.1 percent per year at the very top. Heterogeneous changes in the cost of living therefore generate persistent inflation inequality across the entire expenditure distribution.

Figure 3a illustrates the dynamics of the cost-of-living indices for select expenditure groups. The figure shows cumulative increases in the cost of living of 850 percent for the bottom ten percent of the expenditure distribution and 644 percent for the top ten percent. The gap of 206 percentage points corresponds to a

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[12] A similar prediction holds for a group, say a decile $d$, over a distribution interval $[x_{d0}, x_{d1}]$. Then $\Delta\ell_d / \Delta x_d = \bar{e}_d / \bar{e}$, where $\bar{e}_d$ is group-$d$ average expenditures and $\Delta\ell_d = \ell(x_{d1}) - \ell(x_{d0})$, $\Delta x_d = x_{d1} - x_{do}$. The aggregate expenditure share of the group becomes $\bar{w}_d = \left(\frac{\Delta\ell_d / \Delta x_d}{\kappa / \kappa_d}\right)^{-\varepsilon} \bar{w}_D$, where $\kappa_d$ is a group-specific aggregation factor given by $\kappa_d = \left[\frac{1}{\Delta x_d}\int_{x_{d0}}^{x_{d1}} \left(\frac{\ell'(x)}{\Delta\ell_d / \Delta x_d}\right)^{1-\varepsilon} dx\right]^{-1/\varepsilon}$.

0.39 percentage point difference in average annual inflation rates between these groups. These differences are consistent with Jaravel and Lashkari (2024), the one study we know of that focuses on long-run changes for the United States, who find near-identical inflation inequality between 1955 and 2019 using CEX microdata. Our analysis consequently reinforces these trends with PCE data.

How much should we care about these long-run developments? After all, a 0.39 percentage point inflation difference may not sound like much in a given year. But small annual differences have large impacts on real consumption measures in the long run. To illustrate, note that the ratio between the official PCE price index and the nonhomothetic PCE cost-of-living index for some group is the percentage change in estimated real consumption growth for that group when switching deflator from the former to the latter.[13] Figure 3a therefore reveals that real consumption growth between 1959 and 2019, measured in 1959 reference prices, is about 14 percent lower for the bottom decile and 8 percent higher for the top decile than what a common homothetic deflator suggests. Real consumption inequality, as measured by the 90/10 percentile ratio, consequently grows by 25 percent more over this period than it does if we ignore the inequality in cost-of-living changes.
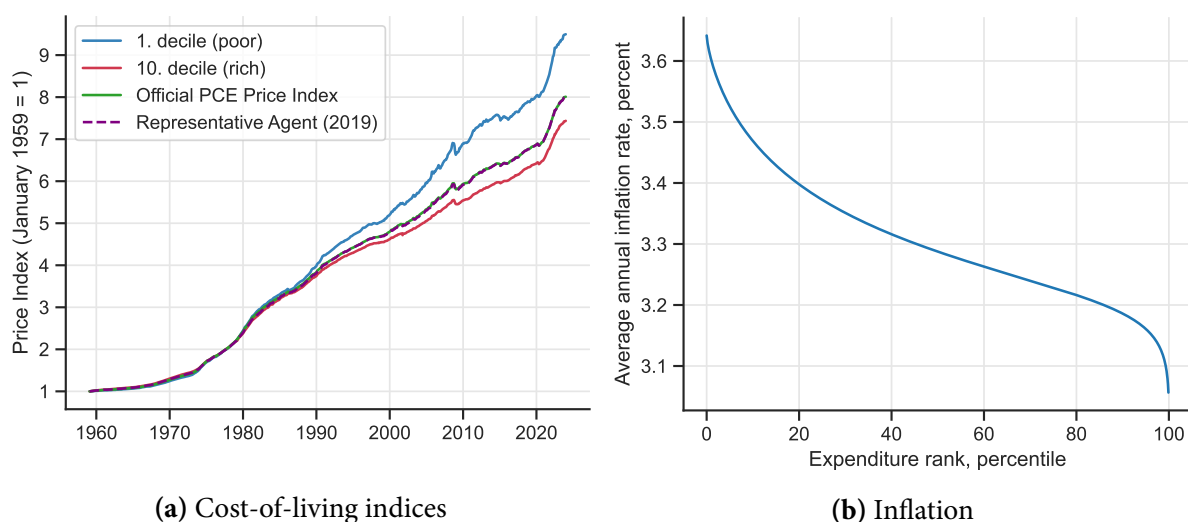


**(a)** Cost-of-living indices

**(b)** Inflation

**Figure 3.** Long-run inflation inequality.

*Notes.* "Representative Agent (2019)" refers to the cost-of-living index that uses the aggregate US expenditure share on necessities in 2019 as index weight.

## 4.2  Inflation Inequality in the Recent Inflation Surge

Amid concerns in the public debate that the recent cost-of-living crisis fell hardest on low-income households, we next ask whether the long-run inflation disparities carry over to the 2021–2023 inflation surge. To that end, Figure 4 reports annualized PCE inflation rates between January 2020 and December 2023 for the same groups considered in Figure 3a. While the inflation dynamics of the nonhomothetic PCE measures closely follow official PCE inflation, we find that as inflation takes off in 2021, then so does the gap between rich and poor. Throughout 2022, the bottom decile experiences inflation rates that exceed those of the top decile by on average 1.9 percentage points, ultimately peaking at 2.9 percentage points in June 2022 before contracting. This gap is roughly an order of magnitude larger than those found in

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[13] For a given change in nominal expenditures $e_t/e_s$ between periods $s$ and $t$, real growth measured in period-$t$ prices is given by the quantity index $Q(u_t, u_s, \boldsymbol{p}_t) = (e_t/e_s) / P(u_s, \boldsymbol{p}_s, \boldsymbol{p}_t)$, where $u_s$ and $u_t$ are the utility levels corresponding to $e_s$ and $e_t$. Abusing notation, denote the official PCE price index and the associated quantity index by $P_{s,t}^{PCE}$ and $Q_{s,t}^{PCE} = (e_t/e_s) / P_{s,t}^{PCE}$. The change in real expenditure growth from switching deflators is then $Q(u_t, u_s, \boldsymbol{p}_t)/Q_{s,t}^{PCE} = P_{s,t}^{PCE}/P(u_s, \boldsymbol{p}_s, \boldsymbol{p}_t)$.

comparable pre-2021 analyses, such as Jaravel (2019), Argente and Lee (2021), and Klick and Stockburger (2021), thus underscoring that concerns about the disproportionate impact on low-income households during the inflation surge are indeed legitimate.
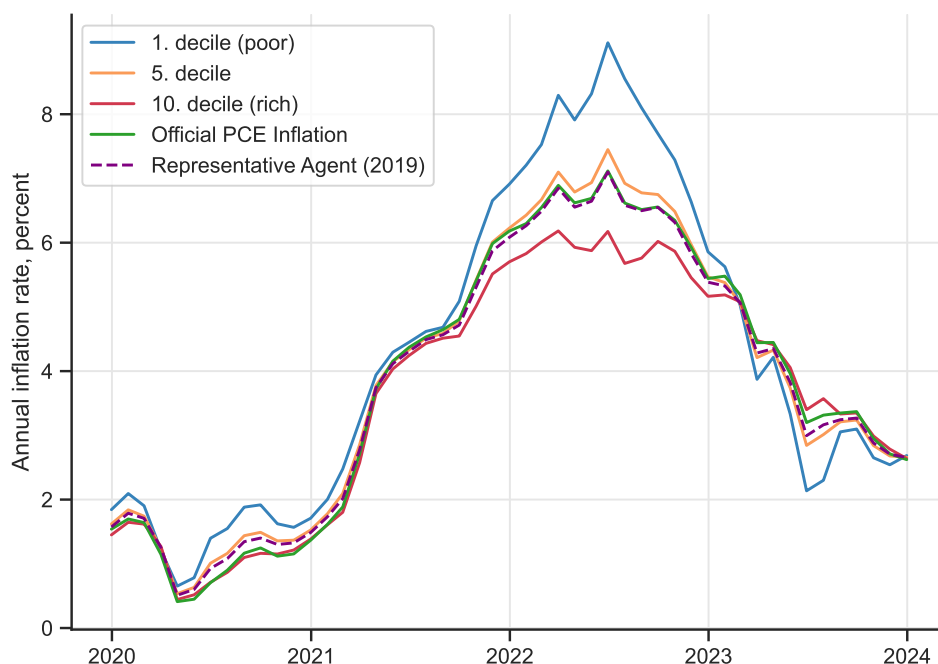


**Figure 4.** Annual PCE inflation rates during the inflation surge.

*Notes.* "Representative Agent (2019)" refers to the inflation implied from the cost-of-living index that uses the aggregate expenditure share on necessities in 2019 as weight.
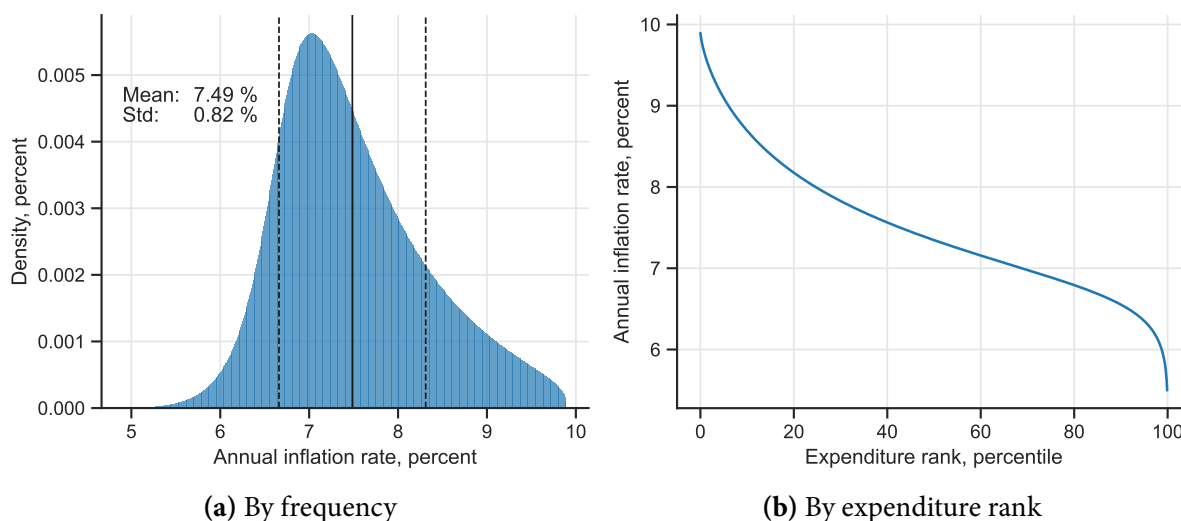


| (a) By frequency | (b) By expenditure rank |
|:---:|:---:|

**Figure 5.** The cross-sectional distribution of PCE inflation rates, June 2022.

*Notes.* The histogram in Figure 5a is constructed with a bin width of 0.01 percentage points. The solid line represents the mean inflation rate and the dotted lines are the mean plus/minus one standard deviation.

To get an idea of what the entire cross-sectional distribution of inflation rates looks like, Figure 5 plots the density of inflation rates and the variation along the full expenditure distribution in June 2022. The distribution in Figure 5a exhibits a mean and standard deviation of 7.49 and 0.82 percent, which implies

that around 70 percent of inflation rates fall within a narrow band of 6.7 to 8.3 percent.[14] This is also the month with the largest inflation disparities and compared to the 0.6 percentage point gap in Figure 3 for the entire sample period, Figure 5b shows an inflation rate gap of up to four percentage points between the very poorest and richest.

What are the underlying sources of these inflation disparities? The negative relationship between the inflation rate and the consumption expenditure level in Figure 4 again points to an increasing relative price of necessities, just as in the long-run case. We can provide a more exact breakdown than this, however, since the PIGL cost-of-living index features a complete decomposition of the contributions of individual products. Using this property, Figure 6 consequently identifies the key drivers at work by decomposing the inflation rate gap between the top and bottom expenditure deciles. For ease of exposition, we aggregate goods into broader groups with Figure 6 subsequently displaying the seven largest contributors.
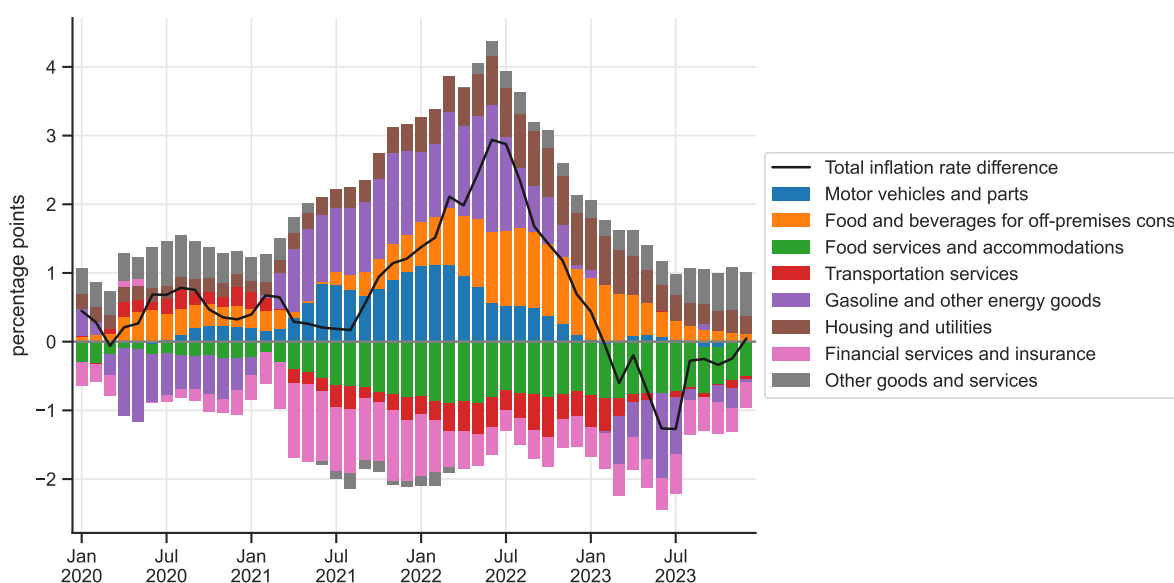


**Figure 6.** Inflation rate gap between the top and bottom expenditure deciles.

From mid-2021 through 2022, the period in which the largest inequality occurs, Figure 6 identifies increasing costs for food consumed at home, energy, and motor vehicles as the primary sources of the higher inflation faced by the poor. For instance, in June 2022, the peak month for inflation inequality, increasing prices for gasoline and other energy products raised the inflation rate for the bottom decile by 1.85 percentage points more than it did for the top decile. The corresponding numbers for food at home, housing and utilities, and motor vehicles are 1, 0.6, and 0.7 percentage points, respectively. Downside contributors are higher prices for food services and accommodations, transportation services, and financial services, which are consumed proportionately more by the rich. Especially the former two are somewhat expected considering the product groups that raise the inflation gap, since food and energy are vital inputs in these two industries.

In sum, this section shows that the short-run inflation inequality found in Consumer Expenditure Survey data and in US scanner data by for example Kaplan and Schulhofer-Wohl (2017), Jaravel (2019), Argente and Lee (2021), and Klick and Stockburger (2021) also holds up in the PCE data. While corroborating the

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[14] The distribution of inflation rates is narrower than those obtained by Kaplan and Schulhofer-Wohl (2017), but the large dispersion in that paper is primarily driven by differences in prices paid and by heterogeneous household characteristics and tastes, which this paper abstracts from.

qualitative conclusions from these studies, the magnitudes found here during the recent inflation surge are considerably larger. The reason is much the same as the reason why inflation was high in general: prices of food and energy soared, and these products are consumed proportionately more by the poor.

# 5 Disentangling the Inflation Differences

While our main results are consistent with much of the recent literature on inflation inequality, they contrast with our own work in Hochmuth, Pettersson and Weissert (2023). There, we use the same approach with CEX microdata and find an inflation rate gap of 0.06 percentage points between the top and bottom deciles between 1995 and 2020. Several factors may explain this difference. For instance, Hochmuth, Pettersson and Weissert focus on consumption which is more limited in scope (durable goods are excluded, for example), use different parameter values, apply empirical rather than imputed expenditure shares in the price index formula, and consider a coarser level of product aggregation. Motivated by these differences, this section attempts to shed light on how these factors affect our baseline PCE results.

## 5.1 The Role of Durable Goods

We first consider the impact of durable goods. In the BEA data, the price of durable goods relative to the overall PCE price index steadily declines from 1950 on, thus implying that the presence of durables dampens the overall inflation level in our main estimates. More uncertainty surrounds the measured inflation inequality, however, where the impact can go in either direction. To investigate the importance of durable goods, we exclude these categories from the sample and redo the main analysis. That is, we subtract the first four major groups in Table 1 (motor vehicles and parts, furnishings and durable household equipment, recreational goods and vehicles, and other durable goods) from the expenditure totals, use the parameter estimate for $\varepsilon$ from the no durables specification in Table 2, and compute all inflation measures again. Recalling that $\varepsilon$ is virtually unchanged when we exclude durables, the drivers in this exercise are the changes that we obtain in the price indices of necessities, luxuries, and the homothetic basket.[15]



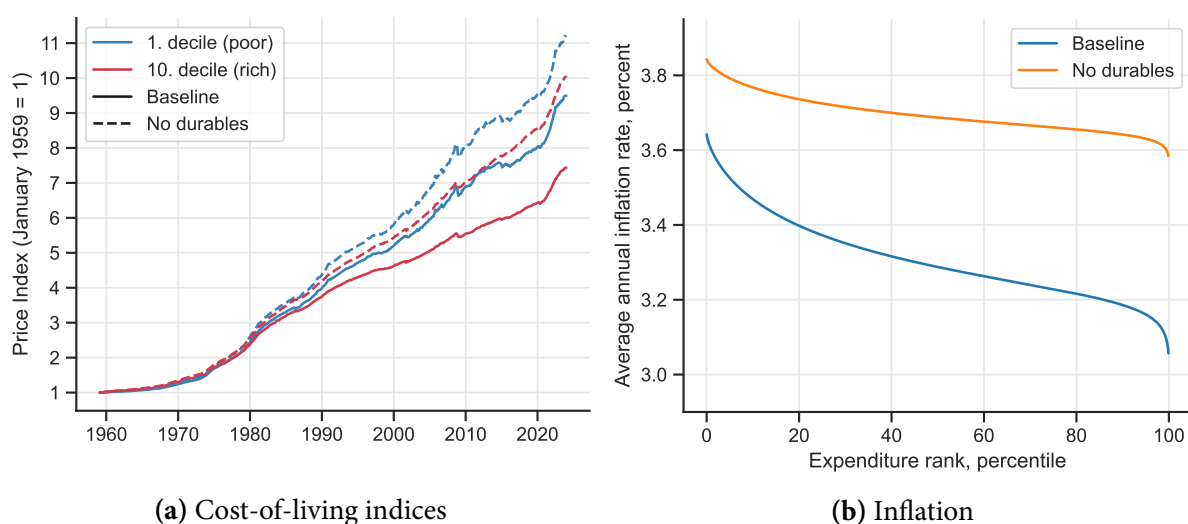| **(a)** Cost-of-living indices | **(b)** Inflation |
|---|---|

**Figure 7.** Cost-of-living indices and average inflation without durable goods.

*Notes.* The scenario without durable goods excludes the first 17 categories of Table 1. The classification into necessity, luxury and homothetic basket is unchanged to the baseline, but $\varepsilon$ is re-estimated.

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[15] Figure A.2 in Appendix A contrasts the basket prices with and without durable goods.

Figure 7 compares the no-durables case to our baseline results, which reveals that durable goods explain about half of the estimated inflation inequality. For instance, the annual inflation rate gap between the top and bottom deciles shrinks from 0.39 to 0.17 percentage points. Meanwhile (and as expected), the overall inflation level increases when we exclude durables, with the average annual inflation rate rising by 0.4 percentage points for the median consumer. The reduction in inflation inequality as measured by absolute differences is thus contrary rather than due to the change in the inflation level. For the 1995–2020 period considered by Hochmuth, Pettersson and Weissert (2023), we also find a decline in the inflation rate gap between the top and bottom deciles from 0.54 to 0.18 percentage points, thus suggesting that durables explain about two thirds of the difference to Hochmuth, Pettersson and Weissert's CEX-based estimates.

## 5.2    The Role of the Parameter Value for $\varepsilon$

The approach in this paper relies on a cost-of-living index that requires the estimation of one exogenous preference parameter. A key concern that this subsection investigates is whether the inflation inequality uncovered above is sensitive to the choice of value for this parameter.

As a starting point, suppose we redo the whole exercise for some other feasible parameter choices. Consider for instance the following cases: homothetic Cobb-Douglas preferences, in which $\varepsilon \to 0$; quasi-homothetic preferences, in which $\varepsilon = 1$; and an intermediate case $\varepsilon = 0.3$ with a lower degree of nonhomotheticity than in our baseline. Figure 8a compares the average annual inflation rates over the full sample period for these specifications against those of the baseline estimation. At first sight, it seems that the choice of parameter value matters a great deal: the inflation gap between the top and the bottom of the distribution ranges from almost 2 percentage points under quasi-homothetic preferences to the zero differences (naturally) obtained with homothetic preferences.



**(a)** Adjusting $w_D$

**(b)** Holding $w_D$ fixed
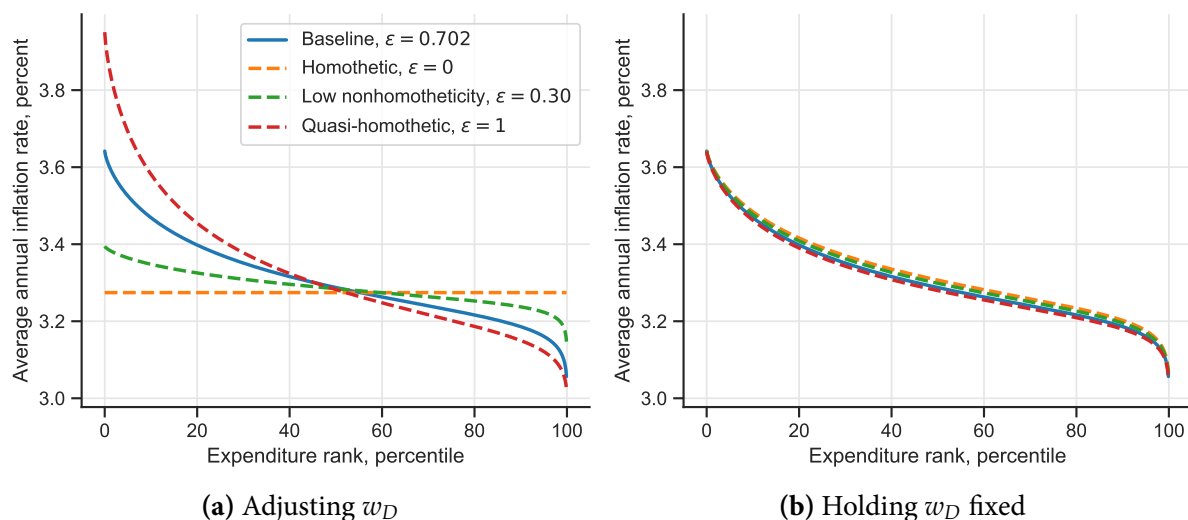
**Figure 8.** Long-run inflation inequality for different parameter values.

These disparities are driven by two possible channels. First, since we consider imputed necessity expenditure shares $w_{Dh} = \left( \ell'(x_h) / \kappa \right)^{-\varepsilon} \overline{w}_D$, the parameter choice affects the base-period allocation and thereby also the index weight on necessities. Second, $\varepsilon$ also affects the predicted substitution behavior of households between the necessity and luxury baskets, as captured by the direct presence of this parameter

in the cost-of-living index formula (10).[16] For applications where base-period expenditure shares on the necessity basket can be directly observed from the data, it is the sensitivity with respect to the second channel that is of primary interest.

A perhaps more interesting analysis is therefore to consider how the results change if we vary the parameter values but keep the base-period consumption patterns fixed according to the baseline estimates. In this case, any differences to the baseline effectively highlight the role of substitution effects across the three different baskets. The results from this exercise, shown in Figure 8b, paint a completely different picture regarding the sensitivity of the results to different parameter choices. At any given point in the expenditure distribution, the range of inflation rates between the four cases is never more than 0.03 percentage points. Differences in inflation inequality are even smaller: the inflation rate gap between the top and bottom deciles is always between 0.39 and 0.40 percentage points. This finding is also not limited to the specific cases in Figure 8: Table A.3 in Appendix A reveals that the gap remains stable over a full grid of parameter values. Thus, both inflation inequality and the general level of inflation are close to identical across the different parameter specifications.

The key takeaway from this exercise is therefore that $\varepsilon$ matters only insofar as we need to impute expenditure shares from individual expenditure levels and aggregate expenditure shares. When individual expenditure shares can be inferred directly from the data for some base period, the choice of parameter value seems inconsequential for the inflation inequality measures obtained with the PIGL cost-of-living index. This distinction is important because for most other applications, the latter is arguably the more relevant case.

## 5.3  The Role of Imputed Expenditure Shares and Product Aggregation

The conclusions from Section 5.2 clearly do not apply to this paper since we *do* impute the necessity expenditure shares from the estimated $\varepsilon$. Because empirical counterparts for these imputed shares do not yet exist at the product aggregation level we consider, we cannot say for sure how sensitive our results are to this imputation. Some insight can be obtained from Garner *et al.*'s (2022) distributional PCE estimates, however, as these data include expenditure shares by consumption decile for 15 broad product groups.[17] Implementing our approach at this coarser level of product aggregation allows us to examine the difference between imputing expenditure shares and using Garner *et al.*'s empirical estimates directly in the price index formula.

In implementing the nonhomothetic PCE index for the product groups in Garner *et al.* (2022), there are now effectively two ways to classify goods into necessities, luxuries, and homothetic goods: either by applying our baseline approach with state PCE data, or by directly inferring expenditure elasticities from the slopes along the cross-sectional distributions of expenditure shares in the distributional PCE data. Applying both approaches, we find identical classifications for over 95 percent of expenditures, with motor vehicles and parts being the only unmatched category.[18] This outcome provides additional support for our baseline classification approach with state PCE data. Proceeding with the classification

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[16] Recall that the elasticity of substitution between the luxury bundle and the necessity bundle in our theoretical framework is given by $1 - \frac{1-w_D}{w_B}\varepsilon$.

[17] These groups include: motor vehicles and parts; furnishings and durable household equipment; recreational goods and vehicles; other durable goods; food and beverages purchased for off-premises consumption; clothing and footwear; gasoline and other energy goods; other nondurable goods; housing and utilities; health care; transportation services; recreation services; food services and accommodations; financial services and insurance; and other services.

[18] See Figure A.3 in Appendix A for a comparison.

based on the distributional PCE data, we estimate an $\varepsilon$ of 0.215 (with a standard error of 0.027) across states, which suggests a lower degree of nonhomotheticity when product categories are more aggregated. We subsequently use this classification and parameter estimate to construct the relevant cost-of-living indices.

Considering both the level and dispersion of inflation rates, we find negligible differences between model-imputed and empirical necessity shares at the coarser level of product aggregation. Figure 9 plots the average annual inflation rates between 1959 and 2023 by expenditure decile, which illustrates a difference between the two cases which is never more than 0.05 percentage points for any given expenditure decile. The similarities are not by construction, since the necessity shares ultimately stem from separate sources: the model-predicted expenditure shares are imputed from the cross-sectional variation in state PCE data whereas Garner *et al.* (2022) construct the distributional PCE estimates from CEX microdata. These findings therefore give us confidence that the imputation also works well in the baseline case with 71 product categories.
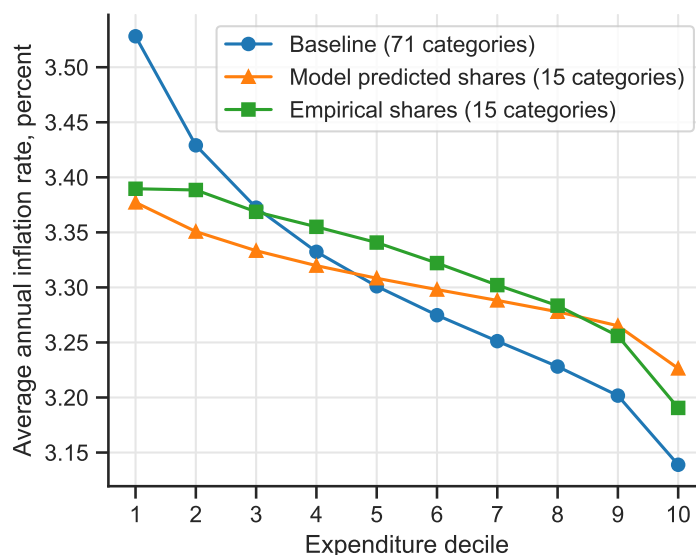


**Figure 9.** Average inflation rates between 1959 and 2023 for different levels of aggregation.

Figure 9 and the lower point estimate for $\varepsilon$ also echo Jaravel's (2019, 2021) emphasis on using the most disaggregated product categories possible when measuring inflation inequality. Plotting the versions with 15 product categories against our baseline results reveals a reduction in the inflation gap by about one half when using the coarser set of products. The difference comes from changes at both ends of the expenditure distribution, narrowing the gap between the first and tenth deciles from 0.39 percentage points in the baseline to about 0.15 to 0.20 percentage points. Consequently, we close the paper by corroborating Jaravel's concern about aggregation bias, showing that it applies not only when working with microdata but also in applications using US PCE data.

# 6 Conclusion

This paper uses recent estimates of the cross-sectional distribution of US Personal Consumption Expenditures to construct a first-ever distribution of PCE inflation across US households. The underlying cost-of-living index originates from a theoretically sound nonhomothetic utility function, generalizes the Törnqvist price index, and only contains one unknown parameter. A central point in the paper is that

the implementation of this index requires no more than a handful of publicly available tables from the BEA's national and regional accounts, provided that a single cross-sectional distribution of consumption expenditures exists.

The nonhomothetic PCE price indices reveal new facts about the distribution of PCE inflation. Using 2019 utility levels as base, the average annual inflation rate of the bottom expenditure decile is 0.39 percentage points higher than that of the top decile over the 65-year period starting in 1959, half of which is explained by a relative price decline of durable goods. A similar 1.9 percentage point difference holds throughout 2022, in the midst of the recent inflation surge. Inflation inequality is therefore a long-run as well as a short-run phenomenon in the United States.

On a broader level, our paper adds to several previous calls for improved distributional national accounts. The documented aggregation bias and the insensitivity of the price index parameter when expenditure shares can be inferred from the data suggest that statistical agencies should aim to construct distributional consumption data at increasingly detailed levels of product aggregation. Such data would allow practitioners to quickly and more accurately obtain nonhomothetic deflators and inflation measures by simply choosing some rough parameter value for the price index formula presented here and plugging in the empirical expenditure shares. While these efforts are already well under way among statistical agencies, much remains to be done.

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# Appendix A    Addtional Figures and Tables

| Category | (1) | (2) | (3) |
|---|---|---|---|
| New motor vehicles, 2.1 % | D | D | B |
| Used motor vehicles, 1.2 % | D | D | D |
| Motor vehicle parts/accessories, 0.6 % | D | D | D |
| Furniture and furnishings, 1.5 % | B | B | B |
| Household appliances, 0.5 % | D | D | D |
| Glassware, tableware & utensils, 0.3 % | B | B | B |
| Tools for house and garden, 0.3 % | D | D | D |
| Video/audio/photo equipment, 1.9 % | B | B | B |
| Sporting equipment and guns, 0.6 % | D | D | B |
| Sports and recreational vehicles, 0.5 % | H | H | H |
| Recreational books, 0.2 % | H | H | D |
| Musical instruments, 0.0 % | B | B | B |
| Jewelry and watches, 0.6 % | B | B | B |
| Therapeutic appliances/equipment, 0.5 % | D | D | D |
| Educational books, 0.1 % | B | B | B |
| Luggage and similar items, 0.2 % | B | B | B |
| Telephone and related equipment, 0.2 % | B | B | B |
| Food and nonalcoholic beverages, 6.9 % | D | D | D |
| Alcoholic beverages, 1.2 % | B | B | B |
| Food produced/consumed on farms, 0.0 % | D | D | D |
| Women's and girls' clothing, 1.4 % | H | H | H |
| Men's and boys' clothing, 0.8 % | D | D | D |
| Children's and infants' clothing, 0.2 % | D | D | D |
| Other clothing and footwear, 0.7 % | D | D | D |
| Gasoline, 2.8 % | D | D | D |
| Fuel oil and other fuels, 0.2 % | D | D | H |
| Pharmaceutical products, 3.4 % | D | D | D |
| Recreational items, 1.4 % | D | D | D |
| Household supplies, 1.1 % | D | D | D |
| Personal care products, 1.1 % | B | B | H |
| Tobacco, 0.9 % | D | D | D |
| Magazines/newspapers, stationery, 0.5 % | B | B | H |
| Rental nonfarm dwellings, 3.7 % | D | B | D |
| Owned nonfarm dwellings, 12.2 % | H | B | H |
| Rental value of farm dwellings, 0.2 % | B | D | D |
| Group housing, 0.0 % | B | H | B |
| Water supply and sanitation, 0.8 % | D | D | D |
| Electricity, 1.5 % | D | D | D |
| Natural gas, 0.5 % | D | D | D |
| Physician services, 4.1 % | H | D | H |
| Dental services, 1.0 % | D | D | B |
| Paramedical services, 2.7 % | B | B | H |
| Hospitals, 7.8 % | D | D | D |
| Nursing homes, 1.4 % | D | D | D |
| Motor vehicle maintenance/repair, 1.4 % | H | H | B |
| Other motor vehicle services, 0.7 % | B | B | H |
| Ground transportation, 0.4 % | B | B | D |
| Air transportation, 0.8 % | B | B | B |
| Water transportation, 0.0 % | D | H | D |
| Membership clubs, 1.5 % | B | B | B |
| Video/audio/photo equip services, 1.0 % | B | B | B |
| Gambling, 1.1 % | B | B | B |
| Other recreational services, 0.5 % | B | B | B |
| Purchased meals and beverages, 5.6 % | B | B | D |
| Food to employees inc military, 0.2 % | D | D | D |
| Hotels, 1.0 % | B | B | B |
| Financial services no payment, 2.4 % | B | B | B |
| Financial services charges/fees, 2.6 % | B | B | B |
| Life insurance, 0.7 % | B | B | B |
| Household insurance, 0.1 % | B | B | H |
| Health insurance, 1.5 % | B | B | B |
| Motor vehicle insurance, 0.6 % | B | B | B |
| Telecommunication services, 1.3 % | B | B | B |
| Postal and delivery services, 0.1 % | D | H | H |
| Higher education, 1.4 % | D | D | H |
| Elementary and secondary schools, 0.3 % | H | H | H |
| Commercial/vocational schools, 0.4 % | B | B | B |
| Professional and other services, 1.5 % | D | D | D |
| Personal care/clothing services, 1.1 % | B | B | B |
| Social services and religion, 1.5 % | B | B | B |
| Household maintenance, 0.6 % | B | B | B |

**Figure A.1.** Classifying products as necessity, luxury, or homothetic.

*Notes.* The figure shows the classification of PCE categories into the necessity (D), luxury (B) and homothetic (H) baskets. Column (1) shows the baseline specification, column (2) shows the specification without RPP adjustment which uses the full 1997–2022 state panel, and column (3) shows the specification controlling for the age structure of the state population. The percentage number after the description shows the 2008–2022 average US expenditure share among the 71 goods we include.
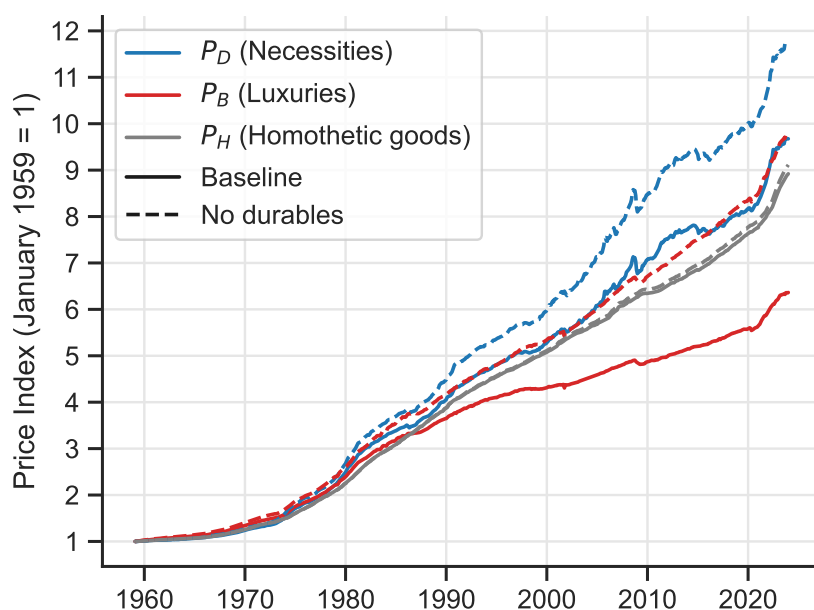
**Figure A.2.** Basket prices with and without durable goods.

*Notes.* The basket prices without durable goods is the equivalent Törnqvist index but excluding the first 17 categories that correspond to durable goods.



**Figure A.3.** Classifying products as necessity, luxury, or homothetic for tier 4 (15 categories).

*Notes.* The figure shows the classification of PCE categories in tier 4 into the necessity (D), luxury (B) and homothetic (H) basket. Column (Direct) shows the classification obtained directly from the distributional PCE data, column (1) shows the baseline specification, column (2) the specification without RPP adjustment and column (3) the specification controlling for the age structure of the state population. The percentage number after the description shows the average US expenditure share between 2008–2022.

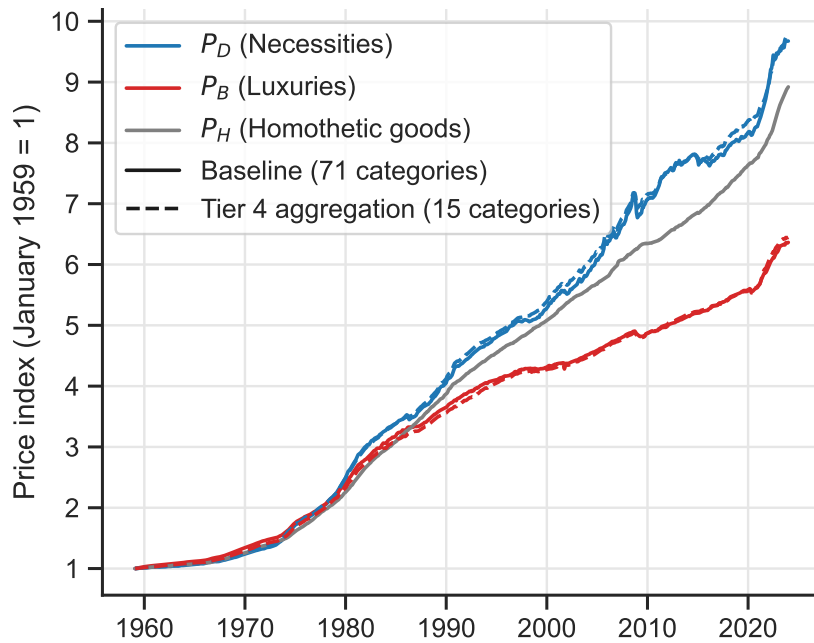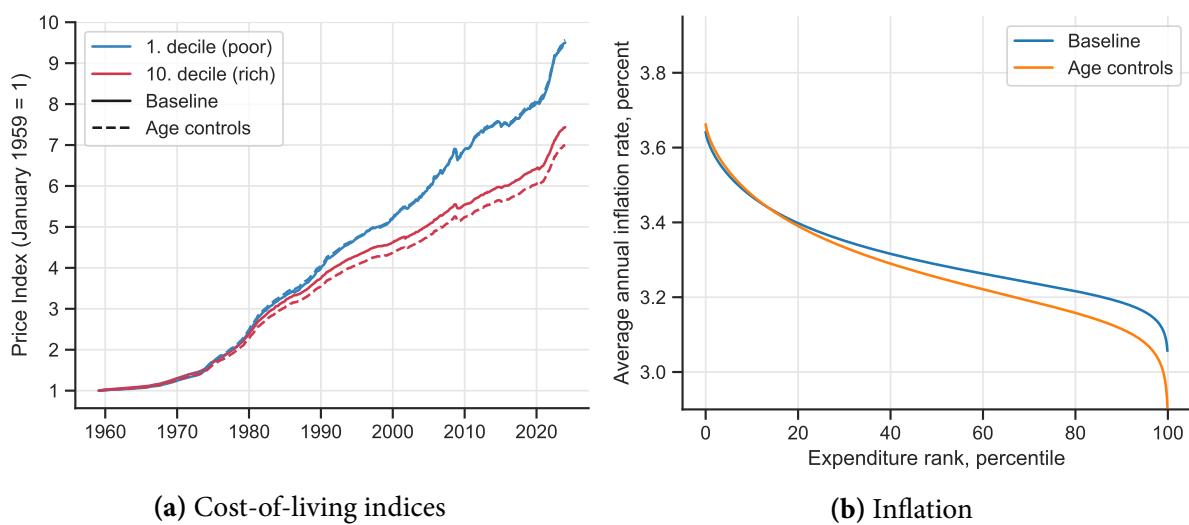**Figure A.4.** Basket prices for different levels of aggregation.

*Notes.* Note that the tier 4 aggregation does not have a single category in the homothetic basket and therefore the price index for the homothetic basket on that level of aggregation is not shown in the figure.



**(a)** Cost-of-living indices        **(b)** Inflation

**Figure A.5.** Cost-of-living indices compared with the scenario including age controls.

## Table A.1. Engel curve classification from state PCE data, robustness.

| PCE category | (1) | | (2) | | (3) | |
|---|---|---|---|---|---|---|
| | Slope | Std. Error | Slope | Std. Error | Slope | Std. Error |
| **Motor vehicles and parts** | | | | | | |
| New motor vehicles | −0.008*** | (0.001) | −0.010*** | (0.001) | 0.006** | (0.002) |
| Net purchases of used motor vehicles | −0.013*** | (0.001) | −0.014*** | (0.001) | −0.013*** | (0.002) |
| Motor vehicle parts and accessories | −0.005*** | (0.001) | −0.006*** | (0.000) | −0.002*** | (0.001) |
| **Furnishings and durable household equipment** | | | | | | |
| Furniture and furnishings | 0.006*** | (0.001) | 0.004*** | (0.001) | 0.006*** | (0.001) |
| Household appliances | −0.002*** | (0.000) | −0.002*** | (0.000) | −0.002*** | (0.000) |
| Glassware, tableware, and household utensils | 0.003*** | (0.000) | 0.004*** | (0.000) | 0.003*** | (0.000) |
| Tools and equipment for house and garden | −0.003*** | (0.000) | −0.003*** | (0.000) | −0.003*** | (0.000) |
| **Recreational goods and vehicles** | | | | | | |
| Video, audio, photographic, and information processing equipment and media | 0.033*** | (0.002) | 0.030*** | (0.001) | 0.032*** | (0.003) |
| Sporting equipment, supplies, guns, and ammunition | −0.005*** | (0.001) | −0.005*** | (0.001) | 0.008*** | (0.002) |
| Sports and recreational vehicles | 0.000 | (0.002) | −0.002 | (0.001) | 0.001 | (0.001) |
| Recreational books | 0.001 | (0.001) | 0.000 | (0.001) | −0.004*** | (0.001) |
| Musical instruments | 0.001*** | (0.000) | 0.000*** | (0.000) | 0.001*** | (0.000) |
| **Other durable goods** | | | | | | |
| Jewelry and watches | 0.006*** | (0.001) | 0.006*** | (0.000) | 0.006*** | (0.000) |
| Therapeutic appliances and equipment | −0.006*** | (0.000) | −0.004*** | (0.000) | −0.003*** | (0.001) |
| Educational books | 0.001*** | (0.000) | 0.001*** | (0.000) | 0.002*** | (0.000) |
| Luggage and similar personal items | 0.003*** | (0.000) | 0.003*** | (0.000) | 0.005*** | (0.000) |
| Telephone and related communication equipment | 0.001** | (0.000) | 0.001*** | (0.000) | 0.001** | (0.000) |
| **Food and beverages purchased for off-premises consumption** | | | | | | |
| Food and nonalcoholic beverages purchased for off-premises consumption | −0.035*** | (0.003) | −0.041*** | (0.002) | −0.030*** | (0.004) |
| Alcoholic beverages purchased for off-premises consumption | 0.002*** | (0.001) | 0.002*** | (0.000) | 0.003** | (0.001) |
| Food produced and consumed on farms | 0.000*** | (0.000) | 0.000*** | (0.000) | 0.000*** | (0.000) |
| **Clothing and footwear** | | | | | | |
| Women's and girls' clothing | −0.002 | (0.001) | 0.000 | (0.001) | −0.001 | (0.001) |
| Men's and boys' clothing | −0.004*** | (0.001) | −0.003*** | (0.001) | −0.004*** | (0.001) |
| Children's and infants' clothing | −0.001*** | (0.000) | −0.001*** | (0.000) | −0.001*** | (0.000) |
| Other clothing materials and footwear | −0.002*** | (0.001) | −0.001** | (0.000) | −0.005*** | (0.001) |
| **Gasoline and other energy goods** | | | | | | |
| Motor vehicle fuels, lubricants, and fluids | −0.049*** | (0.003) | −0.049*** | (0.002) | −0.040*** | (0.004) |
| Fuel oil and other fuels | −0.003*** | (0.001) | −0.005*** | (0.000) | 0.000 | (0.001) |
| **Other nondurable goods** | | | | | | |
| Pharmaceutical and other medical products | −0.042*** | (0.003) | −0.034*** | (0.002) | −0.054*** | (0.003) |
| Recreational items | −0.011*** | (0.001) | −0.011*** | (0.000) | −0.013*** | (0.001) |
| Household supplies | −0.003*** | (0.000) | −0.004*** | (0.000) | −0.005*** | (0.001) |
| Personal care products | 0.004*** | (0.001) | 0.009*** | (0.001) | 0.000 | (0.001) |
| Tobacco | −0.009*** | (0.001) | −0.012*** | (0.001) | −0.009*** | (0.001) |
| Magazines, newspapers, and stationery | 0.002** | (0.001) | 0.003*** | (0.001) | −0.002 | (0.001) |
| **Housing** | | | | | | |
| Rental of tenant-occupied nonfarm housing | −0.034*** | (0.005) | 0.040*** | (0.002) | −0.064*** | (0.005) |
| Imputed rental of owner-occupied nonfarm housing | −0.009 | (0.010) | 0.060*** | (0.005) | −0.003 | (0.009) |
| Rental value of farm dwellings | 0.002* | (0.001) | −0.007*** | (0.000) | −0.003** | (0.001) |
| Group housing | 0.001*** | (0.000) | 0.000 | (0.000) | 0.001*** | (0.000) |
| **Household utilities** | | | | | | |
| Water supply and sanitation | −0.006*** | (0.000) | −0.005*** | (0.000) | −0.007*** | (0.001) |
| Electricity | −0.018*** | (0.001) | −0.015*** | (0.001) | −0.016*** | (0.001) |

**Table A.1.** Engel curve classification from state PCE data, robustness. (Cont.)

| PCE category | (1) Slope | (1) Std. Error | (2) Slope | (2) Std. Error | (3) Slope | (3) Std. Error |
|---|---|---|---|---|---|---|
| Natural gas | −0.009*** | (0.001) | −0.010*** | (0.001) | −0.009*** | (0.001) |
| **Health care** | | | | | | |
| Physician services | 0.001 | (0.002) | −0.005*** | (0.001) | 0.002 | (0.004) |
| Dental services | −0.003*** | (0.001) | −0.003*** | (0.000) | 0.003*** | (0.001) |
| Paramedical services | 0.007*** | (0.002) | 0.005*** | (0.002) | −0.003 | (0.003) |
| Hospitals | −0.085*** | (0.004) | −0.084*** | (0.003) | −0.087*** | (0.006) |
| Nursing homes | −0.012*** | (0.001) | −0.014*** | (0.001) | −0.024*** | (0.001) |
| **Transportation services** | | | | | | |
| Motor vehicle maintenance and repair | −0.002 | (0.001) | 0.000 | (0.001) | 0.003** | (0.001) |
| Other motor vehicle services | 0.005*** | (0.001) | 0.006*** | (0.001) | 0.001 | (0.002) |
| Ground transportation | 0.004*** | (0.001) | 0.006*** | (0.001) | −0.004*** | (0.001) |
| Air transportation | 0.020*** | (0.002) | 0.020*** | (0.001) | 0.020*** | (0.002) |
| Water transportation | 0.000** | (0.000) | 0.000 | (0.000) | −0.001*** | (0.000) |
| **Recreation services** | | | | | | |
| Membership clubs, sports centers, parks, theaters, and museums | 0.016*** | (0.002) | 0.016*** | (0.001) | 0.017*** | (0.003) |
| Audio-video, photographic, and information processing equipment services | 0.008*** | (0.001) | 0.007*** | (0.001) | 0.004*** | (0.001) |
| Gambling | 0.005* | (0.002) | 0.005*** | (0.001) | 0.015*** | (0.002) |
| Other recreational services | 0.005*** | (0.001) | 0.005*** | (0.000) | 0.010*** | (0.001) |
| **Food services and accommodations** | | | | | | |
| Purchased meals and beverages | 0.010*** | (0.002) | 0.009*** | (0.001) | −0.014*** | (0.003) |
| Food furnished to employees (including military) | −0.001*** | (0.000) | −0.001*** | (0.000) | −0.001*** | (0.000) |
| Accommodations | 0.012*** | (0.002) | 0.012*** | (0.001) | 0.012*** | (0.002) |
| **Financial services and insurance** | | | | | | |
| Financial services furnished without payment | 0.012*** | (0.002) | 0.015*** | (0.001) | 0.007*** | (0.002) |
| Financial service charges, fees, and commissions | 0.027*** | (0.002) | 0.024*** | (0.002) | 0.015*** | (0.004) |
| Life insurance | 0.002*** | (0.001) | 0.004*** | (0.000) | 0.003*** | (0.001) |
| Net household insurance | 0.000** | (0.000) | 0.000** | (0.000) | 0.000 | (0.000) |
| Net health insurance | 0.014*** | (0.003) | 0.005** | (0.002) | 0.032*** | (0.007) |
| Net motor vehicle and other transportation insurance | 0.004** | (0.001) | 0.004*** | (0.001) | 0.003** | (0.001) |
| **Communication** | | | | | | |
| Telecommunication services | 0.008*** | (0.001) | 0.011*** | (0.001) | 0.011*** | (0.002) |
| Postal and delivery services | 0.000** | (0.000) | 0.000 | (0.000) | 0.000 | (0.000) |
| **Education services** | | | | | | |
| Higher education | −0.010*** | (0.002) | −0.007*** | (0.002) | 0.001 | (0.002) |
| Nursery, elementary, and secondary schools | 0.000 | (0.000) | 0.000 | (0.000) | 0.000 | (0.000) |
| Commercial and vocational schools | 0.007*** | (0.000) | 0.007*** | (0.000) | 0.006*** | (0.001) |
| **Other services** | | | | | | |
| Professional and other services | −0.004* | (0.002) | −0.005*** | (0.001) | −0.007*** | (0.002) |
| Personal care and clothing services | 0.022*** | (0.002) | 0.018*** | (0.001) | 0.020*** | (0.002) |
| Social services and religious activities | 0.021*** | (0.005) | 0.018*** | (0.003) | 0.008* | (0.003) |
| Household maintenance | 0.005*** | (0.000) | 0.006*** | (0.000) | 0.010*** | (0.001) |
| Time and regional fixed effects | ✓ | | ✓ | | ✓ | |
| Controls for regional price parities | ✓ | | | | ✓ | |
| Sample years | 2008–2022 | | 1997–2022 | | 2008–2022 | |
| Observations per good | 765 | | 1,326 | | 765 | |

*Notes.* Each specification shows the slope coefficients from regressing state-level aggregate expenditure shares on the corresponding level of logarithmized consumption expenditures per capita. (1) is the baseline classification, (2) uses the full state panel without RPP controls, and (3) adds additional controls for the state-level age composition. States are weighted by their population size. Standard errors in parentheses are clustered by year-by-state cells. *, **, and *** denote statistical significance at the 5 percent, 1 percent, and 0.1 percent levels.

**Table A.2.** Classifying products as necessity, luxury, or homothetic in the CEX.

| CEX category | (1) | | (2) | |
|---|---|---|---|---|
| | Engel slope | Std. Error | Engel slope | Std. Error |
| Food Home | −0.1264*** | (0.0058) | −0.1230*** | (0.0071) |
| Food Away | 0.0086** | (0.0032) | 0.0056 | (0.0035) |
| Alcoholic beverages | 0.0036*** | (0.0007) | 0.0024* | (0.0011) |
| Owned Dwellings | 0.0601*** | (0.0095) | 0.0937*** | (0.0134) |
| Rented Dwellings | −0.0743*** | (0.0085) | 0.0264 | (0.0205) |
| Other Lodging | 0.0291*** | (0.0030) | 0.0201*** | (0.0026) |
| Utilities | −0.0204*** | (0.0021) | −0.0318*** | (0.0031) |
| Phone | −0.0138*** | (0.0011) | −0.0126*** | (0.0014) |
| Water | −0.0040*** | (0.0012) | −0.0088** | (0.0026) |
| Household Operations and Furnishings | 0.0671*** | (0.0082) | 0.0491*** | (0.0101) |
| Other Expenses | 0.0075*** | (0.0012) | 0.0060*** | (0.0014) |
| Apparel | 0.0066** | (0.0023) | 0.0043 | (0.0021) |
| Gasoline | −0.0235*** | (0.0022) | −0.0302*** | (0.0027) |
| Other Vehicle Expenditures | −0.0088** | (0.0033) | −0.0180*** | (0.0047) |
| Public Transport | 0.0126*** | (0.0020) | 0.0166*** | (0.0026) |
| Health | 0.0127** | (0.0048) | −0.0271*** | (0.0066) |
| Entertainment | 0.0368*** | (0.0043) | 0.0101 | (0.0080) |
| Personal Care | 0.0029*** | (0.0005) | 0.0012* | (0.0004) |
| Reading | 0.0022*** | (0.0003) | 0.0011* | (0.0005) |
| Education | 0.0287*** | (0.0051) | 0.0258*** | (0.0032) |
| Tobacco | −0.0073*** | (0.0011) | −0.0111*** | (0.0020) |
| Time and regional fixed effects | ✓ | | ✓ | |
| Controls for regional price parities | ✓ | | | |
| Sample years | 2008–2020 | | 1995–2020 | |
| Observations per good | 519 | | 1,046 | |

*Notes.* Each specification shows the slope coefficients from regressing state-level aggregate expenditure shares on the corresponding level of logarithmized consumption expenditures per capita. States are weighted by their population size. Standard errors in parentheses are clustered by year-by-state cells. *, **, and *** denote statistical significance at the 5 percent, 1 percent, and 0.1 percent levels.
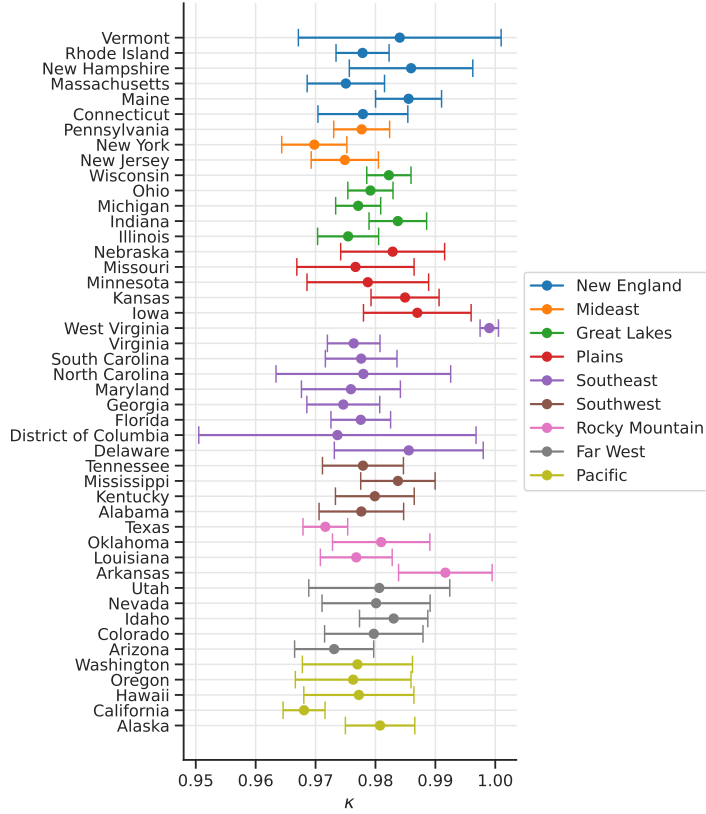
**Figure A.6.** Empirical measure of the aggregation factor, $\kappa_t$, by US states using microdata from the CEX.

*Notes.* Data from the CEX with the same sample restrictions as in Hochmuth, Pettersson and Weissert (2023). The dots show the average and the error bars show the standard deviation of $\kappa_t$ for $\varepsilon = 0.702$ over all years. Some US states are missing because they the CEX sample we use does not contain any observations within these.

**Table A.3.** Long-run inflation rate gap for different parameter values with $w_D$ fixed.

| $\varepsilon$ | $\gamma$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **0.1** | **0.2** | **0.3** | **0.4** | **0.5** | **0.6** | **0.7** | **0.8** | **0.9** | **1** |
| **0** | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 | 0.35 | 0.35 | 0.34 | 0.34 |
| **0.1** | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 | 0.35 | 0.35 | 0.34 |
| **0.2** | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 | 0.35 | 0.35 |
| **0.3** | 0.42 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 | 0.35 |
| **0.4** | 0.42 | 0.42 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 | 0.36 |
| **0.5** | 0.43 | 0.42 | 0.42 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 | 0.36 |
| **0.6** | 0.44 | 0.43 | 0.42 | 0.42 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 | 0.37 |
| **0.7** | 0.45 | 0.44 | 0.43 | 0.43 | 0.42 | 0.41 | 0.40 | 0.39 | 0.39 | 0.38 | 0.37 |
| **0.8** | 0.46 | 0.45 | 0.44 | 0.43 | 0.43 | 0.42 | 0.41 | 0.40 | 0.40 | 0.39 | 0.38 |
| **0.9** | 0.47 | 0.46 | 0.45 | 0.44 | 0.44 | 0.43 | 0.42 | 0.41 | 0.40 | 0.40 | 0.39 |
| **1** | 0.48 | 0.47 | 0.46 | 0.45 | 0.44 | 0.44 | 0.43 | 0.42 | 0.41 | 0.40 | 0.40 |

*Notes.* The table shows the difference in the average annual inflation rate between the top and bottom expenditure deciles over the period January 1959 to December 2023 when the base-period allocation is held fixed at the baseline estimates. All numbers are in percentage points. The table considers the general model of Boppart (2014), in which $V(e, \boldsymbol{p}) = \frac{1}{\varepsilon}\left[\left(\frac{e}{F(H(\boldsymbol{p}),B(\boldsymbol{p}))}\right)^{\varepsilon} - 1\right] - \frac{\gamma}{\gamma}\left[\left(\frac{D(\boldsymbol{p})}{B(\boldsymbol{p})}\right)^{\gamma} - 1\right]$ and $P(u, \boldsymbol{p}_s, \boldsymbol{p}_t) = \left[\left(1 - \frac{\varepsilon w_{Ds}}{\gamma}\right)P_{Bt}^{\gamma} + \frac{\varepsilon w_{Ds}}{\gamma}P_{Dt}^{\gamma}\right]^{\frac{1}{\varepsilon}}P_{Ft}P_{Bt}^{-\frac{\gamma}{\varepsilon}}$. The diagonal corresponds to the benchmark model in this paper.