



WORKING PAPER

MEASURING INFLATION IN GHANA: EVIDENCE FROM BIG DATA AND ARTIFICIAL INTELLIGENCE TECHNIQUES

Prepared by **Francis Mawuli Abude, Collins Kwesi Appiah, and Julius B. Dasah**
WPS/26/002

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2026

OCTOBER

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 October, 2026

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ABSTRACT

The delay in the publication of key macroeconomic indicators, especially inflation, has been a major concern for fiscal and monetary authorities, investors, researchers, and development partners over the years. In Ghana, inflation statistics for a particular reference month are published two weeks after the end of that month, even though price data are collected in the first week. With the advent of advanced technologies and Artificial Intelligence (AI), an important macroeconomic indicator such as inflation can be obtained in real time by leveraging AI methodologies and algorithms. This paper proposes a novel inflation measurement framework called e-Inflation, which employs Big Data and AI tools and technologies to extract large volumes of price data from non-traditional data sources (websites) for real-time computation of the Consumer Price Index (CPI) and inflation in line with international best practices. Preliminary results show that the e-Inflation framework nowcasts official inflation rates accurately in a cost-efficient manner. Furthermore, the framework is dynamic and robust enough to accurately capture inflation dynamics in both stable and unstable macroeconomic environments.

JEL Classification: C53, C55, E27, E31

Keywords: CPI, Inflation, e-Inflation, Web-Scraping, Big Data, Artificial Intelligence, Monetary Policy, Ghana

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Acknowledgements

The authors are grateful to the Management of the Bank of Ghana for their support and guidance in shaping the paper. Our special appreciation also goes to Dr. Philip Abradu-Otoo, the former Director of the Research Department, for his interest in the study from its inception and for providing the necessary resources and technical guidance. We also acknowledge the staff of the Research Department for their constructive feedback and valuable technical suggestions.

PUBLIC

1.0 Introduction

Central banks, especially those implementing an Inflation Targeting (IT) regime, require real-time inflation statistics for economic policy formulation and implementation (Chakraborty & Joseph, 2017; Andrieu et al., 2013). However, national statistical offices in most Sub-Saharan African (SSA) countries struggle to provide real-time Consumer Price Index (CPI) statistics, due mainly to expensive surveys, the non-availability of complete and timely data, inadequate logistics and funding, the use of outmoded survey methods, inadequate skilled personnel, lack of technological infrastructure, weak central coordinating systems for statistics, and political interference, among others (Cai & Zhu, 2015; Hammer et al., 2017; NDPC/GSS, 2018).

Central governments continue to allocate substantial budgetary support to statistical offices to conduct surveys, particularly CPI surveys, also known as the “brick-and-mortar” stores approach. The monthly cost components include vehicles and maintenance costs, fuel costs, allowances for field staff, as well as occasional ‘gifts’ to sellers and respondents. Beyond the significant fiscal impact of this approach, there are challenges posed by changing market outlets and products, sampling errors, response fatigue, and data entry errors (GSS, 2020; IMF, 2004).

Consequently, Cavallo and Rigobon (2016) and Bentley and Krsinich (2017) assert that the traditional survey method (or the “brick-and-mortar” stores approach) is outdated, slower, costly, more complex, and error-prone. Similarly, Konny et al. (2019) argue that respondent and field officer fatigue, low response rates, and budgetary constraints impede the rapid production and dissemination of CPI in the United States. Another key limitation of the traditional CPI survey approach becomes evident during natural disasters (e.g., earthquakes) and pandemics, which usually force statistical offices to impute price data. For instance, COVID-19 lockdowns in 2020 and social-distancing directives disrupted routine price

collection at almost all statistical offices globally, compelling them to impute or extrapolate price data for the lockdown periods to compute inflation rates (AFRISTAT et al., 2020; Tissot & De Beer, 2020).

Since 1948, the Ghana Statistical Service (GSS) has gathered price data through traditional surveys. To do this, hundreds of data collectors visit market centres, supermarkets, and retail outlets for data collection. As a result, the earliest inflation statistics for a month are only published two weeks after the month ends, despite price data being collected in the first week. This delay is similar to what occurs in advanced economies such as the United States, United Kingdom, Germany, New Zealand, Canada, and Japan.

This development has compelled many Inflation Targeting (IT) central banks such as the U.S. Federal Reserve (Fed), the Bank of England (BoE), the South African Reserve Bank (SARB) and the Bank of Ghana (BoG), among others, to resort to nowcasting and forecasting inflation using statistical models, structural econometric models and machine learning algorithms (Araujo & Gaglianone, 2023; Bok et al., 2018; Elshendy & Colladon, 2017). The most common models for nowcasting/forecasting inflation include the random walk, Phillips curve, linear regression, Autoregressive Moving Average (ARMA), autoregressive integrated moving average (ARIMA), seasonal autoregressive integrated moving average (SARIMA), dynamic factor model (DFM), vector autoregression (VAR), random forest, support vector machine, long short-term memory, ridge regression, and elastic net models. Similarly, the judgement method and the Survey of Professional Forecasters (SPFs) are used to forecast inflation and other macroeconomic indicators. However, these approaches, which are usually expensive, do not always produce accurate and real-time inflation nowcasts (Macias et al., 2023). Hence, there is a need for more innovative and cost-efficient methodologies, leveraging Big Data and Artificial Intelligence (AI) techniques, tools, and technologies.

Given the weaknesses of traditional inflation measurement and nowcasting approaches in Ghana and other countries, this paper proposes a novel framework called “*e-Inflation*”. This framework employs Big Data and AI tools, technologies, and techniques to construct a real-time CPI and inflation. It is called e-Inflation because its methodology uses data from *electronic (websites/internet)* sources instead of traditional sources to estimate CPI, headline inflation, food inflation, and non-food inflation rates.

The paper employs Big Data and AI tools and techniques to extract a large set of consumer product prices from 120 e-commerce shops in Ghana, as well as institutional websites, by deploying web scrapers or robots. According to Cavallo and Rigobon (2016), extracting data from online sources is cheaper, faster, and more accurate. These data can therefore be used to complement or replace traditional survey-based CPI methods in countries with advanced digitisation and digitalisation. The methodologies employed in this paper strictly align with the Classification of Individual Consumption according to Purpose (United Nations Statistics Division [UNSD], 2018; ILO et al., 2004) and GSS (2020) methodological manuals for compiling and computing CPI. Although most purchases are still made in physical stores by Ghanaians, online shopping is gaining traction, as about 68.2 percent of the population currently uses the internet (GSS, 2021). In addition, the International Trade Administration (2023) estimates that approximately 15 million Ghanaians have access to e-commerce platforms. The most patronised e-commerce shops in the country include Jumia Ghana, Jiji Ghana, Tonaton, Melcom, Shoprite, Palace Mall Online Shopping, Hubtel, MaxMart Family Shopping Centre, Eden Tree, KiKUU Online Shopping Mall, Alibaba, Ubuy, and Amazon.

The central question of whether online prices are identical to those in physical shops remains the main concern of this research. However, Cavallo (2017) found that in 72 percent of cases, prices were similar across 56 large retail shops in 10 countries, including the United States and

South Africa. Similarly, our survey revealed that online and offline sources have statistically identical prices in Ghana. Based on this, we are confident in the representativeness of the price data extracted from online sources and in its use in computing the CPI and inflation rates for Ghana.

This paper details the methodologies used to nowcast inflation in Ghana using Big Data and AI since May 2021. The specific objectives of the paper are as follows:

- To identify new data sources (data pipelines) for collecting prices of consumer goods and services.
- To compare the coverage of the official basket of goods and services with the e-Inflation framework.
- To construct the overall, food, and non-food consumer price indices, as well as their respective inflation rates, and compare the nowcast values with the official outturns from the GSS.

The paper is structured as follows: Section 2 reviews the literature on the application of Big Data and AI in inflation measurement and discusses some stylised facts about CPI computation in Ghana. Section 3 provides a detailed description of the novel e-Inflation framework for Ghana. Section 4 further discusses the data sources and pipelines used, while Section 5 presents the preliminary results. Finally, Section 6 presents the conclusion and policy recommendations.

2.0 Literature Review

This section presents the theoretical and empirical literature reviews of the concept of Artificial Intelligence (AI) and its relevance to monetary policy analysis. It also examines the concept of Big Data, technologies and tools, including web-scraping, as well as some empirical studies on the use cases of Big Data in constructing a CPI.

2.1 Theoretical Review of AI and Big Data in Macroeconomics

AI is arguably one of the most important advances expected to drive the Fourth Industrial Revolution (4IR). AI is generally defined as the science and engineering of developing and training (computer) systems with human-like intellectual capabilities such as reasoning, discovering meanings and patterns, and learning from experience. It is an umbrella term for Machine Learning (ML), Natural Language Processing (NLP), Deep Learning (DL), Internet of Things (IoT), Big Data (BD), Big Data Analytics (BDA), Robotics, Computer Vision, Expert Systems, and Speech Recognition, among others (Khan & Al-Badi, 2020). According to some researchers (e.g., Borana, 2016; Zawacki-Richter et al., 2019; Cioffi et al., 2020), extensive theoretical and experimental studies coupled with practical applications have extended the boundaries of AI into several multidisciplinary fields such as philosophy, mathematics, medicine, computation, psychology, biology, neuroscience, healthcare, robotics, law, engineering, finance/business, economics, education, gaming, aviation, and meteorology among others. In particular, AI technologies including the Internet of Things, Machine Learning, Deep Learning, Computer Vision, Robotics and Automation, Big Data, Natural Language Processing, Cloud Computing, Blockchain, and Cryptocurrency have been identified as enhancing central banking and monetary policy formulation through macroeconomic modelling and forecasting, communication analysis, fraud detection, sentiment analysis, and fake currency detection.

The term “Big Data” emerged in the literature about two decades ago, without consensus on its definition (Hammer et al., 2017; Garboden, 2019; Bok et al., 2018). However, Tissot (2019) and Baldacci et al. (2016) have described Big Data as any voluminous amount of data collected using information technology infrastructure and technologies to obtain insights to drive business objectives. Big Data is usually characterised by the so-called V’s, which keep

multiplying. It began with the 3V's – Volume, Velocity, and Variety, then 4V's – Volume, Velocity, Variety, and Veracity, and 5V's – Volume, Velocity, Variety, Veracity, and Value (Sangeetha & Sreeja, 2015). Soomro's (2023) 10V's include Volume, Variety, Velocity, Veracity, Validity, Value, Variability, Venue, Vocabulary, and Vagueness. Similarly, Arockia Panimalar et al. (2017) proposed the 17V's. A critical review of the recent extension to 17V's reveals little substantial or contextual deviation from the 5V's.

In practice, Big Data has attracted growing interest from researchers across different fields, including economics, finance, medicine, biology, aerospace, and engineering. In the field of economics, Bok et al. (2018) underscored the relevance of Big Data by stating that, *“Data, data, data... Economists know their importance well, especially when it comes to monitoring macroeconomic conditions – the basis for making informed economic and policy decisions”*. According to Garboden (2019), the Big Data taxonomy literature identified nine primary sources for macroeconomic forecasting. These are: 1) financial market data; 2) e-commerce and credit cards; 3) mobile phones; 4) search; 5) social media data; 6) textual data; 7) sensors and the internet of things; 8) transportation data; and 9) other administrative data. The concept of Big Data presents both prospects and challenges to macroeconomists. In terms of prospects, Hammer et al. (2017) noted that Big Data helps to discover new (non-traditional) data sources. These new data sources can be leveraged to address macroeconomic inquiries, develop new macroeconomic indicators, enable timely and accurate forecasting, and reduce time lags in the publication of official statistics.

Despite the many prospects and rapid interest in Big Data analytics among macroeconomic forecasters, some challenges have been identified. These include the difficulties in handling large and complex datasets, the use of undocumented and dynamic data structures, the need for a cutting-edge information technology (IT) infrastructure, cloud (distributed) computing, high

initial costs, access to Big Data, and difficulty in establishing causation. Other challenges include a lack of data professionals such as AI/ML Engineers, Big Data Specialists, Data Scientists, and Cloud Architects with proficiency in Python, R, MATLAB, SAS, and Power BI, among others (Cai & Zhu, 2015; Bok et al., 2018; Hammer et al., 2017). Although these challenges are not trivial, they have also presented econometricians and data scientists with new opportunities to explore, develop, and extend statistical methods, measurements, and modelling techniques to Big Data expertly and effectively.

2.2 Web-Based CPI

Although this paper appears to be novel in the African context, a survey by AFRISTAT et al. (2020) reports that a few advanced countries have leveraged AI to complement or replace the traditional brick-and-mortar stores approach to collecting CPI data. The literature identifies Professor Alberto Cavallo as the foremost economist to use online price data to compute CPI in Argentina from 2007 to 2011, following suspected manipulation of the official inflation rates by the government and national statistical office (National Statistics Institute, INDEC). His findings were largely consistent with those produced by leading monetary economists and independent research institutions in the country (Cavallo, 2013). The findings, coupled with experience from an earlier project, motivated him to start the Billion Prices Project at the Massachusetts Institute of Technology (MIT) in 2008 to gather price data across many countries, including the United States, using web-scraping techniques (Cavallo & Rigobon, 2016). Subsequently, Cavallo and Rigobon established PriceStats as a private company that is dedicated to collecting and analysing price data from over 60 countries (Cavallo & Rigobon, 2016). Since 2016, the Australian Bureau of Statistics has been utilising web-scraping tools to collect over a million prices per week from 65 different retail shops (ABS, 2020). Also, countries like Canada, New Zealand, Norway, and Poland, among others, have used web-

scraped data to measure inflation (Johannessen, 2020; Ravindra, 2019; Macias & Stelmasiak, 2019; Bentley & Krsinich, 2017). Empirical results have shown that web-based consumer price indices constructed in some jurisdictions have closely mimicked official CPIs with insignificant deviations within some periods (see Cavallo & Rigobon, 2016; Bentley & Krsinich, 2017). This indicates that the use of web-scraping techniques and AI to measure CPI/inflation can serve as a useful complement to the (manual) official CPI.

2.3 Stylised Facts about CPI Computation in Ghana

This section examines common methodologies for computing CPI and inflation in Ghana. It also describes how the GSS produces its official inflation statistics, as well as the evolution of the fixed basket of goods and services over the years.

2.3.1 Overview of CPI Compilation and Computation in Ghana

The GSS was established in 1948 and is the institution legally mandated to compute and publish official national statistics, including CPI and inflation rate. On a monthly basis, the GSS releases the CPI and inflation rates for the Ghanaian economy. The CPI and inflation rates published by the GSS have been widely used by fiscal and monetary authorities, researchers, investors, and development partners in many contexts. The GSS has its own CPI methodological manual, which draws on the international best practices of the COICOP manual. The COICOP manual remains the most authoritative reference manual for theoretical and conceptual methodologies on CPI compilation and computation for most national statistical offices in the world (UNSD, 2018; ILO et al., 2004). In collecting price data, the GSS continues to conduct traditional surveys to gather prices and expenditures of consumers from physical shops, markets, stores, and government offices, among others, to conform to global standards based on the 1993 and 2008 Systems of National Accounts (SNA) and the recommended COICOP manual for classifying private consumption expenditure (PCE).

The CPI was expanded and rebased in 2019 to capture structural changes in the economy. There were methodological changes following the rebasing. First, the basket of goods and services was expanded from 267 to 307 items. Second, the base year was changed from 2012 to 2018. Third, the expenditure weights used after the rebasing were derived from the Ghana Living Standard Survey round 7 (GLSS 7) conducted in 2016/2017, with combined weights of 43.7 percent and 56.3 percent assigned to all food and non-alcoholic beverages and non-food items, respectively. Fourth, the number of pricing varieties also increased from 605 to 710, with coverage of 222 basic headings based on the COICOP manual.

The GSS basket comprises 44 groups, 98 classes, 156 sub-classes, and 307 item-level observations in line with the COICOP manual (GSS, 2020). Regarding the number of markets to visit for price data, the rebased CPI data were collected from 44 markets compared to 42 under the old CPI methodology. Of the 44 markets, 15 were in the urban areas, while the remaining 29 were in the rural areas. The GSS's price data collectors had to visit 7,195 shops and outlets (3,218 in urban areas and 3,977 in rural areas) to collect data during the first week of every month. As part of the pre-processing flowchart, the 710 price items were sorted and classified manually into 222 basic headings by the officers at the various regional offices.

After the creation of six (6) additional administrative regions in the country, some quantity adjustment issues led the GSS to change the reference year from 2018 (2018=100) to 2021 (2021=100). Additionally, the number of markets was increased from 44 to 57 (although the basket remained the same with 307 items), while the number of outlets increased from 7,195 to 8,337. Another significant change concerned the expenditure weights for food and non-food components. Whilst the food component of the CPI now has a combined expenditure weight of 42.7 percent, the non-food component has 57.3 percent. Currently, the price data used to

calculate inflation rates in Ghana are collected for 47,877 products and services across the 16 regions using the traditional survey approach.

The data are captured in Microsoft Excel and subsequently submitted to the head office in Accra for further analysis. The data are then exported into the Indexer Software (Prima) or R software for the computation of the Consumer Price Index. Computationally, the index is based on the Laspeyres formula, which is a special case of the Lowe formula. The Lowe index is defined in Equation 1.

$$CPI^{0,t} = 100 * \left[\sum_{i=1}^n \frac{p_i^t}{p_i^0} \right] \left[\frac{p_i^0 q_i^b}{\sum_{i=1}^n p_i^0 q_i^b} \right] \dots \dots \dots (1)$$

Where:

$CPI^{0,t}$ is the consumer price index of a fixed-basket item at time t with base period, 0.

p_i^t denotes the average price of representative aggregate (item) i at the time t ,

p_i^0 is the average price of representative aggregate (item) i at the base period, 0.

q_i^b represents the quantity of item i at time period, b .

n is the number of items in the basket (307 items).

The Laspeyres index is obtained from Equation 1 when $b = T = 0$.

$$CPI^{0,t} = 100 * \left[\sum_{i=1}^n \frac{p_i^t}{p_i^0} \right] \left[\frac{p_i^0 q_i^{b=0}}{\sum_{i=1}^n p_i^0 q_i^{b=0}} \right] \dots \dots \dots (2)$$

The last part of the identity at the right-hand side of Equation 2 represents the expenditure weights, w , derived from the GLSS 7 conducted in 2016/2017. Therefore, we have,

$$CPI^{0,t} = 100 * \left[\sum_{i=1}^N \frac{p_i^t}{p_i^0} \right] * w_i \dots \dots \dots (3)$$

We obtain annual inflation, π^t , using Equation 4.

$$\pi^t = \left[\frac{CPI^{0,t}}{CPI^{0,t-12}} - 1 \right] * 100 \dots \dots \dots (4)$$

Similarly, month-on-month inflation is obtained using Equation 5.

$$\pi_m^t = \left[\frac{CPI^{0,t}}{CPI^{0,t-1}} - 1 \right] * 100 \dots \dots \dots (5)$$

3.0 Measuring e-Inflation in Ghana

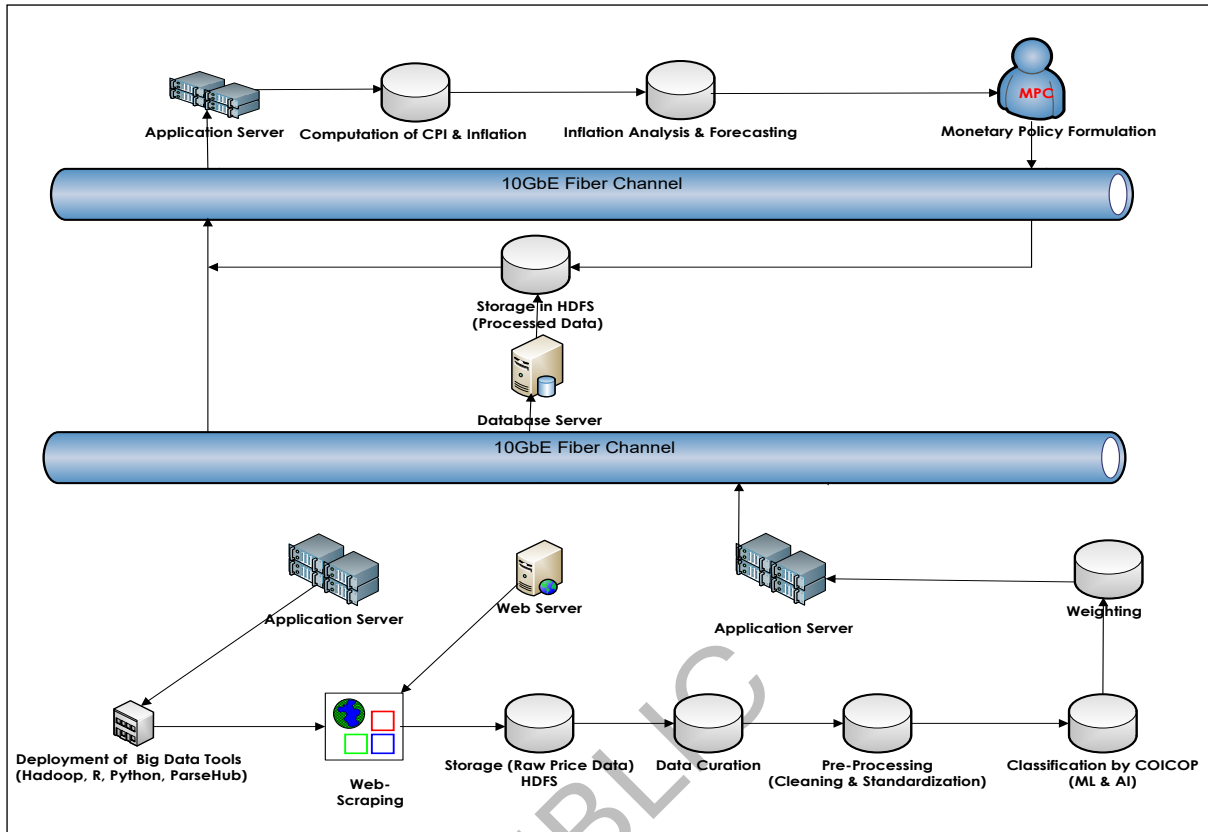
In this section, we present the steps involved in deploying the Big Data tools for extracting consumer product and price data from the internet/websites to construct an AI and Big Data-driven CPI (e-Inflation) for Ghana. This includes the architectural design of the robotic system, data pipelines, web-scraping tools, and the challenges encountered during the study, which are discussed in Section 6.3.

3.1 Robotic and Automated System for the e-Inflation Framework

In Figure 1, we present the automated Big Data-driven infrastructure as well as the processes to follow in computing the e-Inflation. It shows how web-scraping is orchestrated with efficient data pipelines using Big Data tools such as Python, Hadoop, R, Apache Spark, SQL, Octoparse, and ParseHub. The raw data are stored in the Hadoop Distributed File System (HDFS), after which data curation and pre-processing activities (including cleaning, formatting, parsing, standardisation, winsorising, and validation) are done in Python or R. Subsequently, an embedded Naïve Bayes classifier sorts the items and prices into their respective categories (divisions) based on the COICOP framework. CPI and inflation statistics are then computed, and a detailed report is generated for Management and the Monetary Policy Committee (MPC).

According to Kreinovich et al. (2018), the most common information technology (IT) tools for collecting Big Data are Apache Hadoop, Apache Spark, Python¹, R, Octoparse, ParseHub, Apache Airflow, and cloud computing services, such as Microsoft Azure, Google Cloud Platform, and Amazon Web Services. After a careful assessment and comparison of their efficiency, we settled on Apache Hadoop, Python, R, Octoparse, and ParseHub. While the first three are code-driven, Octoparse and ParseHub are “point-and-click” software solutions that require little or no technical experience in computer programming. Scraping with Application Programming Interfaces (APIs) is fast and less cumbersome because it connects the “*web-scrapers or robots*” directly to the database of the retailer. However, APIs are usually restricted (private) for cybersecurity reasons and are therefore rarely used in web-scraping (Macias & Stelmasiak, 2019; Konny et al., 2019). This notwithstanding, a strategic deployment of robots without APIs has been efficient in extracting the needed price data from the targeted e-commerce and institutional websites.

¹ The most common Python libraries for web-scraping are BeautifulSoup and Selenium.

Figure 1: The Robotic and Automated System for e-Inflation Framework

Source: Authors' design

3.2 Big Data Techniques, Tools, and Technologies for Web-Scraping

In this paper, we designed and programmed robots to extract data on the name of retailers, product identification number, product name, product description, product brand, product package size (weight in kilograms or grams), price, and discount price (if available). After the data are curated, pre-processed, and cleaned, the heterogeneous products are then sorted and classified into their appropriate categories/divisions based on the COICOP approach using the Naïve Bayes classifier. This process is critical to reduce, if not eliminate, mismatch and misclassification of products, which is common with the manual process.

4.0 Variables and Data Sources (Pipelines)

This section describes, in detail, the processes to identify and select outlets for data scraping. It also lists the web addresses of some of the outlets, as well as the coverage of the e-Inflation framework compared to the official inflation methodology.

4.1 Selection of Retailers, Institutions, and Other Data Sources

Our preliminary web search revealed a growing number of e-commerce platforms displaying product names, categories, prices, and weights (in kilograms or grams). With the relatively high internet penetration resulting in the “massification” of e-commerce platforms, Ghanaians are able to shop online for consumer goods and services. Some of these items include ready-made food (e.g., *fufu*, cooked rice, jollof, *kenkey* with fried fish, *banku*, and beans with fried plantain, among others), groceries, fashion products, electronics and lighting items, health and beauty items, automobiles/vehicles, furniture and home products, baby/toy products, and sports and fitness goods. Many of these products can be delivered to buyers’ doorsteps by delivery service providers, including Hubtel, Uber, and Bolt, among others. This is made possible through the introduction of the Ghana Post Digital Address System and the Global Positioning System (GPS), the centralised National Biometric Identity System (the Ghana Card), and consistent growth in the use of mobile money and other electronic payment platforms in the country (Opoku-Afari, 2021). To be able to extract adequate price data for CPI computation, this paper explored several non-traditional data sources. These sources include the Ghana Private Road Transport Union (GPRTU), the Electricity Company of Ghana (ECG), the Ghana Water Company Limited (GWCL), the National Health Insurance Authority (NHIA), the University of Ghana, the University of Cape Coast, the University for Development Studies, the Central University, the Ho Technical University, and the Ghana Oil Company PLC (GOIL) (see Table A2 in Appendix). The selection of these outlets was based on the following criteria

(in decreasing order of importance): (1) having an active website (regularly updated with products, prices, and weights); (2) expressing prices in the local currency, Ghana Cedi (GHS); (3) possibility of web-scraping; and (4) having a physical presence such as a store or office. In all, price data are collected from 120 websites, which equate to market centres under the GSS approach. Table A2 in Appendix contains the list of data sources for the CPI divisions and sub-groups as defined by the GSS/COICOP manuals and used in this paper.

4.2 Coverage of Official Inflation and e-Inflation Methodologies

To ensure that the e-Inflation framework is comprehensive and tracks the official inflation rates, we compare their basket sizes and expenditure weight allocations. Table 1 shows that both approaches have the same basket size of 307 consumer items. However, while the GSS relies on data from 57 market centres to compute the official CPI, the e-Inflation framework leverages Big Data tools (robots) to extract data from 120 websites/online sources. Similarly, the e-Inflation framework uses about 500,000 price data points (which are averaged for the 307 items), while the official CPI statistics are based on 47,877 price data points. The approach used in collecting online price data complies with the data collection protocol of the GSS, which requires that price data be collected in the first week of the month and ordered in a hierarchy of 13 divisions, 44 groups, 98 classes, and 156 sub-classes.

The e-Inflation framework is capable of collecting price data every week for monetary policy decision-making and for general economic policy analysis. More importantly, relative to the traditional approach of compiling price data, the e-Inflation framework has the unique advantage of providing real-time CPI statistics as needed (see Table 1). Despite these advantages, the accuracy of e-Inflation statistics depends largely on the availability of current price data on the websites of the selected e-commerce shops and institutions. It is therefore

important that regular surveys are conducted to determine the frequency of website updates and to compare online prices with those from market centres and brick-and-mortar shops.

Table 1: Comparison of Coverage of Official Inflation and e-Inflation Methodologies

Dimension	GSS (Official)	e-Inflation
Size of basket	307	307
Number of markets/websites	57	120
Number of outlets	8,337	20,000 ²
Number of price data	47,877	500,000 (Big Data)
Data collection time	1 st week of the month	1 st week of the month
CPI/inflation release time	Middle of the ensuing month	≈ Real-time

Source: Authors' compilation, 2024

To ensure that the results obtained are a true representation of the official basket of goods and services, the study compares the allocation of expenditure weights using the e-Inflation framework and the traditional methodology for compiling price data. The GSS obtains consumer expenditure weights from the GLSS, which is conducted every five (5) years. The comparison in Table A1 in Appendix shows that the novel e-Inflation framework adopts the same expenditure weights as the official survey-based method by the GSS. This is to ensure that the proposed framework captures the same price (inflation) developments as the traditional (benchmark) methodology. For example, the total weight for the 15 sub-groups of the food and non-alcoholic beverages component is 42.7 percent, which tallies with that of the new framework. The cereals and cereal products sub-group has a weight of 7.8 percent under both the GSS approach and the e-Inflation framework. The sub-items include imported rice, local

² This consists of the URLs of 120 online shops.

rice, millet, maize, guinea corn (sorghum), wheat flour, corn dough, bread, biscuit, and instant noodles. Similarly, fish and other seafood sub-group has a total expenditure weight of 7.6 percent under both approaches. The main items constituting this sub-group are *tilapia*, sea fish, smoked herrings, river fish, tuna, mackerels, sardines, fried fish, shrimps, and crabs. Live animals, meat, and other parts of slaughtered land animals sub-group consisting of live poultry, snails, beef, goat meat, dog meat, and bushmeat, among others, has a weight of 3.2 percent under both methodologies.

The non-food CPI component of the benchmark methodology has a total weight of 57.3 percent, which matches that of the new framework. The transport division has the largest non-food expenditure weight at 10.5 percent. Individual items under this division include prices of new cars, used cars, motorcycles, bicycles, tyres, spark plugs, petrol, diesel, lubricants, driver's licensing fees, taxi fares, bus and *Trotro*³ fares, air travel, and postal services, among others. Another significant division is housing, water, electricity, gas, and other fuels, with a consumer expenditure weight of 10.2 percent. It is important to disclose, however, that it is currently difficult to find prices directly online for four items under this division, namely public toilet fees (with a weight of 0.28 percent), re-sold tap water (with a weight of 0.74 percent), charcoal (with a weight of 1.49 percent), and solid fuel (firewood) (with a weight of 0.34 percent). Therefore, these items are either estimated or collected from market centres. Payment for rent, roofing sheets, iron rods, cement prices, cement blocks, windows and doors, wood, and labour for maintenance are some of the specific consumer goods and services under this division. Also, the alcoholic beverages, tobacco, and narcotics division, with consumer goods such as *Akpeteshie*, bitters, spirits, gin, whisky, wine, beer, *pito*, cigarettes, and *kola nuts*, has a total weight of 3.9 percent, while the clothing and footwear division attracts a consumer expenditure

³ *Trotro* is a local terminology in Ghana used for privately owned share mini and long buses plying a fixed route.

share of 8.0 percent. Both methodologies have the same weight of 3.1 percent for the furnishings, household equipment, and routine maintenance division. Furthermore, the education services division, with an expenditure weight of 6.6 percent, has items such as Senior High School (SHS) Core English Language textbook, SHS Core Mathematics textbook, dictionary, stationery and drawing materials, pre-primary and primary education fees, private secondary school fees, post-secondary non-tertiary education fees, university fees, and education not definable by level.

5.0 Results and Discussion

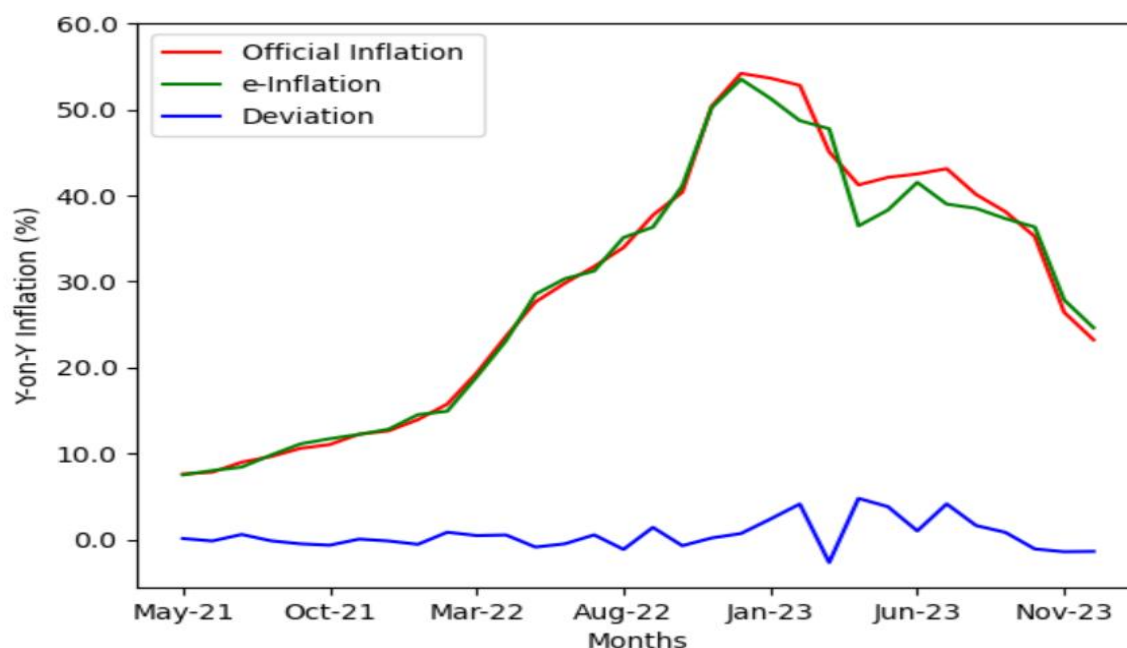
This section presents the results from the study, which began in May 2021. The results are compared with the official outturns (targets) produced and published by the GSS. The section also presents the results from some accuracy metrics, including mean deviation (error) and the Pearson correlation coefficient (r).

5.1 Comparison of Official Inflation and e-Inflation (Headline)

Figure 2 shows that official annual headline inflation increased sharply from 7.7 percent in May 2021 to 12.6 percent in December 2021 and subsequently from 37.2 percent in September 2022 to 54.1 percent in December 2022. However, disinflation started in January 2023, and inflation declined to 23.2 percent by December 2023, though it remained above the Bank's medium-term target of 8.0 ± 2 percent. Interestingly, the e-Inflation framework nowcasts inflation rates that closely matched the official figures released by the GSS, four weeks later. The results show that the novel e-Inflation framework is accurate in nowcasting headline inflation rates in Ghana. This observation is further confirmed by a Pearson correlation coefficient (r) of 0.9941 between the nowcast values and the outturns. Furthermore, based on the mean error metric, the deviation of e-Inflation nowcasts from the target (official inflation) was only 0.3684 percentage points. The results further establish that the e-Inflation framework

is dynamic enough to accurately capture inflation developments in a macroeconomic environment that is either stable or unstable. Overall, the novel e-Inflation framework provides an accurate and robust leading indicator of headline inflation in the country. The proposed framework is accurate in magnitude and direction relative to the target.

Figure 2: Official Inflation versus e-Inflation (Headline)



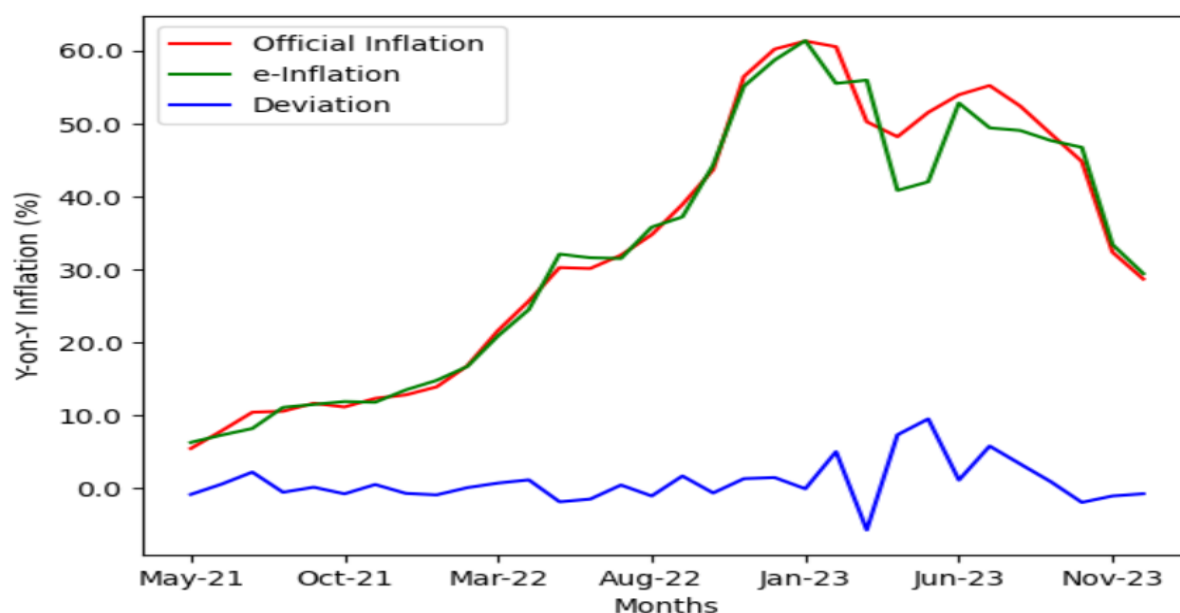
Source: Authors' Compilation

5.2 Comparison of Official Inflation and e-Inflation (Food)

Similarly, Figure 3 shows close co-movement between the two series with official food inflation rising sharply to 59.7 percent in December 2022 from 37.8 percent in September 2022, 12.8 percent in December 2021, and 5.4 percent in May 2021. The rate reached 61.0 percent in January 2023, but the disinflation period began in February 2023 and continued to December 2023 with some intermittent spikes. A visual inspection of the graph reveals that the e-Inflation framework nowcasts did not deviate significantly from the outturns released by the GSS. Furthermore, we estimate the degree of relationship between the two series using correlation analysis and obtain a coefficient of 0.9836, suggesting a near-perfect positive relationship.

Also, the mean deviation was 0.6909 percentage points. This suggests that the novel framework tracked the official series closely in both magnitude and direction. The implication is that the e-Inflation framework's food component has similarly strong predictive power to nowcast the official food inflation four weeks ahead of the official announcement by the Ghana Statistical Service.

Figure 3: Official Inflation versus e-Inflation (Food)



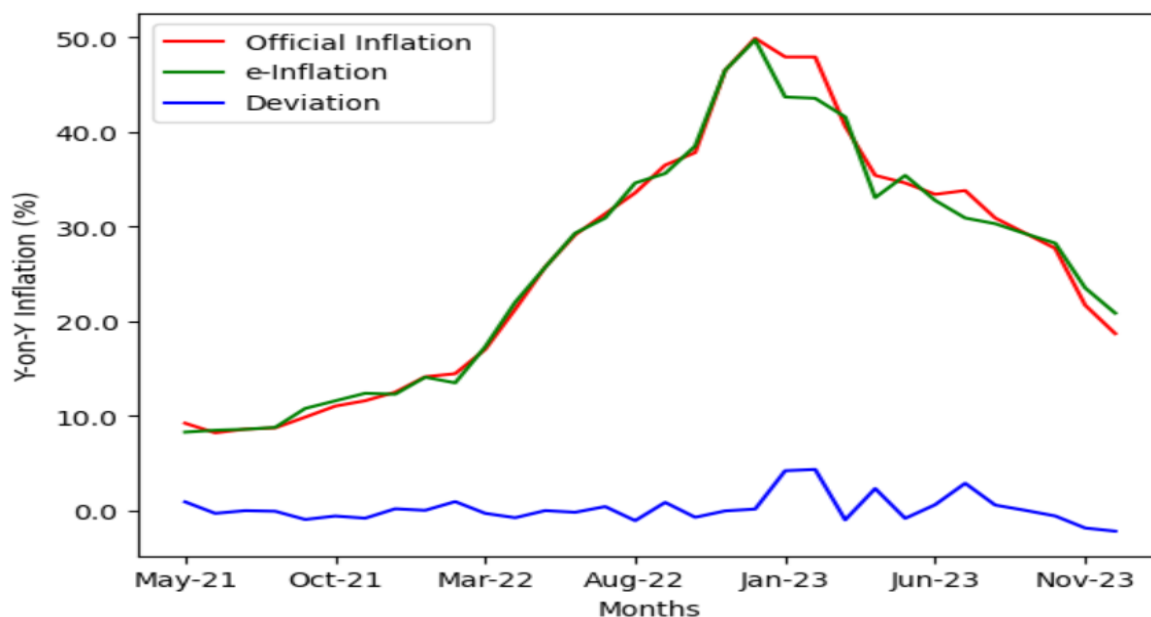
Source: Authors' Compilation

5.3 Comparison of Official Inflation and e-Inflation (Non-Food)

Officially, Ghana's non-food inflation rose to 12.5 percent in December 2021, up from 9.2 percent in May 2021 and further spiked to 49.9 percent in December 2022, up from 36.8 percent in September 2022. This upward trend, however, reversed in January 2023 when non-food inflation declined to 47.9 percent and slowed to 18.7 percent in December 2023. These outturns were largely nowcast by the e-Inflation framework weeks before they were announced, as depicted in Figure 4. By inspection, the e-Inflation framework appears to have accurately

predicted the official outturns, and this is confirmed by the high correlation coefficient between the two series ($r = 0.9944$). We also computed the nowcast error using the mean deviation, which was only 0.1375 percentage points. This suggests that the non-food component of the framework produced nowcasts deviate only slightly from official non-food inflation.

Figure 4: Official Inflation versus e-Inflation (Non-Food)



Source: Authors' Compilation

6.0 Conclusion and Policy Recommendations

This section presents the summary and conclusions drawn from the study. It also contains recommendations for institutions and policymakers on obtaining real-time CPI and inflation statistics to support timely policy formulation and implementation.

6.1 Conclusion

This paper leveraged Big Data and Artificial Intelligence (AI) to compute inflation in Ghana. The proposed e-Inflation framework provides policymakers with real-time price data to support the timely formulation and implementation of monetary policy. The process involved

identifying new (non-traditional) data sources for collecting consumer price data; designing a robotic and automated system for data collection, storage, processing, and computation; and comparing the resulting inflation nowcasts with the official outturns published by the Ghana Statistical Service (GSS). To facilitate a comprehensive comparison, e-Inflation was further decomposed into food and non-food inflation components.

The results demonstrate that e-Inflation is a highly accurate and robust real-time indicator of official headline, food, and non-food inflation rates in Ghana. This finding is supported by near-perfect correlation coefficients of 0.9941, 0.9836, and 0.9944 and statistically insignificant mean deviations of 0.3684, 0.6909, and 0.1375 percentage points for headline, food, and non-food inflation, respectively, between the official inflation and the corresponding e-Inflation inflation. These results reinforce the potential of the framework to provide timely and reliable indications of inflationary trends ahead of the release of official statistics.

The framework is particularly valuable during periods of heightened economic uncertainty, such as episodes of sharp currency depreciation and public health emergencies, including the COVID-19 pandemic, when policymakers require timely inflation estimates to inform effective and responsive policy decisions.

This study underscores the growing significance of Big Data and AI in macroeconomic analysis, particularly in supporting monetary policy formulation, implementation, and evaluation. It also represents the first attempt, in May 2021, to integrate AI-powered techniques into the monetary policy formulation process at the Bank of Ghana. By demonstrating the potential of the e-Inflation framework to generate timely and reliable inflation estimates, the study contributes to the emerging literature on AI-driven inflation measurement and establishes a foundation for further research and innovation in macroeconomic analysis. These

contributions have practical implications for strengthening inflation measurement, enhancing macroeconomic nowcasting and forecasting, and promoting evidence-based policymaking in Ghana and other economies.

6.2 Policy Recommendations

Based on the findings above, the following recommendations are made for consideration:

- Given that the e-Inflation framework has proven to be cost-efficient, timely, robust, and, importantly, accurate, central banks, national statistical offices, and other research institutions are encouraged to adopt it for real-time inflation-related policy decision-making.
- The IMF should provide technical assistance and training to ministries, central banks, and statistical agencies in developing countries on Artificial Intelligence (AI) and data science. Such support would facilitate the implementation of these projects and enhance predictive capabilities.
- Development partners interested in strengthening statistical capacity and digital systems in Africa should provide the resources needed to implement this framework across countries participating in the Strategy for the Harmonisation of Statistics in Africa (SHaSA) initiative.
- To support the implementation of the single currency in the Economic Community of West African States (ECOWAS), it is recommended that the West African Monetary Institute (WAMI), the West African Monetary Agency (WAMA), the West African Institute for Financial and Economic Management (WAIFEM), and the ECOWAS Commission collaborate to develop and replicate the proposed methodology across all member states.

- Central banks and national statistical offices should build expertise in data science, Artificial Intelligence, and Big Data analytics to leverage modern techniques, tools, and technologies for more accurate macroeconomic and social indicator measurement.
- Governments should accelerate digital transformation initiatives and strengthen digital infrastructure to promote e-commerce, digital payments, and broader participation in the digital economy.

6.3 Limitations and Mitigating Measures

The main challenge encountered during the implementation of the e-Inflation framework was the risk of scraping outdated price information from some websites, which could have affected the accuracy and reliability of the inflation estimates. In addition, some websites restricted or blocked web-scraping activities, making it difficult to obtain the data required for the calculation of inflation. To mitigate these challenges, efforts were made to identify reliable data sources and validate the consistency of the collected price information. Future implementations could benefit from establishing collaborative relationships with e-commerce platform operators to facilitate access to up-to-date pricing data, enable periodic comparisons between online and brick-and-mortar prices, and reduce restrictions on data collection activities. Furthermore, the applicability of the framework depends on the level of digitalisation and the maturity of the e-commerce ecosystem within an economy. As a result, economies with limited digital infrastructure, low internet penetration, or less developed online retail markets may face difficulties in implementing the framework in its entirety. However, it can be deployed in phases by supplementing survey price data with available online data.

6.4 Areas for Further Research

Future research should extend the nowcasting framework employed in this study to other key macroeconomic variables, such as GDP and unemployment, to strengthen macroeconomic

policy formulation, implementation, and evaluation. Additionally, leveraging machine learning (ML) algorithms to forecast price dynamics could enhance inflation projections over the medium- to long-term.

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APPENDIX

Table A1: Allocation of Consumer Expenditure Weights to Divisions/Sub-Groups

Item Descriptions	Consumer Expenditure Weight	
	Official CPI	e-CPI ⁴
FOOD AND NON-ALCOHOLIC BEVERAGES	42.7	42.7
Cereals and Cereal Products	7.8	7.8
Live Animals, Meat and Other Parts of Slaughtered Land Animals	3.2	3.2
Fish and Other Seafood	7.6	7.6
Milk, Other Dairy Products and Eggs	1.2	1.2
Oils and Fats	1.2	1.2
Fruits and Nuts	1.1	1.1

⁴ Technically, the e-Inflation framework can collect price data covering an overall expenditure weight of 97.15, comprising 42.70 for the food component and 54.45 for the non-food component. The remaining four items, with a combined expenditure weight of 2.85, are surveyed at market centres or estimated using anecdotal information obtained from the internet. These four items fall under the Housing, Water, Electricity, Gas and Other Fuels division and comprise public toilet fees (weight = 0.28), re-sold tap water in buckets, barrels or jerrycans (weight = 0.74), charcoal (weight = 1.49), and solid fuel (weight = 0.34).

Vegetables, Tubers, Plantains, Cooking Bananas and Pulses	9.5	9.5
Sugar, Confectionery and Desserts	1.0	1.0
Ready-Made Food and Other Food Products n.e.c.	8.0	8.0
Fruit and Vegetable Juices	0.2	0.2
Coffee and Coffee Substitutes	0.1	0.1
Tea, Maté and Other Plant Products for Infusion	0.1	0.1
Cocoa Drinks	0.0	0.0
Water	1.1	1.1
Soft Drinks	0.6	0.6
NON-FOOD	57.3	57.3
Alcoholic Beverages, Tobacco and Narcotics	3.9	3.9
Clothing and Footwear	8.0	8.0
Housing, Water, Electricity, Gas and Other Fuels	10.2	10.2
Furnishings, Household Equipment and Routine Maintenance	3.1	3.1
Health	0.7	0.7

Transport	10.5	10.5
Information and Communication	3.6	3.6
Recreation, Sport and Culture	3.5	3.5
Education Services	6.6	6.6
Restaurants and Accommodation Services	4.3	4.3
Insurance and Financial Services	0.4	0.4
Personal Care, Social Protection and Miscellaneous Goods and Services	2.5	2.5
OVERALL WEIGHT	100.0	100.0

Source: Extracted from the GSS Statistical Bulletin, 2024

Table A2: Data Sources for CPI Divisions and Sub-Groups by the COICOP Manual

No.	Division/Item Classification	Data Sources (Pipelines)
1. FOOD AND NON-ALCOHOLIC BEVERAGES		
1.1	Cereals and cereal products	Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Jumia Ghana (https://www.jumia.com.gh/), Ghana Fruit Cart (https://ghfruit.com/), GHBasket (https://ghbasket.com/), Pesewa Shop (https://pesewashop.com/), Konzooom (https://konzooom.shop/), Cape Coast Mall (https://capecoastmall.com/?v=6848ae6f8e78), Reapp (https://reapp.com.gh/), Foodstuff Home (https://foodstuffhome.com/shop/), Nkulenu Industries Limited (https://nkulenu.com/shop/), Akwaaba Mart (https://akwaabamartgh.com/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
1.2	Live animals, meat and other parts of slaughtered land animals	Maxmart Family Shopping Centre (https://maxmartonline.com/), Tonaton (https://tonaton.com/), Jiji Ghana (https://jiji.com.gh/), Plendify (https://www.plendify.com/),
1.3	Fish and other seafood	Tonaton (https://tonaton.com/), Jiji Ghana (https://jiji.com.gh/)
1.4	Milk, other dairy products and eggs	Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Jumia Ghana (https://www.jumia.com.gh/), Ghana Fruit Cart (https://ghfruit.com/), GHBasket (https://ghbasket.com/), Eden Tree (https://edentreegh.com/), Tonaton (https://tonaton.com/), The Farmer's Market (https://thefarmersmarket.odoo.com/), FarmersHausGh (https://farmershausgh.com/), Pesewa Shop (https://pesewashop.com/), Konzooom (https://konzooom.shop/), Cape Coast Mall (https://capecoastmall.com/?v=6848ae6f8e78), Reapp (https://reapp.com.gh/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
1.5	Oils and fats	Ghana Fruit Cart (https://ghfruit.com/), Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/),

		Maxmart Family Shopping Centre (https://maxmartonline.com/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
1.6	Fruits and nuts	Eden Tree (https://edentreegh.com/), Ghana Fruit Cart (https://ghfruit.com/), Tonaton (https://tonaton.com/), The Farmer's Market (https://thefarmersmarket.odoo.com/), FarmersHausGh (https://farmershausgh.com/)
1.7	Vegetables, tubers, plantains, cooking bananas and pulses	Ghana Fruit Cart (https://ghfruit.com/), The Farmer's Market (https://thefarmersmarket.odoo.com/), FarmersHausGh (https://farmershausgh.com/), Eden Tree (https://edentreegh.com/), Tonaton (https://tonaton.com/),
1.8	Sugar, confectionery and desserts	Melcom (https://melcom.com/), Ghana Fruit Cart (https://ghfruit.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
1.9	Ready-made food and other food products n.e.c.	Glovo (https://glovoapp.com/gh/en/accra/), Foodstuff Home (https://foodstuffhome.com/shop/), Nkulenu (https://nkulenu.com/shop/), Jiji Ghana (https://jiji.com.gh/), Tonaton (https://tonaton.com/), Bolt (https://bolt.eu/en-gh/food/)
1.10	Fruit and vegetable juices	Ghana Fruit Cart (https://ghfruit.com/), The Farmer's Market (https://thefarmersmarket.odoo.com/), FarmersHausGh (https://farmershausgh.com/)
1.11	Coffee and coffee substitutes	Melcom (https://melcom.com/), Ghana Fruit Cart (https://ghfruit.com/), Plendify (https://www.plendify.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/)
1.12	Tea, maté and other plant products for infusion	Ghana Fruit Cart (https://ghfruit.com/), Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
1.13	Cocoa drinks	Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Ghana Fruit Cart (https://ghfruit.com/), Palace Mall Online Shopping (https://palacesuperstores.com/), Plendify (https://www.plendify.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/)

1.14	Water	Melcom (https://melcom.com/), Ghana Fruit Cart (https://ghfruit.com/), Shoprite (https://www.shoprite.com.gh/), Plendify (https://www.plendify.com/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/)
1.15	Soft drinks	Melcom (https://melcom.com/), Shoprite (https://www.shoprite.com.gh/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Ghana Fruit Cart (https://ghfruit.com/), Plendify (https://www.plendify.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
2. NON-FOOD		
2.1	Alcoholic beverages, tobacco and narcotics	Melcom (https://melcom.com/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Mega Disc Store (https://mega-gh.store/), Ghana Flag Supermarket (https://ghanaflagsupermarket.com/), Cape Coast Mall (https://capecoastmall.com/?v=6848ae6f8e78), Shopbeta (https://shopbeta.com.gh/), MyGhanaMarket.com (https://myghmarket.com/shop/)
2.2	Clothing and footwear	Horseman Shoes (https://horsemanshoes.com/), Jumia Ghana (https://www.jumia.com.gh/), Jiji Ghana (https://jiji.com.gh/), Tonaton (https://tonaton.com/), Loozap (https://gh.loozap.com/), MyGhMarket (https://myghmarket.com/), BayGH (https://www.baygh.com/), Ishtari Ghana (https://www.ishtari.com.gh/), Trade Africa Online (https://v2.tradeafricaonline.com/)
2.3	Housing, water, electricity, gas and other fuels	MeQasa (https://meqasa.com/), Tonaton (https://tonaton.com/), Jiji Ghana (https://jiji.com.gh/), National Petroleum Authority (https://npa.gov.gh/), Public Utilities Regulatory Authority (https://www.purc.com.gh/), Electricity Company of Ghana (https://ecg.com.gh/index.php/en/), Ghana Water Company (https://www.gwcl.com.gh/), Ghana Oil Company PLC (https://www.goil.com.gh/), Norfram (https://www.nortramretail.com/), BayGH (https://www.baygh.com/)
2.4 2.5	Furnishing, household equipment and routine maintenance	MyGhMarket (https://myghmarket.com/), Electromart Ghana (https://www.electromart.com.gh/), UNA Agencies (https://www.unaagencies.com/), Jumia Ghana (https://www.jumia.com.gh/), Jiji Ghana (https://jiji.com.gh/), Tonaton (https://tonaton.com/), Lawvis Timbers (https://lawvis-timbers.business.site/), Manuel Johnson Hardware (https://manueljohnsongh.com/), Melcom (https://melcom.com/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart

		Family Shopping Centre (https://maxmartonline.com/), Soja Group (https://sojagroup.com/), MyGhanaMarket.com (https://myghmarket.com/shop/), Diamond Energy (https://diamondenergygh.com/), BayGH (https://www.baygh.com/), Deus (https://deus.com.gh/), Ishtari Ghana (https://www.ishtari.com.gh/), Goodluck Africa (https://goodluckafrica.com/), Get4Less Ghana (https://get4lessghana.com/), Trade Africa Online (https://v2.tradeafricaonline.com/)
2.6	Health	National Health Insurance Authority (https://www.nhis.gov.gh/nhia), AddPharma Retail (https://addpharma4u.com/), New Crystal Health (https://obm.newcrystalhealth.org/), Country Medical Pharmacy (https://countrymedicalpharmacy.com/), Health Online (https://healthonlineghana.com/), Ministry of Finance (https://mofep.gov.gh/), BayGH (https://www.baygh.com/), MyGhanaMarket.com (https://myghmarket.com/shop/)
2.7	Transport	State Transport Company (https://stc.gov.gh/), Toyota Ghana (https://www.toyotaghana.com/index.php), cars45 (https://www.cars45.com.gh/), Tonaton (https://tonaton.com/), Autochek (https://autochek.africa/welcome), GPRTU (via online news portals https://www.ghanaweb.com/ and https://www.myjoyonline.com/), Abossey Okai (https://www.abosseyokaihub.com/shop-all), Passion Air (https://flypassionair.com/), Cari Africa (https://cars.gh.cari.africa/), Stevens Driving School (https://stevensdrivingschoolgh.com/)
2.8	Information and communication	MTN (https://mtn.com.gh/), Telecel Ghana (https://telecel.com.gh/), Compu Ghana (https://compughana.com/), Franko Trading Enterprise (https://frankotrading.com/), MyGhanaMarket.com (https://myghmarket.com/shop/), Telefonika (https://telefonika.com/), Melcom (https://melcom.com/), BayGH (https://www.baygh.com/)
2.9	Recreation and culture	Ghana Tourism Authority (https://ghana.travel/), National Theatre (https://www.nationaltheatre.gov.gh/), Ministry of Finance (https://mofep.gov.gh/)
2.10	Education services	Kingdom Books and Stationery (https://www.kingdomgh.com/), Continental Books and Stationery Services (https://continentalbooksgh.com/), University of Ghana (https://www.ug.edu.gh/), University of Cape Coast (https://ucc.edu.gh/), University for Development Studies (https://www.uds.edu.gh/), Central University (https://www.central.edu.gh/), Ho Technical University (https://htu.edu.gh/), Takoradi Technical University (https://ttu.edu.gh/), Accra Technical University (https://atu.edu.gh/),

		Nursing Training College – Ho (https://www.ntcho.edu.gh/), Accra College of Education (https://acce.edu.gh/), Flowers Gay School-Cape Coast (https://fgs.edu.gh/), and Chopbox (https://www.chopboxonline.com/)
2.11	Restaurants and accommodation services	Freedom Hotel – Ho (https://www.freedomhotel.com.gh/fh/), Modern City Hotel-Tamale (https://www.moderncityhotelgh.com/), Bookings (https://www.google.com/search?q=hotels+with+ratesandoq=hotels+with+ratesandgslcrp=EgZjaHJvbWUyBggAEEUYOTIHCAEQABiABDIHCAIQABiABDIHCAMQABiABDIHCAQQABiABDIHCAUQABiABDIHCAYQABiABDIHCACQABiABDIHCAGQABiABDIHCAkQABiABNIBCDcwMTBqMGo5qAIAsAIAandsourceid=chromeandie=UTF-8)
2.12	Insurance and financial services	MTN (https://mtn.com.gh/), Telecel Ghana (https://telecel.com.gh/), National Insurance Commission (https://nicgh.org/), State Insurance Company (https://www.sic-gh.com/main/), Enterprise Life Insurance (https://mobilife.enterprisegroup.net.gh/), Prudential Life Insurance Ghana (https://www.prudential.com.gh/), Phoenix Insurance (https://phoenixinsurancegh.com/), Nationwide Medical Insurance (https://nationwidemh.com/), Premier Health Insurance (https://premierhealthinsurance.org/), Vanguard Assurance Company (https://www.vanguardassurance.com/)
2.13	Personal care, social protection and miscellaneous goods and services	Melcom (https://melcom.com/), Palace Mall Online Shopping (https://palacesuperstores.com/), Maxmart Family Shopping Centre (https://maxmartonline.com/), Tonaton (https://tonaton.com/), Ghana Bar Association (https://ghanabar.org/), Jiji Ghana (https://jiji.com.gh/), BayGH (https://www.baygh.com/)

Source: Authors' compilation