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A New Method for Calculating Consumer Price Indices: Incorporating Consumer Perceptions and Attitudes with Item Response Theory

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Abstract

This paper presents a conceptual approach to improve consumer price indices (CPI) by incorporating consumers' perceptions and attitudes towards pricing. The proposed approach uses item response theory (IRT) and aims to overcome the limitations of existing CPI methods. The paper provides a comprehensive literature review of existing CPI methods and discusses their potential advantages and limitations. The methodology covers survey design, data collection and data analysis, with a focus on IRT theory and methodology. This approach has the potential to improve the accuracy of CPIs by incorporating consumers' perceptions and attitudes towards pricing. However, the paper also acknowledges potential limitations, including the need for a representative sample and the complexity of the IRT model. Overall, this conceptual paper contributes to the literature on CPIs by proposing a new approach that addresses the limitations of existing methods and has the potential to provide more accurate measures of inflation. The ideas presented in this paper could serve as a basis for future research and inform the development of new CPI methods.

Keywords: Consumer Price Indices, Consumer Perceptions, Consumer Attitudes, Item Response Theory.

Introduction

Inflation measured by consumer price indices (CPI) is an important economic indicator that has a significant impact on policy-making and decision-making at both the national and international levels. The COVID -19 pandemic has made the importance of accurate and reliable CPI even more apparent, as disruptions in the global supply chain and changes in consumer behaviour have affected pricing and inflation rates.

One of the main problems with current methods of CPI is their reliance on a fixed basket of goods and services (Diewert et al., 2022). The basket is assumed to be representative of

the consumption patterns of the population, but it may not accurately reflect changes in consumer behaviour over time. This is particularly problematic for rapidly changing markets where new products and services are frequently introduced, or in cases where consumer preferences change significantly (Felix, 2015).

Cakici & Tekeli (2022) also point out that current methods of calculating CPIs do not take into account individual differences in perceptions and preferences. Consumers may differ in their ability to detect quality differences or perceive price changes. For example, some consumers may be more sensitive to price changes in goods and services, while others may be less sensitive. Similarly, some consumers may attach greater importance to certain attributes of products or services, such as brand name or quality, while others may give preference to other attributes.

These individual differences in perception and preferences can have a significant impact on the accuracy of CPIs. For example, if the price of a particular brand of coffee increases, some consumers may switch to a cheaper brand while others continue to buy the more expensive brand. Current methods for calculating CPIs would not distinguish between these two groups of consumers and would assume that the price increase affects all consumers equally.

The motivation behind this research is to overcome the limitations of existing methods for calculating CPIs that do not fully capture individual differences in perceptions and preferences. These limitations can have a significant impact on the accuracy of CPIs, especially in light of the recent COVID -19 pandemic, which has led to significant changes in consumer behaviour and preferences. By incorporating item response theory (IRT) into the calculations of CPI, we aim to provide a more comprehensive and accurate measure of consumer prices that takes into account individual differences in perceptions and preferences. To our knowledge, no previous study has examined the use of IRT in the context of CPIs, and our approach has the potential to provide valuable insights into the factors that influence consumers' price perceptions.

Our proposed approach can use either one-dimensional or multidimensional IRT models. The unidimensional model assumes that price perception is influenced by a single underlying factor, while the multidimensional model considers the possibility that perception may be influenced by multiple underlying factors (de Ayala, 2022).

In this paper, we will discuss the proposed approach in detail, including the underlying theories and methods of IRT, survey design and data analysis. We will also discuss the potential benefits and limitations of the approach and its relevance for policy makers and economists. In conclusion, we believe that incorporating IRT into the calculation of CPIs has the potential to revolutionise the way we measure inflation and consumer purchasing power. By accounting for individual differences in perceptions and preferences, we can provide a more accurate and comprehensive measure of consumer prices, which has significant implications for economic policy and decision-making.

Literature Review

CPIs are widely used to measure inflation and consumer purchasing power. However, traditional methods CPI have been criticised for their limited ability to capture individual differences in perceptions and preferences, leading to potential biases in calculations CPI (Cakici & Tekeli, 2022). In recent years, researchers have proposed several methods to address these limitations and improve the accuracy of CPI measurements.

One of these methods is the use of hedonic price indices (HPIs), which incorporate information about the characteristics of goods and services to account for differences in quality and amenities. This approach has proven useful in capturing changes in the quality of goods and services over time, as suggested by (Crawford & Neary, 2021). However, HPIs are limited in their ability to capture changes in consumer preferences and attitudes.

Another method that has been suggested is the use of consumer perception surveys to capture individual differences in perception and preference. Studies have shown that incorporating survey data into CPI calculations can improve the accuracy of CPI measurements and reduce potential bias (Białek et al., 2022). However, this approach is limited by the quality and representativeness of survey data.

In addition to these methods, several other CPI measures have been developed to address certain limitations of traditional CPI methods. Kliesen (2021) used the Personal Consumption Expenditures Price Index (PCEPI) is an alternative measure of inflation that covers a broader range of goods and services than the CPI. The chain-weighted CPI takes into account changes in consumer behaviour over time and is considered by some economists to be a more accurate measure of inflation, such as (Genc et al., 2022). The Experimental Price Index for Underlying Inflation is a measure of inflation that excludes goods and services with volatile prices, such as food and energy (Abe & Shinozaki, 2018). The Everyday Price Index (EPI) is a measure of inflation that focuses on goods and services that are frequently purchased by consumers (Hersugondo et al., 2022). Sticky Price CPI is a measure of inflation that focuses on goods and services whose prices do not change frequently (Kundu et al., 2021). The Perceived Price Index (PPI) is a measure of inflation that takes into account consumers' perceptions of price changes (Sebestyén & Szabó, 2022).

Despite their potential advantages, these methods also have their limitations. The PCEPI may overstate inflation in times of rapid technological change, as Kliesen (2021) has shown. The chain-weighted CPI may underestimate inflation during periods of significant price change (Genc et al., 2022). The EPI may not capture price changes in goods and services that are excluded from measurement (Hersugondo et al., 2022). The EPI and Sticky Price CPI may not be representative of overall inflation experienced by consumers (Hersugondo et al., 2022; Kundu et al., 2021). Sebestyén & Szabó (2022) suggested the PPI may be subject to biases in consumers' perceptions of price changes.

Given the limitations of these existing methods, there is a need for a new approach to capture individual differences in perception and preference. One possible solution is to use IRT, which is widely used in psychometrics to model individual responses to test items and has recently been applied to capture individual differences in preferences and attitudes towards goods and services (de Ayala, 2022). By using IRT, it may be possible to more accurately measure changes in consumer preferences and attitudes over time and reduce potential bias in the calculations of CPI.

Methodology

The methodology section provides a comprehensive discussion of the underlying theories and techniques of IRT, as well as the survey design and data analysis methods proposed in this study.

Underlying Theories and Methods of IRT

IRT is a psychometric framework that models the relationship between item characteristics and individual responses. IRT assumes that there is an underlying property, such as perception

or preference, that influences the way individuals respond to items in a survey. The goal of IRT is to estimate the value of the underlying trait for each person based on their responses to survey items. IRT models can be one-dimensional or multidimensional, depending on the number of underlying traits being modelled.

The mathematical model developed specifically for IRT is based on item characteristics categorised as dichotomous and polytomous. Dichotomous refers to items that have only two response options. The three main dichotomous IRT models are the one-parameter logistic model (1PL), the two-parameter logistic model (2PL) and the three-parameter logistic model (3PL). On the other hand, polytomous items have more than two response options. The polytomous IRT models include the Nominal Response Model, the Graded Response Model, the Rating Scale Model, the Partial Credit Model and the Generalised Partial Credit Model. In this study, we propose IRT to estimate the best possible prices for each item in the consumer price index, taking into account individual differences in perceptions and preferences.

Survey Design

The survey is designed to collect individual responses on consumers' experiences with different prices for different goods and services. The survey is conducted online and consists of a series of questions about consumers' past experiences of purchasing different goods and services. For each item, respondents are asked to rate their experiences with different prices on a Likert scale. The survey also collects demographic information about respondents, such as age, gender and income.

Conceptual Framework

The conceptual framework for this study is based on the assumption that consumer perceptions and preferences influence how individuals respond to different prices for goods and services. The aim of the study is to propose a more accurate and comprehensive measurement of consumer prices by taking into account individual differences in perceptions and preferences.

Data Analysis

The data collected in the survey will be analysed using IRT. IRT is a psychometric framework that allows the estimation of individual latent characteristics (i.e. price perceptions) based on item responses (i.e. consumers' experiences with different prices for different goods and services). IRT models the relationship between item characteristics (i.e. prices of goods and services) and individual responses to those items (i.e. how consumers perceive and evaluate prices) and provides estimates of the most likely price for each item that take into account individual differences in perception and preference.

There are two different approaches to IRT: unidimensional and multidimensional models. The unidimensional model assumes that price perception is influenced by a single underlying factor, while the multidimensional model considers the possibility that perception is influenced by multiple underlying factors. The choice of model depends on the results of the preliminary analyses, including exploratory factor analysis and confirmatory factor analysis, which assess the dimensionality of the data and identify the most appropriate IRT model.

The analysis is conducted in several steps. First, the data are cleaned and prepared for analysis by checking for missing values, outliers and other data quality issues. Second, the dimensionality of the data is assessed using exploratory factor analysis (EFA) to determine the

number of underlying factors that influence price perceptions. Third, confirmatory factor analysis (CFA) is used to confirm the factor structure identified in the EFA and to assess the fit of the IRT models. Fourth, the IRT models are estimated using the Graded Response Model (GRM) for the unidimensional model and the Multidimensional GRM (MGRM) for the multidimensional model. Fifth, the estimated parameters are used to construct item characteristic curves (ICCs) and item information functions (IIFs) that provide information about the discrimination, difficulty and reliability of each item. Sixth, the estimated prices are calculated based on the item parameters and individual responses, taking into account individual differences in perception and preference. Finally, the estimated prices are compared with the actual prices to assess the validity of the approach.

All data analyses are carried out using statistical software such as R or Stata. In addition to the IRT models, descriptive statistics and regression analyses are used to investigate the relationships between demographic variables (e.g. age, gender, income, education) and price perceptions. Sensitivity analyses are also conducted to assess the robustness of the results to different model specifications and assumptions.

Research Framework

The conceptual framework of this research is based on the assumption that CPIs should reflect individual differences in perceptions and preferences and that IRT can provide a more accurate and comprehensive measure of consumer prices by taking these differences into account. The research aims to develop a new approach to calculating CPI by embedding IRT, which has not been explored in this context before.

The research framework consists of three main components: Survey Design, Formulation of CPI-IRT, Data Analysis and Policy Implications. Survey design involves collecting data on consumers' experiences with different prices for different goods and services, as well as demographic information that may influence price perceptions. CPI-IRT is derived by integrating established CPI methods with an IRT model. This model applies modern test theory to pricing to determine the latent characteristics of individuals based on the parameters of difficulty, discrimination and rates or carelessness. Meanwhile, the Laspeyres, Paasche and Fisher price indices are widely used CPI methods that have the potential to be integrated with IIRT.

A sound statistical model should include statistical analysis capable of generalising unobserved data variables. In practise, cross-validation can be used to determine the accuracy of IRT. Cross-validation is used to assess the ability of a model to identify consumer prices. The data are divided into two subgroups: Training and Testing. The training section improves the model's ability to identify the optimal consumer price with sparse data. In the test section, more data is used to calculate CPI.

In addition, the training part identifies possible errors or outliers for validation. Errors are incorrect prices, while outliers are large price movements compared to most price movements. This validation process confirms and validates the prices identified as outliers or anomalies. Any typos should be corrected. Outliers found to be credible should be used to calculate the index.

In data analysis, IRT is used to estimate the best possible prices for each item, taking into account individual differences in perception and preference. Policy implications discuss the potential benefits and limitations of the approach and its relevance for policy makers and economists. The analysis is conducted in several steps, including data cleaning, dimensionality

assessment, IRT model estimation and sensitivity. In summary, the framework of the study can be illustrated by the flowchart shown in Figure 1.

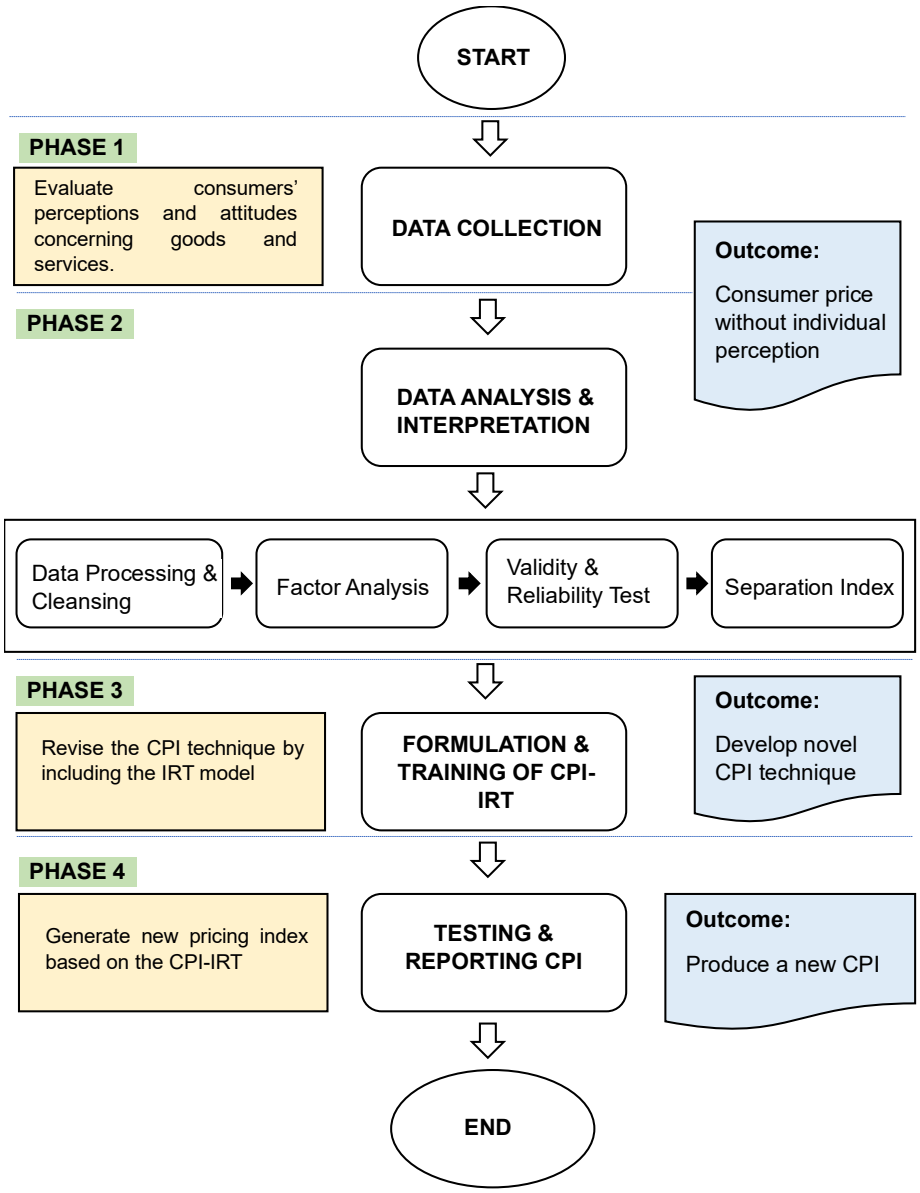

Figure 1. The Research Flowchart of the Study

Possible Advantages and Limitations

The proposed approach of incorporating IRT into the calculation of CPI has the potential to overcome the limitations of existing methods and provide a more accurate and comprehensive measure of consumer prices. In this section, we will discuss the potential advantages and limitations of this approach and its relevance for policy makers and economists.

One of the main advantages of the proposed approach is its ability to account for individual differences in perceptions and preferences. By using IRT to estimate the best possible prices for each item, we can develop a more nuanced understanding of how consumers perceive and value different goods and services. This in turn can lead to more

accurate measures of inflation and consumer purchasing power, which has important implications for economic policy and decision-making.

Another potential advantage of the proposed approach is its flexibility with regard to the use of one-dimensional or multidimensional IRT models. The use of multidimensional IRT models allows the study of the influence of several underlying factors on price perceptions, which can provide more comprehensive insights into the drivers of consumer behaviour.

However, there are also some limitations of the proposed approach that need to be considered. One potential limitation is the need for survey data to collect individual responses on consumers' experiences with different prices for different goods and services. This can be time-consuming and costly, and the quality of the data collected may depend on the representativeness of the sample.

Another potential limitation is the complexity of the IRT models used in the analysis, which may require specialised expertise to implement and interpret. This could limit the acceptance of the approach by policy makers and other stakeholders who may not have the necessary technical skills.

Despite these limitations, the proposed approach is of great importance to policy makers and economists. By providing a more accurate and comprehensive measure of consumer prices, this approach can support economic policy decisions related to inflation targeting, monetary policy and the measurement of economic activity. It can also provide valuable insights into consumer behaviour and preferences that can inform the development of marketing strategies and the allocation of resources by firms.

In summary, the proposed approach of incorporating IRT into the calculation of CPI has the potential to revolutionise the way we measure inflation and consumer purchasing power. While there are some limitations to consider, the benefits of this approach in providing a more accurate and comprehensive measure of consumer prices are significant and have implications for economic policy and decision-making.

Conclusion

In summary, this conceptual paper proposed a new approach to the calculation of CPI by embedding IRT, a psychometric framework that has not been previously explored in the context of CPI. Our approach involves using survey data to collect individual responses on consumers' experiences of different prices for different goods and services, which are then analysed using IRT to estimate the best possible prices for each item, taking into account individual differences in perception and preference.

The proposed approach, using IRT, can potentially contribute to research in the field CPI by overcoming the limitations of current methods and enabling a more comprehensive measurement of consumer prices. By accounting for individual differences in perception and preference, this approach can provide a more nuanced understanding of the factors that influence price perceptions and allow for a more accurate measurement of consumer inflation and purchasing power. This potential contribution highlights the importance of accounting for individual differences in the calculation of CPIs and the potential benefits of using IRT in this context.

However, it is important to note that the proposed approach has some limitations. First, the approach requires a large and representative sample of consumers to provide accurate data. Second, the approach is dependent on the accuracy and honesty of consumer responses. In addition, the proposed approach may require more resources and time compared to existing methods.

Despite these limitations, we believe that incorporating IRT into the calculation of CPI has significant implications for policy makers and economists. By providing a more accurate and comprehensive measure of consumer prices, policy makers and economists can make more informed decisions about economic policy and resource allocation.

In conclusion, this paper has presented a novel approach to calculating CPI involving IRT, which has not been studied before in the context of CPI. This approach has the potential to provide a more accurate and comprehensive measure of consumer prices that is relevant to policy makers and economists. We recommend further research to explore the potential of this approach in practise.

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