Modeling the Impact of Economic Indicators on Personal Consumption Expenditures

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Background and Research Questions

Personal Consumption Expenditures (PCE) serve as a primary indicator of consumer spending and are integral to assessing the economic vitality. PCE accounts for changes in the price level and inflation, thus providing a clearer picture of spending trends and living standards. This capstone study explore the relationship of PCE with economic indicators, such as unemployment rates and inflation rates. With this premise, I seek to answer:

1. What is the relationship between PCE and other economic indicators?
2. How can these relationships be modeled to predict future trends in PCE?

By addressing these questions, we aim to construct a comprehensive model that encapsulates the nuanced interplay between consumer behavior and the broader economic environment.

Data

Data Description

The data used in this study comprises economic data from Q1 2019 to Q4 2023, sourced from Federal Reserve Economic Data (FRED), the Bureau of Economic Analysis (BEA), and the Federal Housing Finance Agency. The final dataset merges several datasets from those sources which include quarterly data from 2019 to 2023 of:

- Percent Change From Preceding Period in Real Personal Consumption Expenditures by Type of Product, which contains 78 individual products and 5 hierarchies
- Real Disposable Personal Income (REDISPINC)
- Real Interest Rate (REINTERATE)
- 10-Year Breakeven Inflation Rate (INFLATRATE)
- Consumer Sentiment (CONSENTI)
- Unemployment Rate (UNRATE)
- House Price Index Purchase Only Data
  - Seasonally-Adjusted Purchase-Only Index (1991Q1=100) (SAPOI1991Q1100)
  - Seasonally-Adjusted Purchase-Only Index % Change Over Previous Quarter (SAPOIPERCHG1991Q1100)

Data Cleaning

The dataset Personal Consumption Expenditures (PCE) dataset exhibits a nested structure where categories and subcategories of products are indicated by leading spaces in each row. To manage this complexity, a function was created to iterate through the dataset, assigning each product to its appropriate hierarchy level based on the number of leading spaces.
This classification was crucial for preparing our data for mixed-effects modeling, ensuring that the nested nature of the data was preserved and accurately represented in the subsequent analysis. The refined dataset now has five columns clearly delineates the hierarchical categories of individual products. In addition, 2 rows of missing data of Personal Consumption Expenditures are removed.

Model Fitting

A linear mixed-effects model was implemented to analyze the relationship between PCE and various economic factors. The initial models exhibited overfitting due to complex random effect structure, with an AIC of 18384.373 and marginal R^2 of 0.057.

$$PCE = \beta0 + \beta1(Year) + \beta2(Quarter) + \beta3(INFLATRATE) + \beta4(CONSENTI) + \beta5(REINTERATE) + \beta6(UNRATE) + \beta7(REDISPINC) + \beta8(SAPOI1991Q1100) + \beta9(SAPOIPERCHG1991Q1100) + (1|Level1) + (1|Level1{:}Level2) + \epsilon$$

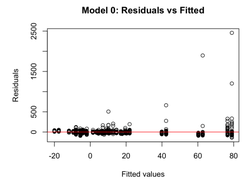

Figure I. The cone shape in residual vs. fitted plot shows violation to the equal variance assumption.

Logarithmic transformation was applied to PCE to normalize distribution, and predictors are standardized to bring them onto a comparable scale. Stepwise elimination based AIC was performed based on a threshold of 10 for the VIF. Variable SAPOIPERCHG1991Q1100 and first-level random effects. The best model selected has a AIC of 3367.084, conditional R^2 of 0.222 and marginal R^2 of 0.191.

$$PCE\_log = \beta0 + \beta1(Year) + \beta2(Quarter) + \beta3(INFLATRATE) + \beta4(CONSENTI) + \beta5(REINTERATE) + \beta6(UNRATE) + \beta7(REDISPINC) + \beta8(SAPOI1991Q1100) + + (1|Level1{:}Level2) + \epsilon$$

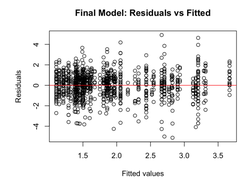

Figure II. The residual vs. fitted plot do not show violation to the equal variance assumption

Diagnostic plots, including residuals vs. fitted and Q-Q plots, were examined for any departure from assumptions. Cook's distance helped identify influential points, while standardized residuals pointed out potential outliers. The final model was refined by excluding influential observations and outliers, which significantly improved model performance metrics such as AIC (2963.593), conditional (0.279) and marginal R^2 values (0.250).

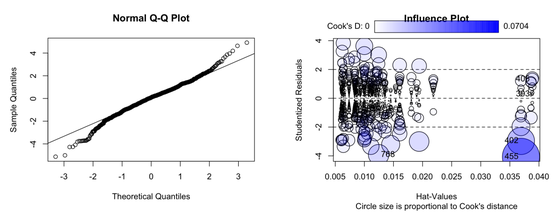

Figure III. The QQ plot on the left do not show major departure from normality and the leverage plot on the right identifies influential cases.

Results

- The model reveals significant relationships between PCE and key indicators like year, quarter, inflation rate, consumer sentiment, unemployment rate, and real disposable income, with a notable impact of the house price index on PCE.
- About 27.9% of PCE's variance is explained by the model, suggesting a good fit without overfitting.
- Variability in PCE not captured by fixed effects is attributed to different categories within the data, as indicated by the random effects associated with Level1 grouping.
- PCE increases over time with year and quarter, whereas indicators like consumer sentiment and real disposable income show a negative impact, highlighting the sensitivity of consumer expenditures to these economic factors.

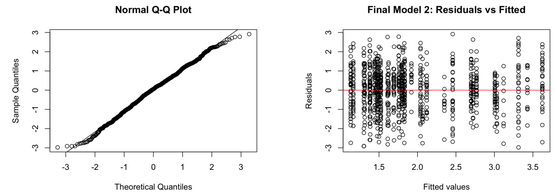

Figure IV. The QQ plot on the left and the residual vs. fitted plot in the middle do not show violation to the equal variance assumption or major departure from normality.

Further Considerations

This model serves as a groundwork for policymakers to anticipate shifts in consumer spending and, by extension, manage economic stability. Further research could extend beyond quarterly data to include monthly granularity, incorporate additional predictive variables, or explore nonlinear relationships.
Limitations to consider include the exclusion of potentially influential macroeconomic factors and the assumption of linear effects. Future work might also delve into the causal relationships using methods like Granger causality to better understand the directionality of influence between the variables.

Reference

U.S. Department of Commerce, Bureau of Economic Analysis. (n.d.). Personal consumption expenditures: Chain-type price index. Retrieved March 13, 2024, from https://apps.bea.gov/iTable/?reqid=19&step=2&isuri=1&categories=survey

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