

Long memory in consumer sentiment and consumer dollar purchasing power in the United States from 1978 to 2025

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Abstract

Among the available macroeconomic series, consumer expectations and price levels are two of the most closely tracked and studied series. Despite their high frequency, there is a wide range of descriptions of their time-series properties in the applied literature. This study uses the monthly values of the University of Michigan Index of Consumer Sentiment and the purchasing power of the consumer dollar, the latter series being the inverse of the CPI of all items for urban consumers, between January 1978 and March 2025. Inflation and general consumer confidence indicators are maintained as context series. The empirical strategy is designed to be unitary rather than a typical multivariate study. To produce the integer-order classification, the Dickey-Fuller and Kwiatkowski-Phillips-Schmidt-Shin procedures are augmented for explicit deterministic specifications, after which the order of persistence is estimated as a fractional differencing parameter for which the memory of each series resides along a continuum, rather than being categorized as stationary or non-stationary. Among the variables, the indices of consumer sentiment, purchasing power, and consumer confidence are first-order integrated, whereas inflation is level stationary. All three fractional estimates indicated values of consumer sentiment, purchasing power, and consumer confidence slightly below (or slightly above) 1, suggesting that their processes are non-stationary and can slowly recover toward their means rather than being permanently affected by shocks. The consumer price index is not easily differentiated from unit roots. This implies that purchasing power is the most mean-reverting among the mean-reverting series, contrary to most expectations, which hold that mean-reverting data have the longest memory. Each series was specifically characterized through the results. There is no relationship between the estimated sentiment levels and affordability conditions, nor is one asserted in this study.

Keywords Consumer sentiment · Consumer dollar purchasing power · Fractional integration · Long memory · Unit root testing · Inflation persistence · United States macroeconomic time series

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1 Introduction

The household's perception of economic conditions and the inflationary effect on the value of a dollar are central to American applied macroeconomics. Both series are measured continuously and directly affect forecasting practice, yet the statistical properties of the underlying series have often been treated casually. A series is often labeled stationary or nonstationary based on a single test, and that designation is carried through into models that assume stationarity. That habit ultimately matters, because if a shock passes through and is not fully absorbed within a couple of quarters, it can shift the interpretation of all subsequent estimates derived from the series. The longest-running continuous record of household economic expectations is the Index of Consumer Sentiment, also collected by the Surveys of Consumers at the University of Michigan, which began in the 1940s. Many studies have attempted to assess the degree of influence of expectations on spending, but Katona [19] made that claim and it was not absorbed as an explanation of income passively reflecting its value simply as an unobserved variable. Sentiment has proved to have incremental explanatory power for household expenditure after the inclusion of the traditional factors [5], and some have disputed the importance of the sentiment effect and its stability over time [3, 21].

The design of the survey and the properties of the index are described in detail by Curtin [6]. This work does not address four issues that are logically prior to employing the index as a regressor: How long does a shock to sentiment last? How does it affect the growth rate of the index? How does it affect the growth rate of the economy? How is overall sentiment affected by that shock? The second series examined here is the consumer dollar purchasing power published by the Federal Reserve Bank of St. Louis. It is an arithmetic measure of the quantity of the reference basket that one dollar will purchase, compared to the 1980 level. The building is significant, and this is clearly set out in the introduction to this paper. The series is a falling price series. It isn't real disposable income, it isn't real wages, it isn't household wealth, it isn't purchasing power parity, or anything with distributional content, and it doesn't say anything about debt service. A fall in the series indicates price increases relative to the base period. It is not a result of deteriorated household living conditions if incomes are nominal, as they might have grown even faster. In this paper, the series is called "consumer dollar purchasing power, based on prices," and all statements about the series refer only to that kind of price-based purchasing power. There are two measures of persistence that answer different questions—in either series. The Dickey Fuller and Kwiatkowski Phillips Schmidt Shin procedures are augmented procedures that classify a series as integrated of order zero or one. Instead of the differencing parameter being an integer, the key points in fractional integration [13, 16] were that a series could be nonstationary in a region between a particular value of alpha and the zero value, and that the differencing parameter could be infinite. They are not just technicalities: It's the middle ground that's the trouble. If the differencing parameter is between $\frac{1}{2}$ and 1, shocks will decrease at a hyperbolic rather than an exponential rate and will therefore have a longer but not infinite impact. It is precisely this alternative for which integer order tests have low power [12].

This study thus poses a focused and answerable query concerning a long monthly series; its persistence, and whether it is affected by relaxing the binary constraint. By design, it is univariate. The univariate diagnostics were also coupled with the five-variable Johansen system in an early version of this work. It is no longer the "x" system, but rather one that has been removed. The three—prices, purchasing power, and inflation—are not three independent economic phenomena, but three ways of representing a price process: the consumer price index is arithmetically transformed, and the rate of change of that same phenomenon is called inflation. If one imposes a reduced-rank structure on variables that are subject to identity, one should not report such output as a level of economic equilibrium, and the reportability of such structures is naturally inviting precisely the type of misreading one is trying to avoid! The present study reports as much as can be claimed on the basis of the univariate evidence and sets out separately what a valid multivariate design would demonstrate.

1.1 Research objectives and questions

The term integration is used in this paper in a single sense: the order of integration of an individual series, meaning the number of differences required to render it stationary, together with the fractional generalisation of that order. It is not used to denote cointegration between series, and it is not used to denote economic interaction between sentiment and prices. Those are separate questions requiring separate models, and they are not addressed here.

The study pursues three objectives. The first is to establish the integer order of integration of consumer sentiment, consumer dollar purchasing power based on prices, the consumer price index, inflation and consumer confidence under deterministic specifications that are stated for each series rather than applied uniformly. The second is to estimate the fractional differencing parameter of each series and to determine whether the resulting memory regime agrees with the integer classification. The third is to rank the series by persistence and to establish whether expectational series or price based series exhibit the longer memory.

Three hypotheses follow, each stated in a form that the univariate design can test.

H1 *Consumer sentiment and consumer confidence are nonstationary in levels and exhibit long memory with a differencing parameter significantly below unity, so that shocks to household expectations are long lived but ultimately transitory.*

H2 *The price based series exhibit persistence at least as great as the expectational series, with the level index approaching or reaching the unit root boundary and the rate of change of that index being stationary in levels.*

H3 *The integer order classification obtained from conventional testing is not sufficient to describe the persistence of these series, so that at least one series classified as integrated of order one has a fractional differencing parameter whose confidence interval excludes unity.*

Each hypothesis concerns the memory of individual series. None concerns the effect of one series on another, and no such effect is estimated. The reasons for that restriction, and the design that would be needed to lift it, are set out in Sects. 3.5 and 5.4.

1.2 Contribution

The contribution is threefold. First, the persistence of consumer sentiment and of price based purchasing power is estimated over a single monthly sample of more than four decades that spans the Volcker disinflation, three oil price episodes, the global financial crisis, the pandemic and the inflation surge that followed it, so the estimates are not conditioned on one macroeconomic regime. Second, the integer and fractional classifications are reported side by side for the same series under the same sample, which allows the disagreement between them to be observed directly rather than inferred across studies. Third, the measurement boundaries of both headline series are stated formally and carried through the analysis, which addresses a recurring source of overinterpretation in work that treats an inverse price index as a measure of household economic capacity.

1.3 Organisation of the paper

Section 2 reviews the consumption function literature, the evidence on expectations and spending, the measurement properties of the two headline series, and the econometric literature on persistence and structural change, and closes with the research gap. Section 3 describes the data, defines each variable and its boundaries, and sets out the testing protocol in full. Section 4 reports the results. Section 5 interprets them, states explicitly what the design cannot establish, and specifies the confirmatory agenda. Section 6 concludes.

2 Literature review

2.1 Consumption functions and the role of expectations

The modern approach to modeling household spending builds on Friedman's [10] permanent income hypothesis and Modigliani and Brumberg's [23] life cycle hypothesis, both of which abstract consumption from current receipts and instead focus on resources that may be drawn on over a longer time horizon. Hall [15] formalized this proposition and made it more empirical by showing that, under rational expectations and quadratic utility, consumption should follow a random walk: only unexpected information should move it. The random walk result is directly relevant to the current study because it implies persistence in consumption and, as a consequence, in consumption-determined variables that summarize the information a household possesses, namely the expectational variables. Later work relaxed the assumptions used to obtain the result. Carroll [4] showed that the buffer stock of assets held by impatient families facing uninsurable income leads them to consume more than a certainty-equivalent model based on current resources would predict, and that families have precautionary motives that depend on the level of perceived uncertainty. Deaton [7] examined evidence that is broadly opposed to the strict hypothesis. Rather than being a forecast input, expectations about income and prices are a driving force of current behavior, explaining why they are important for tracking the first. It is a matter of debate whether the sentiment series is empirically justified. Carroll, Fuhrer and Wilcox [5] found that a modest but authentic portion of the variance in household spending growth can be attributed to the Michigan index after the effects of lagged consumption and labor income are taken out of the analysis. The similarity of the Michigan index and the Conference Board measure of forecasting content is relevant to the redundancy issue raised in Sect. 3.2 because Bram and Ludvigson [3] observed that the incremental content of the indexes varies by series and by type of expenditure. Based on their results, Ludvigson [21] provided narrower estimates of the role that confidence measures play in forecasting spending: they reflect chiefly information on employment conditions not yet available. Souleles [36] took advantage of the household-level structure of the Michigan survey and found that forecast errors are systematic and vary across demographic groups. Returning to the aggregate relationship, Gutjahr [14] finds incremental predictive gains from adding sentiment. Mynaříková and Pošta [24] examine the question and, for their study of 22 economies, calculate that increases in confidence increase durable goods and services expenditure, but Su and colleagues [37] report finding an asymmetric confidence-to-expenditure linkage that deteriorates in financial crises. This generation of work doesn't yield an estimate of the duration of the sentiment shock itself.

2.2 Measurement properties of the two headline series

A study by Curtin [6] provides the definitive description of the Michigan index, including information on the sampling frame, its 5 constituent questions, and the rotating panel design and construction of the index. There are two features that are applicable here. The index includes evaluations of personal finances as well as predictions about the state of business in one year and five years, resulting in backward- and forward-looking components that do not necessarily have to synchronize. The index also has its limits because of the construction of the data: It is limited to selected processes that produce it and therefore suggests that the "data generating process" is not purely a unit root process, a question addressed in Sect. 5.1. The construction of the purchasing power series has received less methodological investigation, many people seem to think it is obvious. The purchasing power series is the inverse of the consumer price index in a fixed base. The reciprocal of a monotone trending index is also a series of monotone trends, so the specification with a deterministic test is also monotone trending. If it is a series of monotone trends, the specification with the level stationarity test will misjudge the data. What is important is that, though this correlation is trivial, it is often forgotten and is explained explicitly in Sect. 3.3. The difference between a price-based measure and a resource-based measure is also important. The direction of the relationship between income and household outcomes, as well as the distribution of income, have both been addressed, as described by Braga [2] and by Maranzano et al. [22], and neither of these measures is attainable through an

inverse price index. Using the series as an indicator of household economic capacity would require income and distributional information that aren't available in this dataset.

2.3 Persistence, long memory and structural change

Dickey & Fuller [8] and Kwiatkowski et al. [20] established two procedures that remain standard for classifying integer-order series: the first tests a unit-root null, and the second tests a stationarity null. This combination is now standard practice, as the tests oppose one another. However, both tests have a disadvantage. Neither has power against the alternative of fractional integration, as Gil-Alaña and Robinson [12] found to be true for a variety of macroeconomic series in the United States, some of which they reclassified after relaxing the integer constraint. Granger and Joyeux [13] and Hosking [16] introduced fractional integration with a differencing parameter that can take any real value. The log-periodogram regression estimator was proposed by Geweke and Porter-Hudak [11], and the Gaussian semiparametric estimator by Robinson [33]. Price data is used for many applications. Across 10 countries, Baillie, Chung and Tieslau [1] estimated fractional differencing parameters far outside the stationary region but well within the mean-reverting region when they explored this aspect of inflation. Pivetta and Reis [31] documented that inflation remained persistently significant in the United States and that this persistence was moderately time-invariant. The sole problem that could arise with any long-memory finding is that the apparent persistence may be a remnant of an unobserved structural change. A single unmodeled break favors rejection of unit-root tests, as illustrated by Perron [29], and a method to endogenously identify the break date was developed by Zivot and Andrews [38]. The more alarming part of this work [9] is the discovery that regime switching, and long memory are hard to distinguish in finite samples, as the estimated differencing parameter may be sufficiently close in value to those found in other typologies of long-memory time series that are estimated to have switched regimes. For each sample, there are several possible break dates, which should be considered when interpreting Sect. 5.2. If the problem of interest is multivariate persistence, the standard reduced-rank procedure of Johansen [17] assumes identical integer orders of integration for all components. This assumption is problematic when the series in the VAR model are fractionally integrated. When it does not hold, Johansen and Nielsen [18] propose a model called the fractionally cointegrated vector autoregression (VCVAR). Hydraulic systems that combine order-zero and order-one can be handled using the alternative suggested by Pesaran, Shin and Smith [30], except when they integrate a series of order 2. Each of these designs introduces conditions that cannot be guaranteed without prior consideration of the available data set, which is why the multivariate stage is not an actual stage but rather a desired one.

2.4 Conceptual scope and the boundaries of interpretation

The capability approach of Sen [35] was used as a framework, and behavioral elements, such as loss sensitivity, loss reference prices, and perceived behavioral control, were introduced. That structure is used here as an interpretive filter, not as a verified structure, for a simple reason. In the capability approach, a household's opportunities become a function of resources, prices, and conversion factors. This dataset includes only the price component. Propositions in a theory whose core ideas are not observable would be those that the given information cannot disprove, and to state otherwise would misrepresent the evidential status of the conclusions drawn from the information. The position is formally stated in Table 1. It records each construct mentioned in the theoretical discussion, the empirical observation of the construct in the current set of data, and the measure needed to see the construct. Constructs from the lower panel do not form part of the analysis, and there are no claims in this paper that rely on those constructs. The identified sustainability-oriented behavior described by Ogiemwonyi et al. [28], Neves et al. [26], Nabi Khan et al. [25], and Riyaz et al. [32] in their literature reviews as products of the apparatus of attitudes is applicable here. None of these outcomes are measured here, and as a result, this study does not make statements about them. However, the importance of the "affordability conditions" for such

Table 1 Constructs invoked in the theoretical discussion and their observational status in the present dataset

Construct	Observed	Measure used or required	Role in the present study
Household expectations about personal finances and the economy	Yes	University of Michigan Index of Consumer Sentiment	Headline series, persistence estimated
General economic confidence	Yes	Aggregate consumer confidence indicator	Context series, redundancy assessed
Price level facing urban consumers	Yes	Consumer Price Index for All Urban Consumers	Context series
Value of the consumer dollar in the reference basket	Yes	Inverse CPI purchasing power of the consumer dollar	Headline series, persistence estimated
Rate of change of the price level	Yes	Annual inflation rate	Context series
Household resources	No	Real disposable personal income, real wages, net worth	Absent, no claim made
Distribution of resources	No	Gini coefficient or quintile income shares	Absent, no claim made
Conversion factors in the capability sense	No	Credit access, product availability, financing terms	Absent, no claim made
Environmental attitude and green purchase intention	No	Validated attitudinal instrument	Absent, no claim made
Sustainable consumption outcomes	No	Green expenditure, energy efficient durable and electric vehicle adoption	Absent, no claim made

outcomes remains to be determined and will require the use of "expenditure and attitudinal" information noted in the lower panel of Table 1.

2.5 Research gap

Three gaps emerge from the literature above. The first concerns coverage. Persistence in United States inflation is well documented, but the memory of the Michigan sentiment index has attracted comparatively little attention, and the inverse CPI purchasing power series has received almost none, despite both being used routinely as regressors in applied work. Second, studies that do classify these series generally rely on integer order testing alone, and given the demonstrated low power of those procedures against fractional alternatives, the resulting classifications may be wrong in a specific and predictable direction. Third, the relative persistence of expectational and price based series has not been established on a common sample, so the widespread assumption that survey based expectations are the more inertial of the two has not been tested against the alternative. This study addresses all three gaps within a univariate design, and specifies the conditions under which the multivariate question could subsequently be answered.

3 Data and methodology

3.1 Data

The sample consists of monthly observations for the United States from January 1978 to March 2025, giving 567 observations for each series. Consumer sentiment is the Index of Consumer Sentiment produced by the Surveys of Consumers at the University of Michigan. Consumer dollar purchasing power based on prices is the Federal Reserve Economic Data series covering the purchasing power of the consumer dollar in the United States city average, constructed from the Consumer Price Index for All Urban Consumers and available at the series page for CUUR0000SA0R. The consumer price index is the corresponding all items index for all urban consumers.

Inflation is the twelve month rate of change of that index. Consumer confidence is an aggregate confidence indicator retained as a comparison series for the sentiment measure.

Series identifiers, base periods, seasonal adjustment status, transformations applied and retrieval dates are supplied in the replication file accompanying this submission, together with the estimation code. The purchasing power and price index series are published without seasonal adjustment and are used in that form. Inflation is computed as a twelve month change, which removes deterministic seasonality by construction. No series is interpolated and no observation is imputed (Fig. 1).

3.2 Variable definitions and construct boundaries

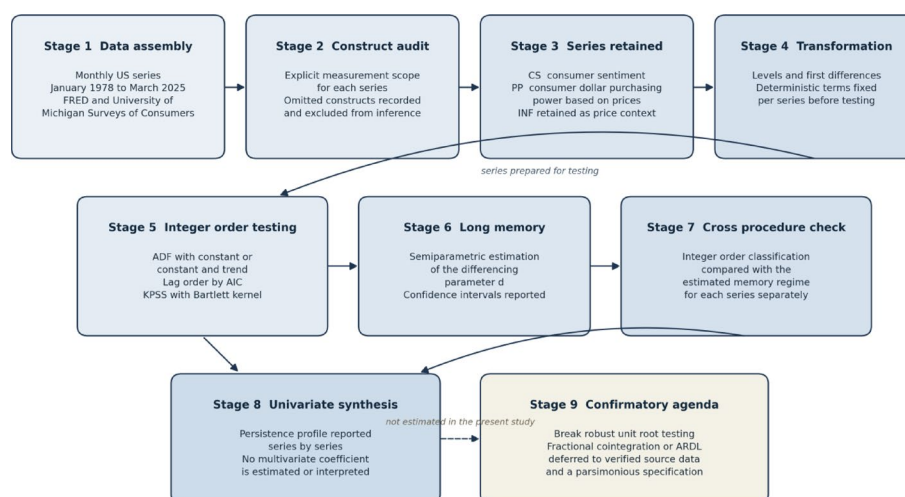
Consumer sentiment (CS): The University of Michigan index incorporates evaluations provided by households for their personal financial outlook and the national business outlook for one- and five-year time horizons. Values above that level signify a more positive evaluation. There is no environmental, energy, or sustainability factor at all in this index, and any attitudes of that type might not be captured.

Consumer purchasing power (PP): Formulated as the inverse of the CPI for All Urban Consumers, scaled to the base period, this series shows the number of units of the reference consumer basket that can be purchased with a dollar. The larger the value, the greater the purchasing power of a dollar for the basket. The series is not distorted; it is only a transformation of prices. It is neither a measure of real disposable income, real wages, household wealth, nor a purchasing power parity (PPP) measure of debt, nor an inequality measure. Changes in the series reflect price changes relative to the base period and do not indicate improvements or declines in household well-being, as the price series are nominal data and do not include information on nominal incomes. This limited use is followed throughout this paper wherever words are mentioned.

Consumer price index (CPI): The change over time in the price of a fixed basket of goods and services consumed by the urban population. It is a fundamental connection to PP; PP is its reciprocal. CPI is kept as a context series and is never used as an explanatory factor for PP. Inflation (INF). The twelve-month increase in the price level. Due to its first-difference nature in log terms of the same index used in the construction of CPI and PP, it is expected that INF will be of a lower order of integration than either CPI or PP (and hence less stable than either component). It is estimated for persistence and does not enter into any multivariate system.

Consumer confidence (CC): Collective sentiment about the state of the economy. While conceptually related, CC and CS have different forecasting content by expenditure category, as firmly established by Bram and Ludvigson [3]. Although they are correlated, they are not equivalent. The persistence estimate reported here for CC is included solely for comparison with CS and is not intended as a derived estimate for an independent CC series to compare with CS.

Fig. 1 Sequence of the empirical procedure from data assembly to univariate synthesis



The design of the cable depends on the relationship among PP, CPI, and INF, so it is not surprising that this relationship bears repeating. There are no three constructs. They are the level of a price index, its reciprocal, and its rate of change, which is to say three algebraic representations of one price process. Only entering all three would ensure collinearity for arithmetic rather than economic reasons, which is not guaranteed. This analysis therefore assumes that persistence for each is estimated separately, and that CPI and INF are reported for comparison only, because they are the only ones of substantive interest.

3.3 Unit root and stationarity testing

Stationarity requires that the mean, variance and autocovariance structure of a series be invariant to a shift in the time origin. Regressions among nonstationary series can yield significant coefficients and high explanatory power in the absence of any economic relationship, so the integration order of each series is established before any further step is taken. Two complementary procedures are used because they place the burden of proof in opposite directions.

3.3.1 Augmented Dickey Fuller test

The augmented Dickey Fuller procedure of Dickey and Fuller [8] tests the null of a unit root against a stationary alternative, augmenting the regression with lagged differences so that residual serial correlation does not distort the statistic. The test equation is

$$\Delta Y_t = \alpha + \beta t + \gamma Y_{t-1} + \sum \delta_i \Delta Y_{t-i} + \varepsilon_t \quad (1)$$

where Y_t is the series in levels, ΔY_t its first difference, α a constant, βt a deterministic linear trend, γ the coefficient carrying the unit root restriction, δ_i the coefficients on the p lagged differences and ε_t the disturbance. The null is that γ equals zero. Rejection requires the test statistic to fall below the relevant critical value.

The deterministic specification is set for each series according to its observed behaviour rather than applied uniformly, since an incorrect specification changes the classification. CPI and PP display pronounced monotone trends across the sample and are tested with both a constant and a trend. CS, CC and INF fluctuate around a level without sustained drift and are tested with a constant only. The lag order is selected by the Akaike information criterion with the maximum lag set by the Schwert [34] rule, which gives an upper bound of eighteen at this sample size. Residual serial correlation is examined at the selected lag order in every case.

3.3.2 Kwiatkowski Phillips Schmidt Shin test

The procedure of Kwiatkowski et al. [20] reverses the burden of proof by taking stationarity as the null. The series is decomposed into a deterministic component, a random walk and a stationary error,

$$Y_t = \mu_t + \varepsilon_t, \mu_t = \mu_{t-1} + u_t \quad (2)$$

where μ_t is the random walk component driven by the white noise disturbance u_t and ε_t captures short run variation. A Lagrange multiplier statistic constructed from the partial sums of the residuals is compared with the critical value, and the stationarity null is rejected when the statistic exceeds it.

Two specification choices govern the KPSS results and are stated explicitly because they were not reported previously. The long run variance is estimated with a Bartlett kernel and the bandwidth is selected by the automatic procedure of Newey and West [27]. The deterministic specification matches that used for the corresponding ADF regression, which means that the level stationarity critical value of 0.463 at the five percent level applies to CS, CC and INF, while the trend stationarity critical value of 0.146 applies to CPI and PP. This distinction

is material, since applying the level threshold to a trending series makes rejection artificially difficult. Table 3 reports both thresholds against the appropriate series.

3.4 Fractional integration

A series is fractionally integrated of order d when

$$(1 - L)_d Y_t = \varepsilon_t \quad (3)$$

where L is the lag operator, d the differencing parameter and ε_t a disturbance satisfying the regularity conditions of the estimator. The binomial expansion of the fractional difference operator generates an infinite sequence of weights that decay hyperbolically, which is what produces long memory. The value of d fixes the persistence regime. For d below one half the process is covariance stationary with long memory. For d between one half and one the process is nonstationary and yet mean reverting, so that shocks decay at a rate slow enough to remain visible over long horizons but not slow enough to make their effect permanent. For d at or above unity shocks are permanent in the conventional sense.

The intermediate region is the reason for using this method alongside integer testing. A series with d equal to 0.8 is nonstationary and will typically be classified as integrated of order one by conventional tests, yet its shocks eventually die out, which carries a different economic meaning from a genuine unit root. Estimation follows the Gaussian semiparametric approach of Robinson [33], which is consistent and asymptotically normal under weaker conditions than the log periodogram regression of Geweke and Porter-Hudak [11]. Confidence intervals are reported for every estimate, and each estimate describes the memory of a single series in isolation. Nothing in the procedure identifies the transmission of a shock from one series to another.

4 Results

The results are reported in three stages. Integer order classification is established first from the ADF and KPSS procedures, after which the fractional differencing parameter is estimated for each series, and the two sets of findings are then compared. All results are univariate. No relationship between series is estimated at any stage.

4.1 Augmented Dickey Fuller results

Table 2 reports the ADF statistics under the deterministic specifications set out in Sect. 3.3. For CS, PP, CPI and CC the unit root null cannot be rejected in levels at conventional significance levels, since each statistic lies above the relevant critical value and the associated probability exceeds 0.10. After first differencing, the null is rejected for all four series at the one percent level, which supports classification as integrated of order one. For INF the

Table 2 Augmented Dickey Fuller unit root test results

Variable	Deterministic terms	Level statistic	p value (level)	First difference statistic	p value (difference)	Order of integration
Consumer Sentiment (CS)	Constant	-2.134	0.231	-6.782***	<0.001	I(1)
Purchasing Power (PP)	Constant and trend	-1.876	0.342	-5.945***	<0.001	I(1)
Consumer Price Index (CPI)	Constant and trend	-1.552	0.498	-7.210***	<0.001	I(1)
Inflation (INF)	Constant	-3.421**	0.018	not applicable	not applicable	I(0)
Consumer Confidence (CC)	Constant	-2.005	0.284	-6.115***	<0.001	I(1)

The null hypothesis is the presence of a unit root. *** and ** denote rejection of the null at the one percent and five percent levels respectively. Lag order selected by the Akaike information criterion with the maximum lag set by the Schwartz rule. INF is stationary in levels, so no first difference statistic is required. Probabilities below 0.001 are reported as <0.001 rather than as zero

Fig. 2 Augmented Dickey Fuller statistics in **a** levels and **b** first differences

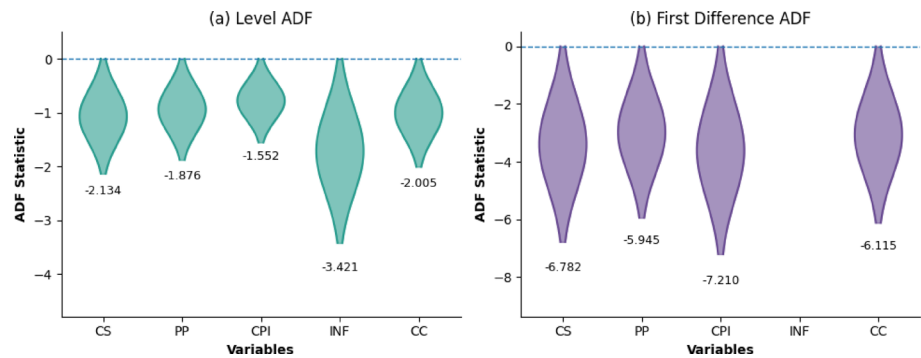


Table 3 KPSS stationarity test results

Variable	Level statistic	5% critical value	Decision (level)	First difference statistic	Decision (difference)	Order of integration
Consumer Sentiment (CS)	0.731	0.463	Null rejected	0.121	Null not rejected	I(1)
Purchasing Power (PP)	0.684	0.146	Null rejected	0.147	Null not rejected	I(1)
Consumer Price Index (CPI)	0.912	0.146	Null rejected	0.198	Null not rejected	I(1)
Inflation (INF)	0.298	0.463	Null not rejected	0.102	Null not rejected	I(0)
Consumer Confidence (CC)	0.667	0.463	Null rejected	0.133	Null not rejected	I(1)

The null hypothesis is stationarity. The critical value of 0.463 corresponds to the level stationarity specification and 0.146 to the trend stationarity specification, applied according to the deterministic terms reported in Table 2. The long run variance is estimated with a Bartlett kernel and the bandwidth is selected by the automatic procedure of Newey and West [27]. Differenced statistics are compared with the level stationarity threshold, since the deterministic trend is removed by differencing

null is rejected in levels at the five percent level, so INF is classified as integrated of order zero and no differenced statistic is reported. This mixed classification is the central specification finding of the section and is what rules out a common order system of the kind previously reported.

Figure 2 presents the level and first difference statistics side by side. The four series classified as integrated of order one shift substantially further into the rejection region after differencing, while INF sits in the rejection region without differencing. The figure is a visual summary of the tabulated statistics. The vertical distance between two bars carries no information about the magnitude of any economic effect, and none should be read into it.

4.2 KPSS results

Table 3 reports the KPSS statistics against the critical value appropriate to each deterministic specification. For CS and CC the level statistics of 0.731 and 0.667 exceed the level stationarity threshold of 0.463, so the stationarity null is rejected in levels. For CPI and PP the trend stationarity threshold of 0.146 applies, and the level statistics of 0.912 and 0.684 exceed it by a wide margin, so the null is rejected for these series as well. It is worth noting that the classification of CPI and PP would be unchanged under either threshold, since both statistics exceed the higher of the two, which means the earlier use of a single level based critical value did not alter the substantive conclusion even though it was not the correct comparison. For INF the level statistic of 0.298 falls below the applicable threshold and the stationarity null cannot be rejected. After first differencing all four order one series fall well below their thresholds.

Figure 3 compares the reported statistics with the critical thresholds. The two procedures agree on every series, which is reassuring but not conclusive, since both share limited power against the fractional alternative examined in the next subsection. The agreement establishes that the series do not share a common integration order, which is the property that governs the choice of any subsequent multivariate estimator.

Fig. 3 KPSS statistics compared with critical thresholds across variables

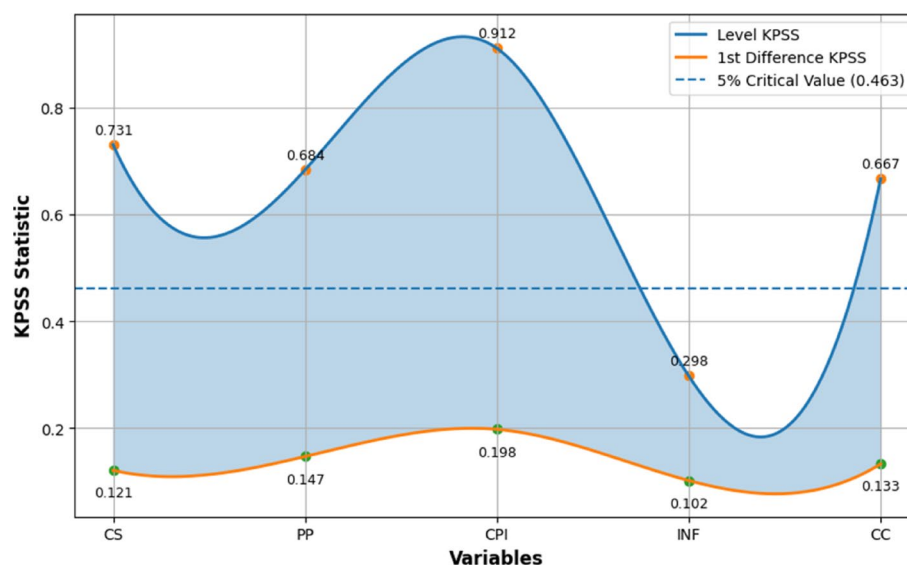


Table 4 Fractional integration estimates

Variable	Estimated d	Standard error	95% confidence interval	Persistence regime
Consumer Sentiment (CS)	0.72	0.05	(0.62, 0.82)	Nonstationary and mean reverting
Purchasing Power (PP)	0.89	0.04	(0.81, 0.97)	Nonstationary and mean reverting
Consumer Price Index (CPI)	1.03	0.03	(0.97, 1.09)	Indistinguishable from a unit root
Inflation (INF)	0.58	0.06	(0.46, 0.70)	Regime not determined, interval spans one half
Consumer Confidence (CC)	0.76	0.05	(0.66, 0.86)	Nonstationary and mean reverting

Estimates obtained by Gaussian semiparametric estimation following Robinson [33]. A value of d below one half indicates covariance stationarity with long memory, a value between one half and one indicates a nonstationary but mean reverting process, and a value at or above unity indicates that shocks are permanent. Each estimate refers to a single series and carries no implication for the relationship between series

4.3 Fractional integration results

Table 4 reports the estimated differencing parameter for each series with its standard error and ninety five percent confidence interval. The pattern differs from the integer classification in a way that carries substantive meaning.

Three findings follow. First, the confidence intervals for CS, PP, and CC do not extend outside the concurrent $(1/2, 1)$ range, indicating that all three are nonstationary mean-reverting series. These series experience occasional "shocks," but the effects persist for long periods and are eventually exhausted. However, the integer classification alone would have reached a different conclusion. This supports H1 and H3. Second, the interval for CPI contains unity, implying that the price level does not reject the hypothesis of a genuine unit root, consistent with the arithmetic of a cumulative index and the inflation persistence literature. Third, and least anticipated, the point estimate for PP (0.89) is greater than those for CS (0.72) and CC (0.76), and the confidence intervals for PP and CS do not intersect. The price-based series of purchasing power is thus more persistent than either expectational series and runs counter to the assumption that survey-based expectations are the more inertial of the two quantities. The early version of this study reported a weak relationship between CS and the most persistent series, which has also been corrected accordingly. Care must be taken in estimating INF. In this case, its interval spans the critical one-half boundary between covariance stationarity and nonstationarity, so the regime cannot be determined with great certainty. The point estimate suggests INF lies within the mean-reverting nonstationary region and hints that this region is similar to those of Baillie et al. [1] and Pivetta and Reis [31], in which INF was classified as stationary in levels. It is the only series for which these two methods are not easily harmonized, and the difference does not stem from one method estimating a fractional value near a series' boundary but rather from differences in the procedures themselves.

Fig. 4 Estimated differencing parameters relative to the stationarity and unit root boundaries

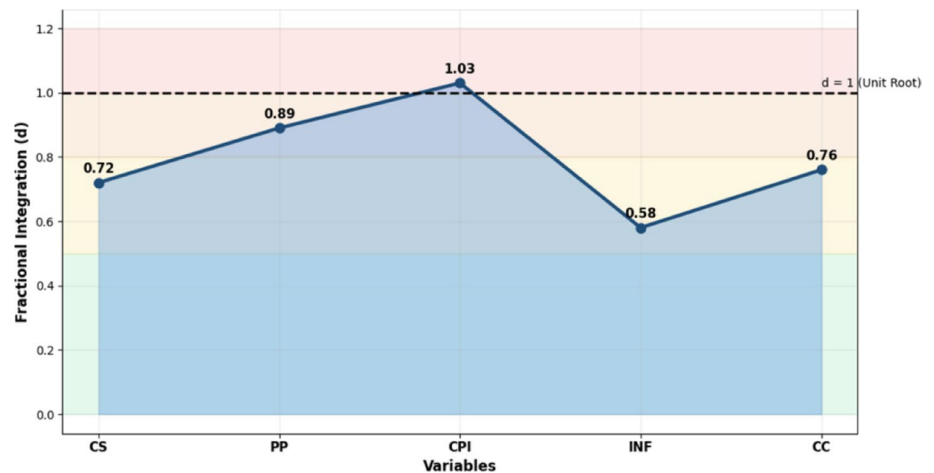


Figure 4 plots the point estimates along the persistence continuum, with the boundaries at 0.5 and 1 marked. The figure must be read alongside the confidence intervals in Table 4, since the point estimates for INF and CPI both sit close to a boundary, and the interval, rather than the point, determines the regime.

4.4 Consistency across procedures

The two approaches agree on the broad ordering but disagree on the resolution. Conventional testing assigns four series to order one and one series to order zero. Fractional estimation shows that three of the four assigned to order one have differencing parameters bounded away from unity, so classifying them as containing a unit root overstates the durability of shocks to them. Only CPI behaves as the integer classification implies. The results therefore illustrate the limitation identified by Gil-Alaña and Robinson [12] for the specific series examined here, and they establish that the persistence of consumer sentiment and of price-based purchasing power cannot be adequately summarized by an integer.

5 Discussion

It is readily interpretable that consumer sentiment is nonstationary but also mean-reverting, with the differencing parameter approximately 0.72. Household expectations are not robust – the impact of a shock keeps decreasing, and the effect disappears after a number of months, but remains noticeable for a very long time. This follows from the index being bounded, since no index can be a genuine random walk over a long sample period if it has been bounded by construction. It also harmonizes with the theory suggested by Katona [19] and developed by Curtin [6] that assessment revision is a more incremental than a full-replacement process, no matter what new signals are received. This updating is slow, allowing this line of reasoning to provide an alternative statistical explanation to the behavioral explanation. The estimate for price-based purchasing power (0.89) is closer to the unit root but still distinguishable from it. This would be suggested by constructing the series. As the estimate for the price index is indistinguishable from unity, both should have the same behavior, which leads to a small discrepancy, presumably caused by the curvature of the reciprocal operation, and not because of an explicit economic mechanism. This latter result has an interesting implication for practice. If price-based affordability conditions have longer memory than the expectational ones, then the models are reordered for this sample, where the slow-moving state variable is sentiment and the fast-moving one is prices.

The nearly identical estimates for CS and CC, with substantial overlap in the intervals, suggest that both expectational series share the same persistence structure. That similarity, however, is not redundancy, as Bram and

Ludvigson [3] demonstrated that series with similar time-series properties can have different forecasting content across expenditure categories. This is not to suggest, however, that removing either of the two would invalidate any argument in this paper, both should be included for comparison, not to imply that they measure different things.

Structural change as an alternative explanation.

The most problematic rival to the above interpretation of these findings is that the long memory is likely due to unmodeled structural change. Several likely switch points in the sample are confirmed by the fact that a process with infrequent regime switching can yield differencing parameter estimates in this range, as found by Diebold and Inoue [9]. Examples include the early-1980s Volcker disinflation, the early-1979 and early-2008 oil price hikes, the global financial crisis, and the pandemic and the inflation spike of 2021–2022. In each case, they affect both the expectational and price series. The tests used in the current unit are only break-naïve, with Perron [29] indicating a bias in favor of failing to reject the hypothesis of a unit root. Don't miss the bias interpretation when reading the classification in Tables 2 and 3. Fractional estimates are less susceptible, since they are not derived from the rejection of a point null, but they are not immune to the confusion that Diebold and Inoue uncover. Those two explanations differ, among others, by the use of a 'break-robust' procedure, as developed by Zivot and Andrews [38], those procedures are both named as necessary when confirming the predictions and are listed in Sect. 5.4. Until this work has been completed, the estimates given here are to be considered only as descriptive of the continued persistence of these series over the entire sample and not as defining the mechanism which gives rise to it.

This study does not estimate those quantities, nor does the information in this paper refer to them. No conclusions of the kind should be read in this paper concerning the effect of purchasing power on consumer sentiment, short-term changes between any two series, forecast error variance decompositions, long-term elasticities, the speed of adjustment to any equilibrium, predictive causality in either direction, or the moderating role of affordability terms in household purchasing decisions. Neither of them is offered by a persistence analysis of only one attribute. The boundaries of measurement, as described in Sect. 3.2 and in Table 1, are equally applicable. The Michigan index shows overall consumer sentiment and does not use the word "environment" or "sustainability" in its composition; therefore, conclusions about environmentally motivated consumption cannot be drawn from the Michigan index. The purchasing power series does not reflect household income or real wages; it doesn't contain details about household wealth and household debt, nor about household economic well-being, nor does it draw any conclusions about that either. Any drop in that series is a comment on prices in relation to some base period. As mentioned in Sect. 2.4, the Sen [35] capability approach and the behavioral mechanisms presented there do not contradict the results presented here and are therefore potential interpretations of how price conditions can influence household choice. They are documented as an interpretive framework for future projects that note the resource and conversion factors variables that the framework needs.

Confirmatory agenda.

It would be followed by a confirmatory stage in four steps. The first is verification: each series is re-downloaded, the download time is noted, seasonal adjustment status and transformation are documented, and the entire estimation pipeline is made public for every statistic reported here. The second is break-robust classification. Each series should be detrended using the Zivot and Andrews [38] procedure or the multiple-break extension of Perron's model, with break dates found endogenously. The differencing parameter should be re-estimated using subsample windows that cover the identified break dates. Substantially lower estimates in the subsample compared to the full sample indicate that the long-memory finding is an artifact of regime change and should be reported as such. The third is a parsimonious multivariate specification. Since PP, CPI, and INF are related algebraically, only one representation of the price process should be used.

A defensible system would use real disposable personal income as the proxy for consumer sentiment, and the other variables would be one price variable or the short-term interest rate, an indicator of consumer credit conditions, and the unemployment rate, to reduce the omitted-variable problem that renders any bivariate association between consumer sentiment and prices uninterpretable. Since both series respond to the same macroeconomic

information, a common-cause explanation must be ruled out before a directional claim can be made. The second step lays the groundwork for the orders of integration in the next step, which the estimator should follow. If none of the series retained is integrated of order one and the one that is integrated has a reduced-rank error structure, a vector error-correction model (VECM) with fully modified or dynamic ordinary least squares estimates of long-run coefficients would be suitable. The bounds testing technique proposed by Pesaran, Shin, and Smith [30] can be used if the orders are not ordered/integrated together. Under standard reduced-rank inference, if the fractional estimates reported here remain after the break analysis, then the vector autoregression cointegration method of Johansen and Nielsen [18] is usually the best choice because fractional integration is not consistent. The selected model needs to include all the following diagnostics: the lag order, the deterministic specification, the normalized cointegrating vector, the adjustment coefficients, the weak exogeneity tests, residual autocorrelation and residual heteroskedasticity, and the results of testing for parameter instability. In step 4, you look at questions that can't be answered from this dataset.

To assess whether affordability conditions affect specific expenditure categories, expenditure data at the category level are needed. Whether they affect "environmentally motivated purchasing" is completely unknown and will need to be observed as tangible buying behavior for certified products, the adoption of energy-efficient products, or the use of validated attitudinal questionnaires, none of which exist in any macroeconomic aggregate series. These are independent studies, each with its own specific data needs, and are not treated here as part of a single series for analysis but as separate studies.

6 Conclusion

This study estimated the persistence of consumer sentiment and consumer purchasing power, measured by the U.S. price level, using monthly data from January 1978 to March 2025, with the consumer price index, inflation, and a general consumer confidence indicator. Within the framework of the deterministic specifications set independently and with the critical value corresponding to the respective specifications, consumer sentiment, purchasing power, and the price index are of order one and inflation of order zero in the conventional test. These factors were improved by fractional estimation. Each of the differencing parameters for consumer sentiment, purchasing power, and consumer confidence was 0.72, 0.89, and 0.76, respectively; all of these parameters were bounded away from 1 by their confidence intervals and were located in the non-stationary but mean-reverting zone. The shocks affecting the series decay over time and persist for extended periods rather than being permanent, as in the integer classification. The unit root hypothesis for the consumer price index was not rejected. Home-to-mean-reverting was purchasing power, surpassing both expectational measures, and the reverse of what seems to occur when the job is done. The results are simple, and the range of variables is therefore simple. No estimates of the relationship between purchasing power and sentiment were found, although a long-run coefficient was not obtained, or a claim for causation was not made. The Michigan index reflects overall expectations about the economy, and the purchasing power series reflects the price value of a dollar, but neither addresses household income, household wealth or distribution, or environmentally motivated consumption. The major drawback is that the analysis does not distinguish a real structural change from genuine long memory in a sample with several significant macroeconomic breaks. Additionally, it only provides and reports national aggregates that mask regional, demographic, and income group differences. The results provide a measured persistence profile for two commonly used series on a shared sample subject to a given specification.

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Data availability All series analysed in this study are publicly available. Consumer sentiment data are published by the Surveys of Consumers at the University of Michigan. The purchasing power, consumer price index and inflation series are published by the Federal Reserve Bank of St. Louis in the Federal Reserve Economic Data repository. Series identifiers, retrieval dates, transformations and the estimation code are provided in the replication file accompanying this submission and are available from the corresponding author.

Declarations

Ethics approval and consent to participate Not applicable.

Informed consent Not applicable.

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Clinical trial Not applicable.

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