South African Reserve Bank

Working Paper Series

WP/16/07

Decomposing inflation using micro-price-level data: Sticky-price inflation

Franz Ruch, Neil Rankin and Stan du Plessis

Authorised for distribution by Chris Loewald

June 2016

South African Reserve Bank

South African Reserve Bank Working Papers can be found at
http://www.resbank.co.za/Research/ResearchPapers/WorkingPapers/Pages/WorkingPapers-Home.aspx

Enquiries

Head: Economic Research and Statistics
Department South African Reserve Bank
P O Box 427
Pretoria 0001

Tel. no.: +27 12 313-3911
0861 12 SARB (0861 12 7272)

Decomposing inflation using micro-price -level data: Sticky-price inflation

Franz Ruch* Neil Rankin † Stan du Plessis‡

June 22, 2016

Abstract

Some prices are stickier than others. In South Africa (SA), consumer prices on average change every five months; with the most frequent prices changing every month and the least frequent changing every 15 months. Firms that change prices less frequently generally need to take account of the likely path of future inflation when setting these prices if they want to maximise profits. Therefore, prices that are sticky contain more forward-looking information and can be exploited to uncover inflation expectations and underlying, or core, inflation. Using micro-price data this paper decomposes goods inflation into a flexible- and sticky-price inflation measure for South Africa at a product level from 2008 to 2015. Flexible-price inflation is more volatile, less persistent, and contributes the most to volatility in overall goods inflation. Sticky-price inflation is more persistent, less volatile and correlates well with future goods inflation. The advantage of sticky-price inflation is that it grounds the concept of underlying inflation into the theoretical framework currently used by central banks to make policy decisions and what is considered optimal policy, making it an ideal core inflation candidate for the central bank. We provide an initial analysis of the appeal of sticky-price inflation comparing it to a number of other core inflation measures including the common exclusion-based measure currently used as well as extend versions of trimmed means and persistence-weighted measures.

JEL Classification: E31, D40, C55

Keywords: sticky-price inflation, core inflation, frequency of price changes; pricing microdata; decomposing inflation

Corresponding author's e-mail address: franz.ruch@resbank.co.za

---

* *Corresponding author*. South African Reserve Bank, PO Box 427, Pretoria, South Africa, 0001. Email: franz.ruch@resbank.co.za. The author would like to thank Marietjie Bennett, Patrick Kelly and Joe de Beer at Statistics South Africa for providing the micro-data that made this paper possible.

† Department of Economics, Stellenbosch University

‡ Department of Economics, Stellenbosch University

Non-technical summary

Some prices are stickier than others. In South Africa (SA), consumer prices on average change every five months; with the most frequent prices changing every month and the least frequent changing every 15 months. Firms that change prices less often generally need to take account of the likely path of future inflation when setting these prices if they want to maximise profits. For example, when an insurance company sets medical aid prices on an annual basis it needs to decide what it expects inflation to be over that period to ensure that its price is optimal. In contrast, when petrol prices change on a monthly basis, these changes are driven by contemporaneous developments in the exchange rate or the international price of oil. Therefore, prices that are sticky contain more forward-looking information and can be exploited to uncover inflation expectations and underlying, or core, inflation.

Determining whether a product's price is considered sticky or flexible requires the direct observations of prices and not just the aggregate indices. This is because aggregate data suffers from a bias which masks the true flexibility of products. This information became available in the mid-2000s when Statistics South Africa allowed researchers to analyse the micro-price data underlying the consumer price index. With this information we can distinguish between the degree of price flexibility of products.

Using the data behind the CPI as well as the intuition that sticky prices contain more forward-looking information this paper decomposes goods inflation into a sticky-price and flexible-price inflation rate. Flexible-price inflation is more volatile than overall goods inflation and sticky-price goods inflation, and accounts for the majority of the volatility in overall goods inflation. Sticky-price inflation is more persistent and less volatile than overall goods inflation and the flexible-price inflation measure. It is also well correlated with future inflation, a vital property of a core inflation measure.

This paper also argues that the sticky-price inflation measure should be considered by the central bank to be its target variable. This is because it fits directly into the theory and models that underpin modern inflation targeting used by central banks to do analysis. It also embraces the theory of forward-looking prices and the idea that firms who do not change prices often need to take account of their inflation expectations in order to maximise profits. Finally, it is constructed at the micro-price level accounting for important heterogeneity that is found in how often prices change and by how much.

Contents

List of Tables

List of Figures

1 Introduction

Some prices are stickier than others. In South Africa (SA), consumer prices on average change every five months; with the most frequent prices changing every month and the least frequent changing every 15 months (Creamer et al., 2012). Firms that change prices less often generally need to take account of the likely path of future inflation when setting these prices if they want to maximise profits. For example, when an insurance company sets medical aid prices on an annual basis it needs to decide what it expects inflation to be over that period to ensure that its price is optimal. In contrast, when petrol prices change on a monthly basis, these changes are driven by contemporaneous developments in the exchange rate or the international price of oil. Therefore, prices that are sticky contain more forward-looking information and can be exploited to uncover inflation expectations and underlying, or core, inflation.

It wasn't until the advent of micro-price data work starting with Bils and Klenow (2004) in the United States (US), and Creamer and Rankin (2008) and Ruch et al. (2016) in SA that we are able to determine the frequency of price changes for the entire consumer inflation basket; i.e. determine the extent of price persistence. With the micro-price data this paper decomposes goods inflation into a flexible- and sticky-price inflation measure for SA from 2008 to 2015.

The advantage of sticky-price inflation is that it grounds the concept of underlying inflation into the theoretical framework currently used by central banks to make policy decisions, and what is considered optimal policy. According to Goodfriend (2007), monetary policy reached a pre-crisis consensus that core inflation rather than headline inflation was the best nominal anchor for a central bank. Core inflation is more stable and would serve as a better anchor for inflation expectations. New Keynesian models such as Clarida et al. (2002), Aoki (2001), and Bodenstein et al. (2008) show that targeting core (or domestic) inflation rather than headline CPI leads to households maximising their welfare. Walsh (2009) shows more generally that inflation leads to the highest welfare loss in sectors where prices are more sticky (or more persistent) with few welfare costs when relative price shocks dissipate quickly. This means that targeting a measure of underlying inflation that is defined by the persistence of prices, such as a sticky-price inflation measure, is optimal.

The contribution of this paper is fourfold. First, we use micro-price data in SA to decompose goods inflation into flexible- and sticky-price inflation and define the properties of each. Second, we show that it is possible to build a measure of underlying inflation based on the sticky-price inflation measure that is both theoretically appealing and fits into the type of modeling and policy analysis done at central banks. By doing this we add to the argument put forward in Du Plessis (2014) that core inflation should be actively considered as the best nominal anchor for an emerging market central bank. Third, we use the dimensionality available at the product level to improve two important core inflation measures in the existing literature that are considered to be good alternatives to the more common exclusion-based measure: persistence-weighted core inflation (first developed in SA by Rangasamy, 2009) and trimmed means inflation. Fourth, we compare sticky-price inflation to our candidate core inflation measures to provide an initial analysis of relative historical performance. Future work should focus on extending the sample period and include services data to achieve a full exposition of the merits of sticky-price inflation.

The paper proceeds as follows: section 2 contextualises this paper in the current literature on core inflation and the theory of forward-looking prices; section 3 decomposes goods inflation into a sticky- and flexible price index; section 4 improves existing measures of core inflation; section 5 provides an initial analysis of the relative performance (in-sample) of the core inflation measures and section 6 concludes.

2 Literature Review

2.1 Core inflation measures in the literature

There are two broad definitions of core inflation expounded in Roger (1998). First, as a 'persistence' concept building on earlier work by Friedman et al. (1963). Friedman et al. (1963, pg. 25) highlights two distinct characteristics of inflation "...between a steady inflation, one that proceeds at a more or less constant rate, and an intermittent inflation, one that proceeds by fits and starts..." the former being core inflation. Second, as a 'generalised' concept as defined initially by Eckstein (1981, pg. 7) as "...the trend increase of the cost of the factors of production" which "...originates in the long-term expectations of inflation in the minds of households and businesses, in the contractual arrangements which sustain the wage-price momentum, and in the tax system".

The unobservable nature of core inflation have seen exclusion-, model- and statistical-based methods all developed in order to estimate a practical measure of core inflation (see for example Cogley, 2002; Cristadoro et al., 2005; Quah and Vahey, 1995; and Bryan and Cecchetti, 1993).

The first and most common approach is an exclusion-based measure that is used today to define core inflation as "excluding food and energy". It has its origins in the 1970s when the US economy faced volatile shocks to both food - due to significant foreign demand and drought - and energy prices - from restrictions to oil supply introduced by the Organization for Petroleum Exporting Countries (OPEC). Detmeister (2012) provides three charateristics that define an exclusion-based index: the excluded items are pre-determined, they do not change often, and the relative weights used are the same as in the overall headline price index. Exclusion-based measures are typically supported by arguments that they are thought to be more easily understood by the general public and can be replicated. The disadvantage of these measures is that they exclude entire components of inflation which may include vital information regarding the underlying trend of inflation.

The second broad approach to the measurement of core inflation is the statistical approach. One, of a range of statistical techniques is used to remove transitory noise from (or smooth) the inflation series (see Blignaut et al., 2009; Rangasamy, 2009; Ruch and Bester, 2013; and Du Plessis et al., 2015). Statistical methods has generated the most work on core inflation using many different techniques, mostly filters. A popular and promising measure is the trimmed means approach by Bryan and Cecchetti (1994). This measure aligns well to inflation as a monetary phenomenon and is likely to better represent underlying inflation by taking into account the positive skewness in prices. An important disadvantage of the trimmed means measure from a theoretical perspective is its inability to distinguish between "transient and persistent extreme price movements" (Wynne, 2008). In SA, Blignaut et al. (2009) and Du Plessis (2014) calculate a number of trimmed means measures. The popularity of this type of core inflation measure has meant that StatsSA now includes a trimmed means which trims five per cent off each tail at the product group level.

To address the inability of trimmed means to identify persistent price changes, Cutler (2001) introduces a persistence-weighted core inflation measure. The measure links underlying inflation to a 'persistence' concept as defined by Friedman et al. (1963) and embraces Woodford's view that "central banks should target a measure of "core" inflation that places greater weight on those prices that are stickier". Components of inflation are weighted based on their persistence, defined here by the autoregressive coefficient. Rangasamy (2009) implemented a persistence-weighted core inflation measure for SA.

The third approach to the measurement of core inflation involves the use of an economic model based on underlying theory such as in Quah and Vahey (1995) or Cristadoro et al. (2005). These approaches add additional information, with economic interactions as well as feedback loops, to inform the path of core inflation. Core inflation is defined in Quah and Vahey (1995) as "that component of measured inflation that has no medium- to long-run impact on real output" which corresponds to Friedman's definition of core inflation. Model-based approaches are appealing since the core inflation measure fits into a framework that ensures consistency in analysing economic interactions. However, they do not escape problems of incorrect model specification, identification and uncertainty.

The various alternative core inflation measures suggest criteria is needed to establish which is 'best'. Clark (2001) argues that policymakers and analysts have reached consensus on the defining properties of a good measure of core inflation. This includes tracking the components of inflation that persist for several years, help predict future headline inflation over the medium term, be less volatile, and simple. One important exclusion from this list is that it is grounded in theory used by central banks. The appeal of this theoretical grounding is threefold. First, although many techniques can remove the higher frequency movements in headline inflation, these measures remain atheoretic and can only be judged based on the sample available. Second, aligning core inflation with theory ensures that the right identifying assumptions are used when building a practical measure of core inflation. Third, the normative objective function of the central bank is defined by core inflation in a welfare theoretic framework.

There are methods already developed that fit theory well, the most successful being model-based definitions such as Quah and Vahey (1995) and persistence-based measures such as Rangasamy (2009). A flaw of model based measures such as Quah and Vahey (1995) is that defining core inflation is done at a macro level allowing only a limited set of economic relationships, such as a short-run Phillips curve and money neutrality in the long-run, in a single sector. Prices are empirically, however, strongly heterogeneous both in the magnitude and frequency of price changes. One possible solution to this is to define core inflation from the perspective of pricing behaviour at a micro-price level as is done in Bryan et al. (2010), Reiff and Várhegyi (2013) and Millard and O'Grady (2012). Sticky-price inflation as defined from a micro-price product level accounts for the heterogeneity that exists and builds its foundation in a theory of forward-looking prices and optimal monetary policy.

2.2 Monetary policy and core inflation as the nominal anchor

Underlying or core inflation is a cornerstone of modern monetary policy. It represents the adequate nominal anchor, in addition to an adequate instrument and credibility, to achieve the goal of price stability. According to Goodfriend (2007), monetary policy reached a pre-crisis consensus that core inflation rather than headline inflation was the best nominal anchor for a central bank. Core inflation is more stable and would serve as a better anchor for inflation expectations. Goodfriend (2007, pg. 62) was referring to a conventional definition of core inflation - "inflation that excludes volatile prices of such goods as food and oil".

Part of reaching the consensus on core inflation was the development of the theory which showed that core inflation rather than headline inflation led to households maximising their welfare. This "consensus" model with features that include monopolistically competitive firms who set prices in a staggered way, rational expectations, households maximising utility, and a prominent role for monetary policy was first expounded in Goodfriend and King (1997) and Clarida et al. (1999). The rationale behind not targeting headline inflation is that this would require a response to relative price shocks that unnecessarily compounds output losses, i.e. force the sticky-price sector to adjust through lower demand and hence decrease prices and wages. Relative price shocks from flexible products such as oil can also be large meaning that the output-inflation trade-off would be costly. This result is echoed in Aoki (2001) and Bodenstein et al. (2008).

The optimality of core inflation is not tied to the New Keynesian paradigm but is a general result in welfare economics. Walsh (2009) shows that inflation leads to the highest welfare loss in sectors where prices are more sticky (or more persistent) with few welfare costs when relative price shocks dissipate quickly. Walsh (2009, pg. 30) stated that "[s]ince food and energy prices display little stickiness, responding quickly to shifts in demand and supply, there is a strong case for excluding them from the inflation rate the central bank attempts to control".

Despite the theoretical appeal of core inflation as the optimal nominal anchor, only Thailand and Norway still target it. The reason for this is that a number of practical arguments for headline inflation, and against core, have been made. These arguments include the welfare foundation of the cost of living index, the supposed communication advantage of headline inflation, its use as a reference rate for wage determination and inflation expectations, the frequency of publication by an independent authority, and the large number of alternative core inflation measures.

The most significant argument endorsing headline inflation comes from its foundation in welfare economics, that a central bank should be concerned with the variable that affects people's lives. This point is rebutted in Du Plessis (2014) who states that the claim that headline CPI is the ultimate goal variable of a central bank does not take account of the outcomes a central bank can control. As stated often in many different forms (see for example Wynne, 1999; Bernanke, 2001; Cecchetti and Wynne, 2003; and Walsh, 2009) a central bank should be concerned with monetary inflation which excludes relative price shocks. Central banks can do nothing about relative price shocks and responding to these shocks is likely to create more volatility (Cecchetti and Wynne, 2003). Similarly, central banks have adopted a theoretic framework (in Clarida et al., 1999) in which to operate that points to the supremacy of core inflation from a welfare maximising perspective.

A practical argument for headline inflation is its supposed communications advantage (see for example Svensson, 1999; Mishkin, 2007; and Roger, 2009). The argument states that headline CPI inflation, which has become a convention when thinking about inflation, is easily understood and accepted by the general public. It is also used in price and wage determination. Du Plessis (2014) argues that it is unlikely that targeting core inflation would undermine the South African Reserve Banks (SARBs) communication strategy, citing recent academic work by Rossouw and Joubert (2005) and Rossouw and Padayachee (2009) suggesting little evidence of the publics understanding of headline inflation or its acceptance as a proxy of inflation. Bernanke (2001, pg. 322) argue that the exclusion-based measures do not complicate communication to the public but rather improves it by showing the "public that not every shock that raises prices will lead to a permanent increase in inflation, and that short-term changes in inflation resulting from supply shocks will be treated differently from changes driven by aggregate demand". A more recent strand of literature looking at inflation forecast disagreement shows that significant differences in inflation forecasts are explained by the gap between a conventional definition of core inflation and headline inflation, the relative prices of food and energy (Siklos et al., 2016). By targeting a core inflation measure a substantial degree of disagreement in inflation forecasts can be discarded improving monetary policy implementation.

A criticism of targeting headline inflation is that it is subject to large and volatile relative price shocks from food and energy prices as well as imported inflation. Interest rates are not able to deal with these relative price movements opening monetary policy up to the 'blunt tool' argument. This also risks a central banks credibility if it is unable to communicate clearly the reasons for a breach of the inflation target from supply-side shocks. Food and energy prices explain almost 40 per cent of headline inflation in SA since the beginning of inflation targeting and generally responsible for breaches of the 3-6 per cent target range. When an economy faces relative price shocks of this magnitude the desire to anchor inflation expectations to a reference measure such as headline CPI can be dangerous. This can lead to inflation expectations becoming unanchored. Of course SARB implements its mandate in a fully flexible manner highlighting core inflation when relative price shocks are significant (Kahn, 2009). In essence targeting core inflation when relative price shocks are present.

An argument against targeting core inflation comes from Walsh (2011) and Rangasamy (2011) who state that excluding food from core inflation misspecifies underlying inflation prompting higher inflation expectations and slow policy responses. This outcome is linked to two results. First, not all food is created equal and hence excluding all food is an undesirable property of core inflation. Second, food inflation plays a significant role in inflation expectations and therefore provides important signals to policymakers. The second point is particularly relevant when second-round effects are present. The dilemma raised by Walsh (2011) and Rangasamy (2011) can be solved by moving away from the conventional exclusion-based definition of core inflation to one that embraces a appropriately theoretical definition. Similarly, if second-round effects are present and well understood, responding to forecasts of core inflation will ensure the central bank adequately responds to changing inflation expectations.

Goodfriend (2007) and Walsh (2009) used the theoretical argument of core inflation to focus on the common exclusion-based inflation measure that most central banks, including SA, use when dealing with how policy will respond to relative price shocks. Walsh (2009, pg. 30) stated that "[s]ince food and energy prices display little stickiness, responding quickly to shifts in demand and supply, there is a strong case for excluding them from the inflation rate the central bank attempts to control." But highlighting only food and energy with no appreciation for all prices that may 'display little stickiness' is too narrow with little theoretical foundation to be an optimal core inflation measure. Woodford (2003, pg. 14) states that "central banks should target a measure of "core" inflation that places greater weight on those prices that are stickier". Therefore using persistence defined as the frequency of price changes at the product level can more accurately capture the theoretical argument for why core inflation is a better nominal anchor. This measure also takes account of the heterogeneity that exists at the product level.

2.3 Theory of forward-looking prices

To show that forward-looking prices contain information about a firms inflation expectations, we start with a simple model of consumers and producers maximising utility and profits. Consumers maximise utility subject to a budget constraint yielding a fimiliar Dixit-Stiglitz demand function such that:

$$C_t(i) = \frac{P_t(i)}{P_t}^{-\theta} C_t \tag{1}$$

where $C_t(i)$ is the demand for product i produced by firm i, $C_t = \int_0^1 (C_t(i)^{1-\theta})^{\frac{1}{\theta-1}}$ is aggregate consumption, $P_t(i)$ is the nominal price of product i, and P_t is the aggregate price level.

Heterogeneous firms operate in a monopolistically competitive market producing differentiated goods using labour such that:

$$Y_t(i) = A_t(i)L_t(i) \tag{2}$$

where $Y_t(i)$ is output of firm i, $A_t(i)$ is exogenous technology and $L_t(i)$ is labour available at a wage rate, w. We assume that log technology evolves as an autoregressive process with mean zero and constant variance.

Following Karadi and Reiff (2012), the model includes some form of price stickiness which can take on the form of time-dependence as in Calvo (1983) or state-dependence (menu-cost based) as in Golosov and Lucas Jr (2007). The form of price stickiness does not change the intuition of the model outcome. Each firm maximises the discounted sum of all future profits subject to its exogenous technology and wages, with the per period profit function specified as:

$$\Pi(P_t(i), A_t(i)) = (P_t(i) - \frac{w_t}{A_t(i)})Y_t(i) \tag{3}$$

Price stickiness means that the firm's pricing decision becomes dynamic. If the firm changes its prices in period t, whether because it is randomly chosen to change its price or pays the menu cost, then the value of the firm would be

$$V^C(A_t(i)) = \max_{P_t(i)}\{\Pi(P^*(i), A_t(i) + \beta E_t V(P^*(i), \sum_{l=1}^{\infty} A_{t+l}(i))\} \quad (4)$$

which is the dynamic optimum[1]. Firms that face price stickiness will therefore set the current price to maximise future profits rather than just focusing on current profits.

There are two components to equation 4: the static optimum, the price that maximises current profits

$P^{*S}(A(i)) = \Pi(P^*(i), A_t(i)) = \frac{\theta}{\theta-1}\frac{w}{A(i)}$

and the forward-looking optimum, the price which maximises the future value of the firm:

$P^{*F}(A(i)) = \beta E_t V(P^*(i), \sum_{l=1}^{\infty} A_{t+l}(i))$

3 Decomposing inflation

To construct a core inflation measure that adequately addresses the theory of forward-looking prices depends on our ability to distinguish between prices which are sticky and which are flexible. It is with the advent of micro-price data work of Bils and Klenow (2004) on CPI in the US, and Creamer and Rankin (2008) and Ruch and Bester (2013) on SA CPI that categorising consumer products became possible. Combining the frequency of price changes with actual price changes at a product level allows us to censor products based on their degree of forward-looking information to construct a flexible- and sticky-price index. The sticky-price inflation measure has the potential to define core inflation that will be optimal for monetary policy, measurable, timely, and defined by the theoretical definition of core inflation. This section will discuss the underlying micro-price data, construct flexible- and sticky-price inflation measures, and look at the basic properties of those measures.

3.1 Micro-price data and calculating frequency of price changes

The micro-dataset used in this study is based on the underlying product data provided by Statistics South Africa (StatsSA) and used to produce CPI. It covers the period January 2009 to May 2015 and is an extension of the dataset used by Creamer and Rankin (2008) which included data

[1]In a menu-cost model the firm would maximise current profits less the cost imposed when changing price, usually a function of labour input.

up to December 2007. Our dataset includes only goods and does not provide any information on services. There are $5,200,466$ individual price quotes in the period under review. In order to prepare the dataset for analysis we include data only with an acceptable status code. This means that prices collected which are indicated as: “Wrong item collected”, “Item available but not comparable”, “Extreme values not verified”, “Quality adjustment” and “Available shelf price wrongly collected” are excluded. This leaves $4,986,454$ individual price quotes; a drop of $214,006$. For more details on the micro-price data also see Ruch et al. (2016).

To calculate the frequency of price changes we create an indicator variable $I_{j,k,t}$ which is equal to 1 if there was a price change and 0 otherwise. Consider a retailer or firm k that sells a variety of a product j at time t. A variety of product refers to a unique brand or type of product. For example comparing one- and two-ply toilet paper from a number of different brands at a specific retailer or firm. To ensure that we compare price changes of identical products over time we create a unique identification number for each product, in a specific region, at a specific outlet, for a specific month, and of a specific type. The data is then sorted based on this identification number and a price change is then calculated as:

$$dp_{j,k,t} = (p_{j,k,t} - p_{j,k,t-1}) \cdot 100 \tag{5}$$

where $p_{j,k,t}$ is the log price of a specific variety of product j at retailer k in time t. We then apply the indicator variable to the micro-data such that:

$$I_{j,k,t} = \begin{cases} 1 & \text{for } dp_{j,k,t} \neq 0 \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

The indicator variable $I_{j,k,t}$ is then aggregated using both the mean and median to the product level i, representing the consumption products collected using Classification of Individual Consumption by Purpose (COICOP) methodology. In this dataset there are 410 individual products. Therefore the mean frequency at product level i is:

$$I_{i,t} = \frac{\sum_{j=1}^{J} \sum_{k=1}^{K} I_{j,k,t}}{J+K} \tag{7}$$

Using the earlier example this would be the aggregation of all varieties of toilet paper as an individual product.

To get the mean and median of the entire dataset we apply expenditure weights as calculated by StatsSA at product level i. Since we do not have full coverage such that weights add up to

1, we have to normalise the frequency calculations.

Over the sample period, the weighted mean frequency of monthly price change is 27.8 per cent. Taking the inverse of this (i.e. $1/0.278$) to get an approximation of duration implies that goods prices change on average every 3.6 months at the mean. This approximation of duration, however, requires that all prices have the same expected duration, an assumption that is unlikely to hold given the heterogeneity in price changes. Therefore another method to calculate the average duration is to take the inverse of the frequency at the product level and aggregate that back to an overall value as is Dhyne et al. (2006). Using this method we calculate that the weighted average duration of price changes is 6.5 months. According to the weighted median frequency of monthly price changes goods prices change 12.5 per cent of the time or approximately every 8.0 months. For a more in-depth discussion on the frequency of price change see Ruch et al. (2016).

3.2 Sticky- vs flexible-prices

The by-product frequency calculations provide two important sources of information. First, this is the foundation of decomposing inflation into its sticky and flexible components. Second, the mean and median frequency changes give us a natural starting point at which to censor the product level data. The goods micro-price data we have includes 39.72 percentage points of the 49.86% weight of goods, based on 2013 weights, in the overall CPI. One important exclusion from the goods products is petrol prices which account for 5.67% of the basket weight. To include this product we assume based on the behaviour of the petrol price that it has a frequency of 0.9, i.e. it effectively changes almost every month. Calculating frequency at an aggregated level (once all the individual and unique price quotes all over the country are aggregated cross-sectionally) is generally not possible for products as there is a substantial aggregation bias. For example, a food product that from the micro-price data has a true frequency of price change of 0.18 has a frequency of price change of 1 when looking at that product aggregated cross-sectionally. This aggregation bias does not hold for petrol prices given the homogeneity of the product and how the price is determined nationwide. The inclusion of petrol increases the coverage of our micro-price data to 45.39 percentage points of the overall CPI basket and over 90% of the goods component.

We decompose inflation into two components; sticky- and flexible-price inflation such that:

$$
\begin{aligned}
\pi_t &= \pi_t^S + \pi_t^F \\
&= \sum_{i=1}^{n} \omega_{i,t} \cdot I_i^S \cdot \pi_{i,t} + \sum_{i=1}^{n} \omega_{i,t} \cdot I_i^F \cdot \pi_{i,t}
\end{aligned}
\tag{8}
$$

where π_t is month-on-month inflation rate, π_t^S is sticky-price inflation, π_t^F is flexible-price inflation, I_i^S is an indicator equal to 1 if $I_i \leq T$ and 0 otherwise, I_i^F is an indicator equal to 1 if $I_i > T$ and 0 otherwise, T is an arbitrary threshold value for the frequency of price changes determining which prices are considered sticky or flexible, $\omega_{i,t}$ are the expenditure weights determined by StatsSA for each sub-index, and $i = 1,...,n$ is products, in this case $n = 410$.

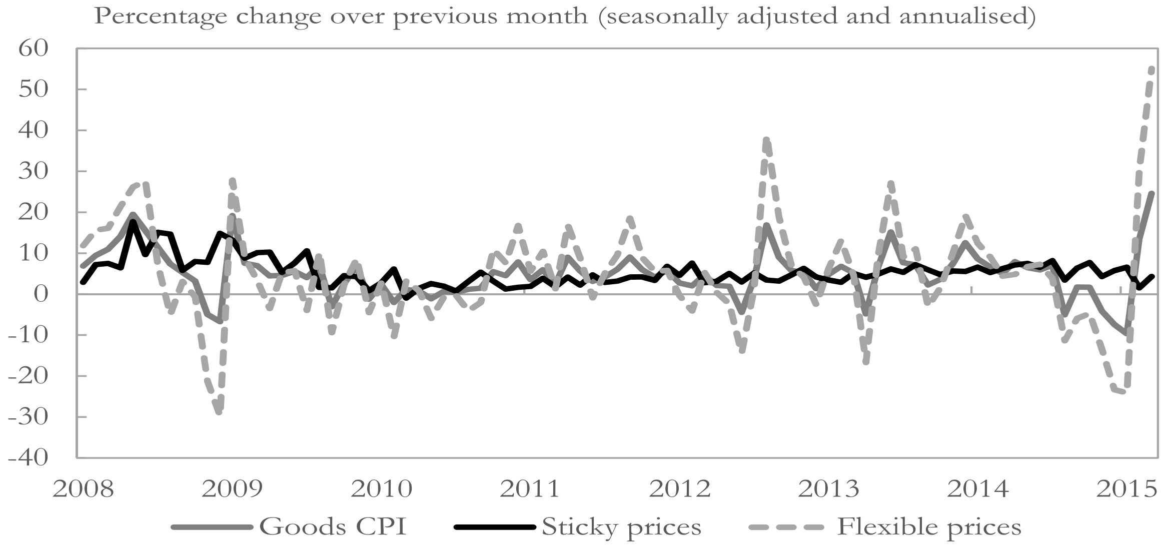
We simplify the calculation of inflation above (as in Blignaut et al., 2009) such that it is the weighted sum of inflation rates and not a modified Laspeyres-type index employed by StatsSA. This means that the construction of goods CPI here will differ slightly from what StatsSA reports. See Aron and Muellbauer (2004) for a detailed discussion of the methodology used by StatsSA and Du Plessis et al. (2015) for an update. We also normalise the sticky- and flexible-price components weights ($\omega_{i,t}$) to 1 individually to aid representation.

Determining which products should be considered flexible or sticky requires a decision on the threshold value T. We follow Reiff and Várhegyi (2013), Bryan et al. (2010) and Millard and O'Grady (2012) and calculate three threshold frequency values including the weighted mean (27.8%) and median (12.5%) of frequency changes, as well as 15% which Reiff and Várhegyi (2013, pg. 7) show ensures that "the extent of forward-lookingness is always more than 60 percent". We mainly present the results for the weighted mean frequency threshold since this ensures sufficient coverage of products on either side of the decomposition.

Figure 1 plots the month-on-month seasonally adjusted and annualised (1a), and the year-on-year (1b), changes in goods CPI against sticky- and flexible-price inflation based on the weighted mean frequency change of 27.8%. The seasonal adjustment is done on the aggregated sticky- and flexible-price indices using X-13ARIMA-SEATS Seasonal Adjustment. It is clear from both 1a and 1b that the division of inflation into these two subcomponents generates a more volatile flexible-price inflation series with peaks and troughs significantly higher than both sticky-price and overall goods inflation, and a more persistent sticky-price inflation index that captures underlying inflationary trends. The average duration of price changes in sticky-price inflation is 5.9 months compared to an average duration of 1.8 months for flexible-price inflation. In comparison, the average duration of sticky-price inflation increases to 12 months when the threshold is at the median of 12.5% while the duration of flexible-price changes rise to 2.5 months.

Figure 1: Sticky- and flexible-price goods inflation

(a)



(b)

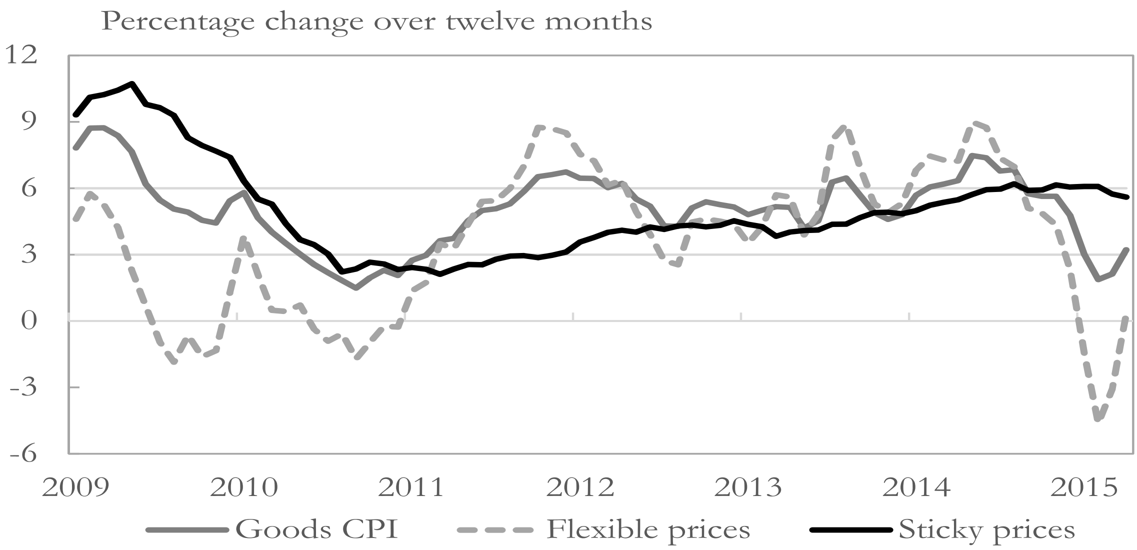


Table 1 shows the decomposition of goods inflation, sticky- and flexible-price inflation into its category components based on the 2013 expenditure weights. Sticky-price goods inflation based on the mean weighted frequency of 27.8% has a weight of 24.5 percentage points (in total CPI) made up mainly of new vehicles (5.29%), alcoholic beverages (3.97%), clothing (2.76%), hotel and restaurant goods (2.54%) and food (1.55%)[2]. Flexible-price inflation on the

[2]The sticky-price inflation measure based on the median frequency value has a total weight of 7.4% while the

other hand has a total weight of 20.86 percentage points of which close to 80% is made up of food (10.73%) and petrol (5.67%). The next biggest category is miscellaneous goods which accounts for 1.47% of flexible-price inflation.

One important finding from the construction of the mean weighted sticky-price inflation is the relative importance of certain components of food as well as non-alcoholic beverages, categories usually excluded from a conventional exclusion-based measure. In the mean weighted sticky-price inflation measure about 10 per cent of food items are classified as core goods with price changes occurring among those goods every 4.3 months on average. The stickiest food product is only changing prices once every 9.3 months. Assuming homogeneity among food products, and excluding them from the common exclusion-based measure used by SARB when defining core inflation, may exclude important information on underlying prices.

Table 2 provides some basic properties of the sticky- and flexible-price inflation measures, based on month-on-month annualised changes, including its standard deviation and persistence (measured by a basic AR(1) equation). We expect flexible-price inflation to contribute most to the volatility in goods inflation and this is clearly the case at all threshold values. For the weighted mean frequency value of 27.8%, flexible-price inflation has a standard deviation almost four times as large as sticky-price inflation at 13.1 per cent compared to 3.4 per cent. The standard deviation of flexible-price inflation does decrease with the lower threshold values as the duration of price changes included in the flexible-price inflation measure decline. Flexible-price inflation is also much less persistent than sticky-price inflation with an autoregressive term of 0.42 compared to 0.88. As the threshold value dividing sticky- and flexible-prices decreases flexible-price inflation becomes more persistent but sticky-price inflation remains relatively unchanged.

---

threshold frequency value has a weight of 7.9%.

Table 1: Weights of sticky- and flexible-price inflation by category (threshold =27.8%)

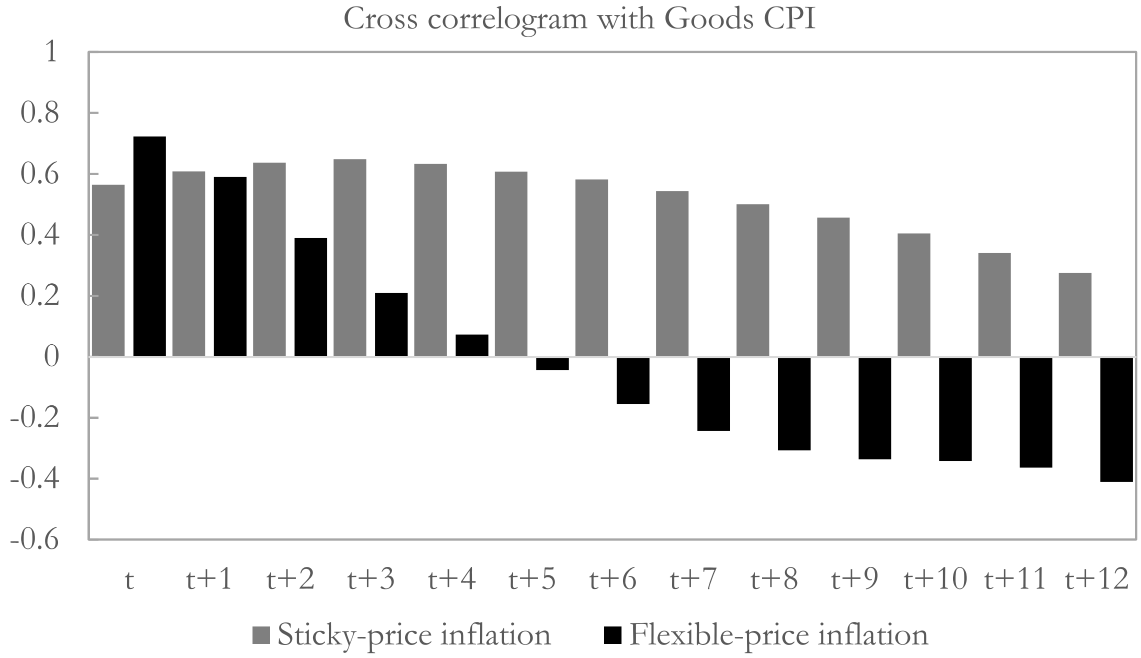
	Total Goods excluding petrol	Total Goods including petrol	Sticky-prices	Flexible-prices
Food	12.28	12.28	1.55	10.73
Non-alcoholic beverages	1.22	1.22	0.64	0.58
Alcoholic beverages	3.97	3.97	3.97	0.00
Tobacco	1.48	1.48	1.48	0.00
Clothing	2.76	2.76	2.76	0.00
Footwear	1.31	1.31	1.31	0.00
Maintenance and Repair of dwelling	1.03	1.03	1.03	0.00
Other fuels	0.05	0.05	0.00	0.05
Furniture and furnishings, carpets and other	0.53	0.53	0.20	0.33
Household textiles	0.59	0.59	0.59	0.00
Household appliances	0.60	0.60	0.52	0.08
Glasswear, tableware and household utensils	0.10	0.10	0.10	0.00
Tools and equipment for house and garden	0.08	0.08	0.06	0.01
Goods for routine household maintenance	0.54	0.54	0.10	0.44
Medical products, appliances and equipment	0.39	0.39	0.39	0.00
Vehicles	5.99	5.99	5.29	0.70
Operation of Vehicles	0.65	6.32	0.21	6.11
Telephone equipment	0.13	0.13	0.00	0.13
Audiovisual and Photographic equipment	0.69	0.69	0.45	0.24
Other recreation equipment	0.84	0.84	0.84	0.00
Newspapers, books and stationery	0.03	0.03	0.03	0.00
Hotel and Restaurant	2.54	2.54	2.54	0.00
Miscellaneous goods	1.92	1.92	0.45	1.47
Total weight	39.72	45.39	24.53	20.86

Table 2: Properties of sticky- and flexible-price inflation

	Goods CPI	Stricky prices	Flexible prices
27.8% threshold			
Standard deviation	5.89	3.37	13.15
AR-coefficient	0.63	0.88	0.42
15% threshold			
Standard deviation		2.81	7.29
AR-coefficient		0.87	0.57
12.5% threshold			
Standard deviation		2.50	6.88
AR-coefficient		0.86	0.57

An important differentiation between sticky- and flexible-price inflation is that sticky prices are set based on firms inflation expectations in a forward-looking manner. This means that sticky-price inflation should be better correlated with future goods inflation compared to flexible prices. To test this hypothesis, figure 2 looks at the cross-correlogram between goods inflation at t+1 to t+12 months ahead against contemporaneous sticky-price and flexible-price inflation, at the mean threshold, on a year-on-year basis. It is clear from the graph that sticky-price inflation has a strong positive correlation with goods inflation with the correlation peaking at t+3 at 0.65 and remaining positive. Flexible-price inflation, on the other hand, has a strong contemporaneous correlation with goods inflation at 0.72 but diminishes quickly, turning negative at t+5.

Figure 2: Correlation of sticky- and flexible-price inflation to overall inflation

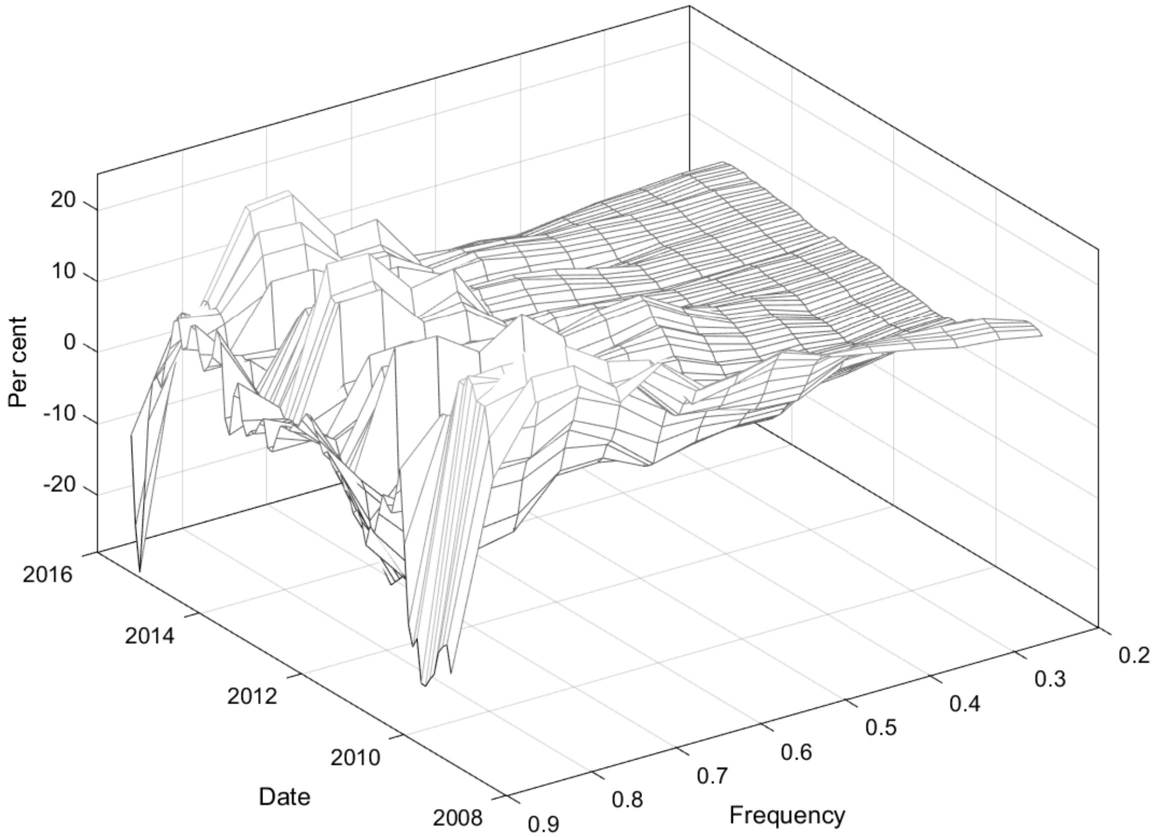


3.3 Distributional properties

Censoring the data at specific threshold values gives an indication of broad-based measures of sticky- and flexible-price inflation but lacks granularity over the entire distribution. To look at the properties of annual goods inflation at different threshold values, figure 3 plots 20 per cent rolling windows of threshold values starting from prices that do not change often, between 0 and 20 per cent frequency of price changes, and rolling forward by 5 percentage points. Hence the observation at 0.2 is annual inflation extracted from prices with a frequency between 0 and 20 per cent, and at 0.3 it is between 10 and 30 per cent. Figure 3 shows that as product prices becomes more flexible their prices also become more volatile. Products that fall between 0 to 20 per cent frequency have an annual inflation range of 2.6 to 8.9 per cent with an interquartile range (IQR) of 2.3 per cent. As product prices become more flexible these values increase. Products that have frequency between 30 and 50 per cent range from inflation rates of -0.7 to 16.3 per cent with an IQR of 3.6 per cent. The most price-flexible products in our dataset falling between frequencies 70 and 92 per cent have inflation rates as low as -27.3 per cent and as high as 13 per cent with an IQR of 7.8 per cent[3].

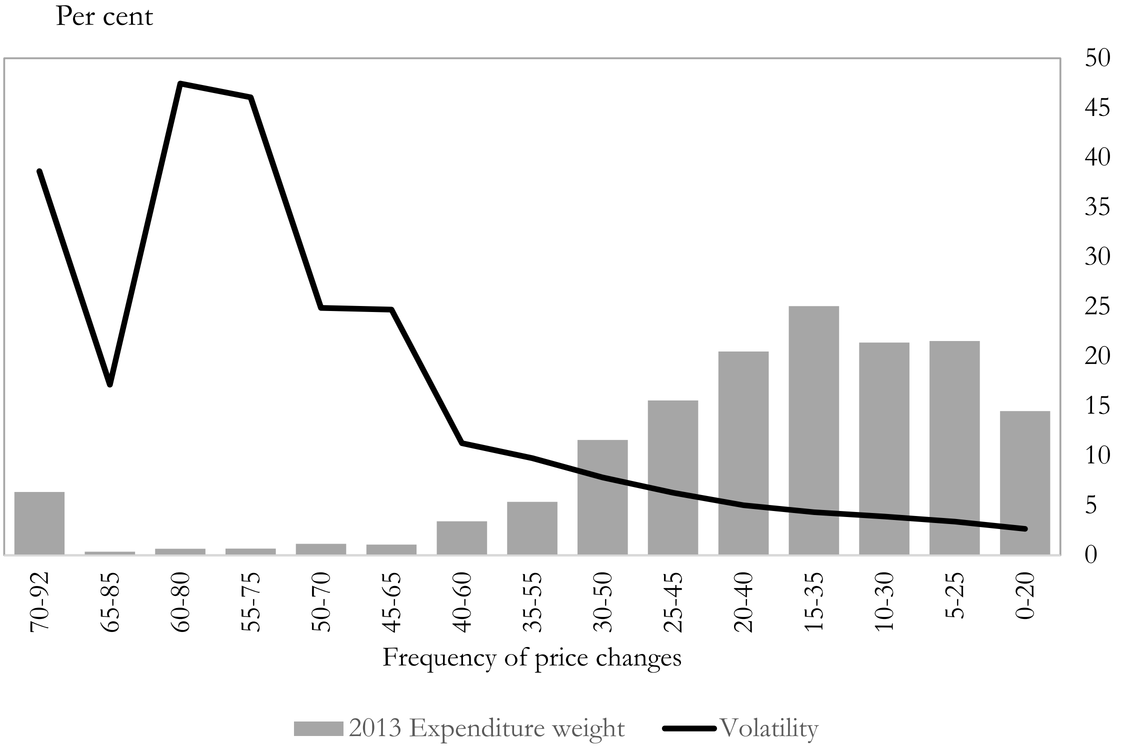
[3]The largest frequency change among the products studied has a frequency of 91.7 per cent so for convenience these are included in the last frequency grouping.

Figure 3: Annual goods inflation by frequency groups



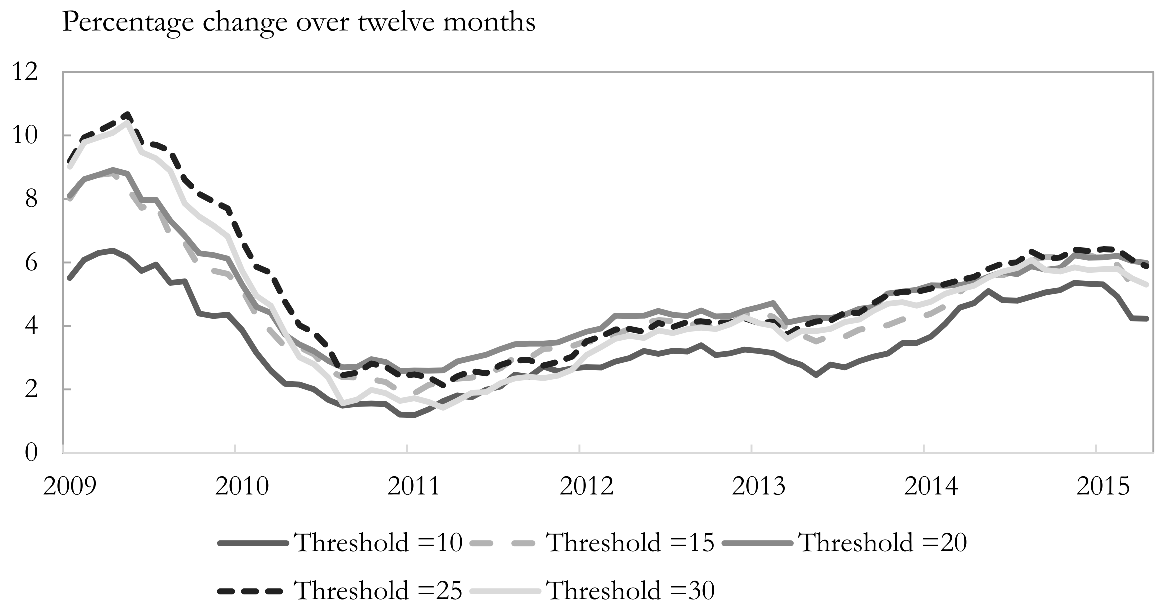
An important outcome of more flexible prices is rising volatility. To guage how this changes over frequencies, figure 4 plots the standard deviation from the groupings in figure 3 as well as the expenditure weights of each group (based on 2013 weights). The standard deviation starts at 2.7 per cent for products with frequencies between 0 and 20 per cent. This falls between the volatility of the sticky-price inflation at the mean and median thresholds. Volatility slowly rises as products become more flexible increasing to 5 per cent for products between 20 and 40 per cent, 7.8 per cent for products between 30 and 50 per cent, and ending at 38.6 per cent for products between 70 and 92 per cent. The graph also shows how the expenditure weights of goods products changes over the frequency groups. Products between 0 and 20 per cent account for 14.5 percentage points of the goods basket, between 20 and 40 per cent - 20.5 percentage points, and 70 to 92 per cent - 6.3 percentage points.

Figure 4: Votalility by frequency groups



To get an idea of what sticky-price inflation would look like over the different threshold values, figure 5 plots sticky-price inflation as the threshold value increases from 10 (prices changing every 10 months) to the 30 per cent, just above the mean threshold. To determine the bounds for this exercise we look at the distribution of frequency of price changes by products, as well as its expenditure weight in the CPI. Based on the 410 products which have frequency information, the minimum frequency of price change is 3.4 per cent and the maximum is 91.8 per cent. We need to ensure that more than one product represents sticky-price inflation. At 5 per cent there are 17 products which make up 4.1 per cent of the products but only 0.46 percentage points based on expenditure weights. Therefore we look for the first frequency change that covers at least ten per cent of total expenditure weights, this occurs at a threshold value of 10 per cent.

Figure 5: Sticky-price inflation at different threshold frequencies



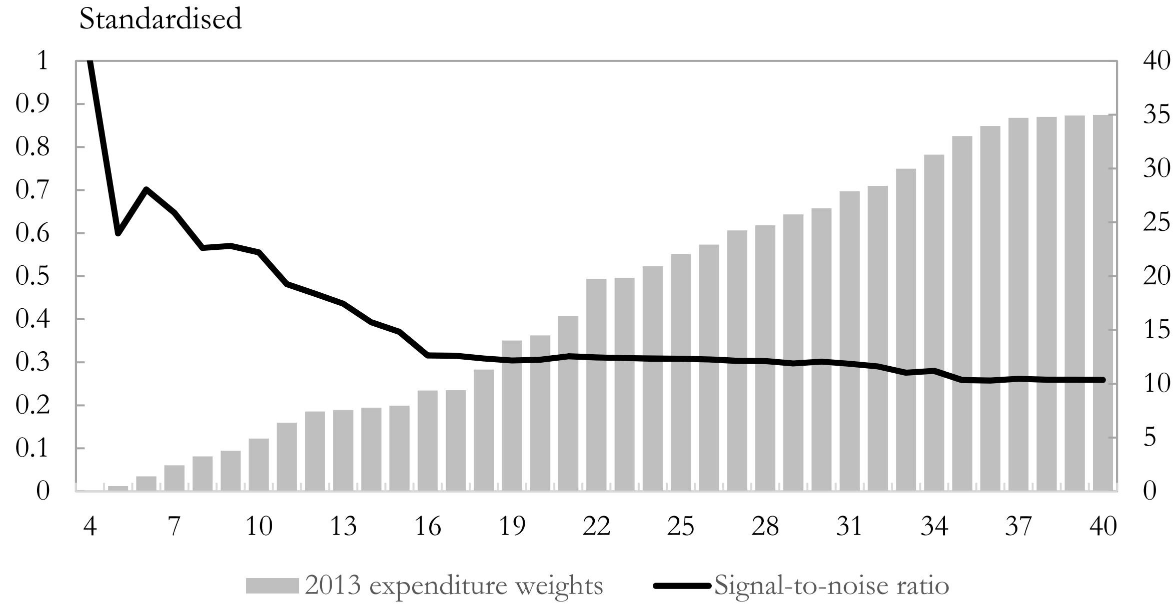
It is clear from figure 5 that there is a strong correlation between various sticky-price inflation measures and that different threshold frequencies do not create entirely different outcomes. Inflation tends to rise as the threshold value increases. Sticky-price inflation at a 10 per cent frequency threshold generally creates the lower boundary while those at a frequency of 25 per cent or lower generally creates the upper boundary. The maximum difference between sticky-price measures in figure 5 occurs at the first peak in 2009 at 4.5 percentage points while the smallest difference occurs in 2014 with a range of 0.7 percentage points.

3.4 Optimising sticky-price inflation

The choice as to where to censor the data between sticky- and flexible-prices is somewhat arbitrary when thinking about sticky-prices from a core inflation perspective. Sticky-price inflation should represent underlying prices in an economy with maximum forward-looking information but also have enough products included to ensure an adequate signal of overall goods inflation. This section will look at which threshold frequency provides the best signal of overall goods inflation, what the minimum amount of products at which this is defined and which products represent this signal.

To determine an 'optimal' threshold value we implement a signal-to-noise ratio test to determine at which point sticky-price inflation represents the optimal signal of overall goods inflation. Examples using the signal-to-noise ratio (SNR) in the literature on core inflation include Mankikar and Paisley (2004), Walsh (2011) and Bullard et al. (2011). Figure 6 shows the signal-to-noise ratio normalised to 1 at its minimum as well as the sum of expenditure weights for frequency values from 4 to 40 per cent. The graph starts at 4 per cent since the lowest frequency by product is 3.2 per cent. To determine the optimal threshold we look for an inflection point where the least amount of information required maximises the signal-to-noise ratio. This occurs at a frequency of 16 per cent where the sum of expenditure weights is equal 9.37 percentage points. In the sample of frequencies shown above the signal-to-noise ratio actually reaches a maximum at a threshold value of 36 per cent, however, the marginal gain in SNR does not justify the higher information requirement.

Figure 6: Signal-to-noise ratio by threshold frequencies



The optimal sticky-price inflation measure is close to the 15 per cent threshold suggested by Reiff and Várhegyi (2013, pg. 7) which ensures that "the extent of forward-lookingness is always more than 60 percent". Optimal sticky-price inflation is made up of 169 products and accounts for 9.37 percentage points of the CPI basket. The product categories which account for over 80 per cent of this weight are clothing (29.5 per cent), hotel and restaurant goods (27.2 per cent), footwear (14.1 per cent), and alcoholic beverages (13.2 per cent).

4 Measures of core inflation

In this section we improve two alternative core inflation measures in the existing literature by recognising the heterogeneity in prices and doing the analysis at a product level. First, the persistence-weighted measure introduced for SA by Rangasamy (2009), which has a sufficiently appealing theoretical foundation as highlighted in Du Plessis (2014). Second, the trimmed means inflation measure first introduced by Bryan and Cecchetti (1994).

4.1 Persistence-weighted core inflation

One possible alternative core inflation measure that defines inflation as a 'persistence' concept is the persistence-weighted core inflation measure implemented by Cutler (2001) and Rangasamy (2009). Persistence-weighted core inflation aligns to core inflation as defined by Friedman et al. (1963) and Woodford's view that "central banks should target a measure of "core" inflation that places greater weight on those prices that are stickier". We improve this measure by calculating persistence at the product level, in this case for 410 individual products rather than at category level (33 categories) as in Rangasamy (2009). This further disaggregation should provide a richer and more accurate measure of core inflation.

To determine persistence we follow Rangasamy (2009) and define an autoregressive model:

$$\pi_{it}^{m} = \sum_{j=1}^{p} \beta_{ij} \pi_{i,t-j}^{m} + \varepsilon_{it} \tag{9}$$

Where π_{it}^{m} is demeaned inflation at time t of product $i = 1, ..., n$, ε_{it} is an error term, and p is the optimal lag length based on the Akaike Information Criterion (AIC) with a maximum lag length of 4. Persistence is then defined as the absolute value of the sum of the autoregressive coefficients such that:

$$P_i = \left| \sum_{j=1}^{p} \beta_{ij} \right| \tag{10}$$

Two weighting schemes are used in order to determine core inflation including weighting based on just persistence (labelled CoreP) and the average of persistence and the expenditure weights provided by StatsSA (labelled CorePC):

$$\begin{aligned} \pi_t^{CoreP} &= \sum_{i=1}^{n} P_i \cdot \pi_{it} \\ \pi_t^{CorePC} &= \sum_{i=1}^{n} (\omega_{it} + P_i)/2 \cdot \pi_{it} \end{aligned} \tag{11}$$

CoreP is based on the weighting scheme proposed by Cutler (2001). The problem with this scheme is that it may unduly exaggerate the importance of outliers. One possible way to deal with this problem is to use the persistence measure scaled by a products relative importance in the expenditure basket as proposed by Babetskii et al. (2007) (CorePC). Figure 8 plots the two persistence-weighted core measures defined in equation 11.

One possible problem with the methodology as applied in Rangasamy (2009) is that the core inflation measures calculated using the persistence weighting scheme do not appear to have lower volatility. This problem is rectified in the application above as there is more differentiation between the persistence of products that make up the overall CPI.

4.2 Trimmed means core inflation

Bryan and Cecchetti (1994, pg. 195) first suggested a trimmed means core inflation measure as a solution to "the measurement of aggregate inflation as a monetary phenomenon". There are two reasons why trimmed means may provide a better representation of underlying inflation. First, Ball and Mankiw (1995, pg. 161) show from a theoretical perspective that in a menu cost model "[w]hen price adjustment is costly, firms adjust to large shocks but not to small shocks, and so large shocks have disproportionate effects on the price level. Therefore, aggregate inflation depends on the distribution of relative-price changes: inflation rises when the distribution is skewed to the right, and falls when the distribution is skewed to the left." This phenomenon means that the distribution of price changes in any particular month will, as shown in the micro-price literature (see Bils and Klenow (2004) as a example and Creamer et al. (2012) for a South Africa specific result) be affected by relative price shocks and have excess kurtosis (or fat tails). This motivates the second reason. From a statistical perspective if a population has excess kurtosis then trimming the distribution will lead to a more efficient estimate of the population mean. An important disadvantage of the trimmed means measure from a theoretical perspective is the ability to distinguish between "transient and persistent extreme price movements" (Wynne, 2008). The popularity of this type of core inflation measure has meant that StatsSA now includes a trimmed means which trims 5 per cent off each tail at the product group level.

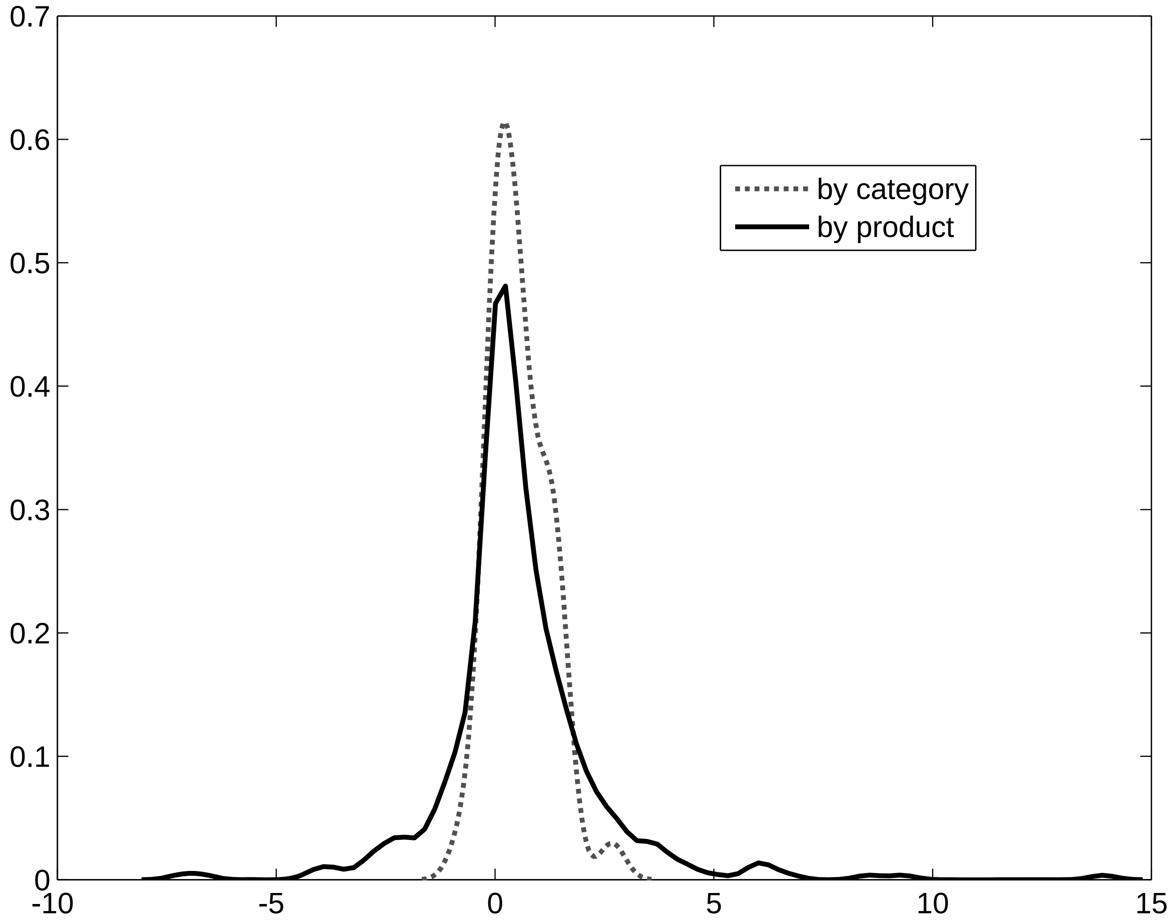
To improve on the trimmed means measures calculated by Blignaut et al. (2009) we introduce a product level trimmed means core inflation measure. The product level calculation has important advantages. First, we do not introduce any aggregation bias that would occur at the category level. Laflèche (1997) and Bryan et al. (1997) highlight that within sub-groups such as food there may be components that are volatile and others which are persistent. The sticky-price inflation measure above also showed that blindly excluding entire categories does not take account of the type of heterogeneity that exists within categories and across products. The product level trimmed mean measure therefore embraces the actual heterogeneity that is found in micro-price data and trims from the "true" distribution of price changes rather than an aggregated version. Second, unlike an exclusion-based measure of core inflation we do not restrict the subset of products that may experience relative price shocks (e.g. to food and energy).

The trimmed means measure is calculated as follows. The month-on-month changes in each individual product is calculated. These price changes are ranked in ascending order with their associated expenditure weights (ω_{it}). The cross-sectional distribution of price changes is then calculated using the cumulative density function. Price changes that fall into the $t_1\%$ of the lower tail and $(1-t_2)\%$ of the upper tail are trimmed. The trimmed means inflation rate for each month is then the weighted sum of the left over products using the associated expenditure weights normalised to 1.

This methodology differs slightly from Blignaut et al. (2009) as we use month-on-month inflation rates rather than year-on-year rates. We choose two trimmed means measures for our analysis including a symmetric trim of 15 per cent off each tail as in Bryan and Cecchetti (1994) and an asymmetric trim of 24 and 17 per cent respectively off the top and bottom of the tail as in Blignaut et al. (2009) to account for the positive skewness inherent in micro-price data. The period under review is too short to determine an optimal trim based on its fit to a trend variable such as the 36-month moving average as in Blignaut et al. (2009). Even if this was possible the desirability to do this remains questionable as these benchmark measures only provide one way to remove relative price shocks and in no way have been proven to be optimal. Our intention in this paper is to look at the value in defining a sticky-price inflation measure and therefore use common trimmed means measures in the literature as our benchmarks.

To highlight the aggregation bias, figure 7 plots the kernel density estimate of month-on-month price changes at the category level, the 44 categories provided by StatsSA, and the product level, over 300 products for September 2013. The by-category distribution has positive skewness of 0.76 while the by-product distribution is more positively skewed at 1.56. The by-product distribution also has fatter tails with kurtosis at 14.5 compared to 3.8 for the by-category distribution.

Figure 7: Kernel density estimate of inflation rates at the product and category level

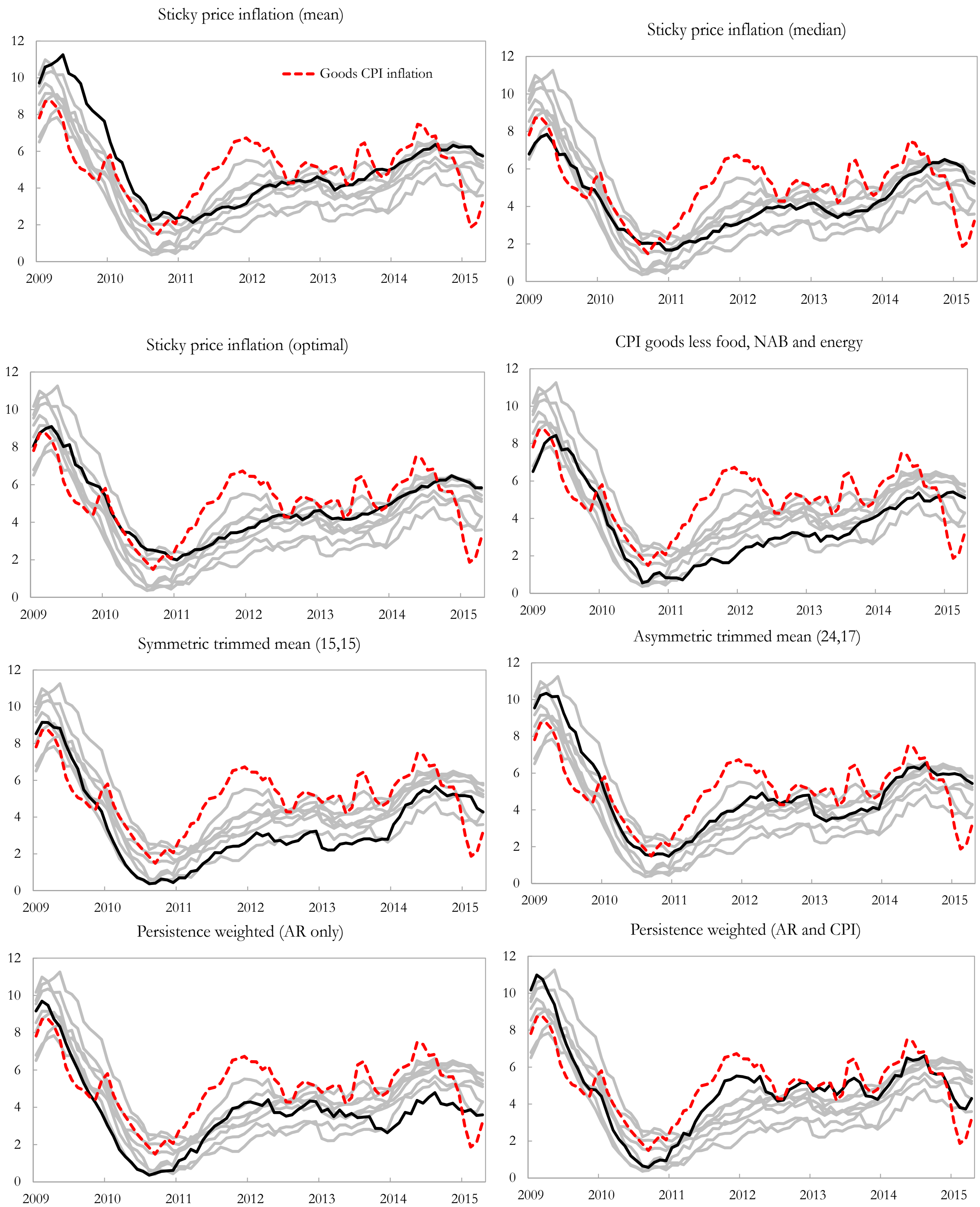


5 Comparative performance

In this section we compare our candidate core inflation measures against the properties of a good core measure and against each other. Due to the short sample period we only analyse in-sample performance: tracking overall inflation with no clear bias and less volatility. Figure 8 plots the eight core inflation measures that we will analyse including the sticky-price inflation measures censored at the mean (27.8%), median (12.5%), and optimal (16%) frequencies of price change. These three measures are compared to the common exclusion-based measure used by central banks: goods CPI excluding food and non-alcoholic beverages, petrol and energy which accounts for 24.6 percentage points of the CPI basket. They are also compared to two versions each of the improved trimmed means and persistence-weighted measures including: a symmetric trimmed means measure with 15% of monthly price changes trimmed off each tail; an asymmetric trimmed means measure where 24% and 17% of the lower and upper tails are trimmed as in Blignaut et al. (2009); a persistence-weighted core inflation where persistence in the sum of the autoregressive coefficients at the product level (AR only); and a persistence-weighted core inflation measure based on the average of the persistence weights and expenditure weights in the CPI (AR and CPI).

Figure 8 shows that all core inflation measures represent some underlying trend of overall goods inflation. The core inflation measures all follow a similar trajectory, falling in line with overall inflation during 2009-10 and rising henceforth. Core inflation measures range between 0.4 and 11.3 per cent compared to overall goods inflation which ranges between 1.5 and 8.7 per cent.

Figure 8: Core inflation measures



5.1 In-sample performance

For core inflation to be an unbiased predictor of overall inflation it needs to have the same mean in the long-run. In table 3, we compare the mean of month-on-month annualised core inflation measures to overall goods inflation. A t-test allowing for unequal variances is used to compare whether the means are statistically different from overall goods inflation. Goods inflation from 2008M02 to 2015M05 has a mean of 5.39 per cent. All core inflation measures have a lower mean value with a minimum value of 3.83 per cent for the symmetric trimmed means measure. Based on the t-test, the exclusion-based goods measure, CPI goods excluding food, non-alcoholic beverages (NAB) and energy prices, the symmetric trimmed means inflation measure and the persistence-weighted inflation measure based on persistence only (AR only) have statistically different means from overall goods inflation.

Another measure of unbiasedness is the mean error. A value close to zero indicates no clear upward ($-$) or downward ($+$) bias. The last column in table 3 shows the mean error for each core inflation measure. The core inflation measure with the lowest mean error is sticky-price inflation (mean) at 0.02 per cent indicating no clear bias during the sample period. The next lowest mean error is attributed to the sticky-price inflation at the optimal threshold with a value of 0.31 per cent. The worst mean error is the symmetric trim mean measure which has a positive bias of 1.69 per cent meaning that on average the core inflation measure is 1.69 percentage points below overall goods inflation.

Testing unbiasedness at the mean is appropriate if the underlying distribution of price changes is normally distributed. This assumption is, however, not necessarily true for inflation which often is positively skewed and has excess kurtosis given the importance of relative price shocks. This property exists at the micro-price level and is likely to exist over time as well. Therefore for core inflation to be unbiased it should also have equal medians. To test this we use the Kruskal-Wallis test for equal medians. Table 3 shows the median for overall goods inflation is 5.33 per cent. As was the case with the mean, all core inflation measures also have a lower median value. Based on the test, the three core inflation measures which were found to have unequal means from overall goods inflation also have unequal medians. However, now sticky-price inflation at the median threshold also has a statistically different median from goods inflation.

A significant barrier to determining which core inflation measure is best is the lack of out-of-sample forecastability of headline inflation. The current sample size does not allow an adequate assessment of how well core inflation forecasts future headline inflation over the policy horizon. Two facets of this criteria which have been inappropriately implemented in the literature, however, need to be assessed. First, much of the work done up to now to determine the ability of core inflation to forecast headline inflation has focused on point forecasts using root means squared errors (see for example Bryan and Cecchetti, 1994; Clark, 2001; Detmeister,

Table 3: Mean, median and volatility

	Mean	Test for equality of means	Median	Test for equality of medians	Standard deviation	Test for equality of variances	Mean Error
Goods inflation	5.39		5.33		5.36		
Sticky price inflation (mean)	5.39	-0.01	4.90	0.17	3.37	2.5***	0.02
Sticky price inflation (median)	4.38	1.6	4.24	3.93**	2.50	4.6***	0.82
Sticky price inflation (optimal)	5.00	0.6	4.65	0.95	2.61	4.2***	0.31
CPI goods less food, NAB and energy	3.84	2.3**	3.54	7.15***	2.97	3.3***	1.36
Symmetric trimmed mean (15,15)	3.83	2.3**	3.71	8.05***	3.34	2.6***	1.69
Asymmetric trimmed mean (24,17)	5.11	0.4	4.86	0.42	3.30	2.6***	0.37
Persistence weighted (AR only)	4.01	2.0**	3.62	6.63***	3.20	2.8***	1.61
Persistence weighted (AR and CPI)	5.04	0.5	4.43	0.75	4.14	1.7***	0.61

*** represents a 1% level of significance, ** a 5% level of significance, and * a 10% level of significance

2012; and Du Plessis et al., 2015). Point forecasts provide little information on core inflation's actual forecast ability since it is too narrow. Instead this criteria should be based on the ability to forecast the centre of the distribution of headline inflation. One possible way to implement this would be to look at the predictive likelihood, which takes account of the entire predictive density function, over the policy horizon. Predictive likelihoods have the added advantage of providing model selection criteria among many different models and weights for model averaging exercises (Warne et al., 2013). Another option is to find the best forecast of the median of headline inflation over the period 18 to 30 months ahead. Since the distribution of headline inflation is likely to be skewed with excess kurtosis, due to relative price shocks, the median provides a better representation of the distribution. Acknowledging this possibility table 3 looks at both the mean and median as a test of unbiasedness.

6 Caveats and future work

There are two important caveats to this paper both which require future work. First, the micro-price data set provided only cover about eight years of data partly due to an important structural break in the CPI methodology. As a result determining whether or not sticky-price inflation provides any substantial benefit, beyond the theoretical argued here, above the current subset of core inflation measures remains unanswered. Future work entails combining the micro-price data set studied in Creamer and Rankin (2008) and Creamer et al. (2012) with this dataset. This would involve linking the previous International Trade Classification (ITC) methodology to the new Classification of Individual Consumption by Purpose (COICOP) methodology to classify household expenditure.

Second, the dataset provided by StatsSA only included goods products and no services. This limited the coverage of our study to only 50% of the overall consumer basket. One possible problem that may arise in the services sector is the process by which certain items are surveyed by StatsSA introducing technical frequency changes that may or may not be appropriate. For example, StatsSA provides a table (Table F - Survey schedule for non-monthly surveys) in its monthly CPI release which indicates which goods and services are surveyed on a quarterly (gymnasium fees, funeral expenses, domestic workers' wages, private-sector hospitals, and taxi fares for example), biannual (including medical aid, television licences, electricians, plumbers, and municipal charges for utilities), annual (private-sector doctors and dentists, rugby tickets, school and university tuition fees, university boarding fees, and stamps for example), and an ad hoc basis (local bus fares). These are surveyed in this way partly because StatsSA knows the prices are unlikely to change between surveys. StatsSA does state in the CPI publication that "[a]dditional surveys are conducted for these items when Stats SA is aware of significant price changes outside regular survey months".

Only once a sticky-price inflation measure can be calculated over a long enough sample and the entire coverage of the consumer basket can we answer the question of whether this theoretically founded measure provides a superior performance to the existing core inflation measures.

7 Conclusion

Using the micro-price data for consumer goods in South Africa from 2008 to 2015 we have decomposed goods inflation into its sticky- and flexible price components. Flexible-price inflation is more volatile than overall goods inflation and sticky-price goods inflation, and accounts for the majority of the volatility in overall goods inflation. Sticky-price inflation is more persistent and less volatile than overall goods inflation and the flexible-price inflation measure.

This paper has shown that it is possible to construct a theoretically coherent definition of core inflation based on the concept of price flexibility using micro-price data. We have also improved two existing measures in the literature including trimmed means and persistence-weighted inflation by calculating these at the product level. In-sample tests show that all core inflation measures have lower volatility than overall goods inflation but not all have equal means. CPI goods less food, non-alcoholic beverage and energy, the symmetric trimmed mean measure and persistence-weighted (AR only) have statistically different means from overall goods inflation. All measures except Sticky-price inflation (mean) also have a downward bias compared to goods inflation.

Future work should focus on extending the sample period and including services products to fully explore the value of sticky-price inflation as a “good” core inflation measure.

References

Anand, R. and E. S. Prasad (2010). Optimal price indices for targeting inflation under incomplete markets. *NBER Working Paper Series*, 16290.

Aoki, K. (2001). Optimal monetary policy responses to relative-price changes. *Journal of Monetary Economics 48*(1), 55–80.

Aron, J. and J. Muellbauer (2004). Construction of cpix data for forecasting and modelling in south africa. *South African Journal of Economics 72*(5), 884–912.

Babetskii, I., F. Coricelli, and R. Horváth (2007). *Measuring and explaining inflation persistence: disaggregate evidence on the Czech Republic*. Czech National Bank.

Ball, L. and N. G. Mankiw (1995). Relative-price changes as aggregate supply shocks. *The Quarterly Journal of Economics*, 161–193.

Bernanke, B. (2001). *Inflation targeting: lessons from the international experience*. Princeton University Press.

Bils, M. and P. J. Klenow (2004). Some evidence on the importance of sticky prices. *Journal of political economy 112*(5), 947–985.

Blignaut, Z., G. Farrell, V. Munyama, and L. Rangasamy (2009). A note on the trimmed mean measure of core inflation in south africa. *South African Journal of Economics 77*(4), 538–552.

Bodenstein, M., C. J. Erceg, and L. Guerrieri (2008). Optimal monetary policy with distinct core and headline inflation rates. *Journal of Monetary Economics 55*, S18–S33.

Bryan, M. F. and S. Cecchetti (1993). The consumer price index as a measure of inflation. *Economic Review* (Q IV), 15–24.

Bryan, M. F. and S. G. Cecchetti (1994). Measuring core inflation. In *Monetary Policy*, pp. 195–219. The University of Chicago Press.

Bryan, M. F., S. G. Cecchetti, I. Wiggins, and L. Rodney (1997). Efficient inflation estimation. *NBER Working Paper* (w6183).

Bryan, M. F., B. Meyer, et al. (2010). Are some prices in the cpi more forward looking than others? we think so. *Economic Commentary 5*(2010), 2010–2.

Bullard, J. et al. (2011). Measuring inflation: the core is rotten. *Federal Reserve Bank of St. Louis Review 93*(4), 223–233.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of monetary Economics 12*(3), 383–398.

Cecchetti, S. G. and M. A. Wynne (2003). Inflation measurement and the ecb's pursuit of price stability: a first assessment. *Economic Policy 18*(37), 395–434.

Clarida, R., J. Gali, and M. Gertler (1999). The science of monetary policy: A new keynesian perspective. *Journal of Economic Literature 37*, 1661–1707.

Clarida, R., J. Galı, and M. Gertler (2002). A simple framework for international monetary policy analysis. *Journal of monetary economics 49*(5), 879–904.

Clark, T. E. (2001). Comparing measures of core inflation. *Economic Review-Federal Reserve Bank of Kansas City 86*(2), 5.

Cogley, T. (2002). A simple adaptive measure of core inflation. *Journal of money, credit and banking*, 94–113.

Creamer, K., G. Farrell, and N. Rankin (2012). What price-level data can tell us about pricing conduct in south africa. *South African Journal of Economics 80*(4), 490–509.

Creamer, K. and N. A. Rankin (2008). Price setting in south africa 2001-2007-stylised facts using consumer price micro data.

Cristadoro, R., M. Forni, L. Reichlin, and G. Veronese (2005). A core inflation indicator for the euro area. *Journal of Money, Credit and Banking*, 539–560.

Cutler, J. (2001). Core inflation in the uk. Technical report, External MPC Unit Discussion Paper.

Detmeister, A. K. (2012). What should core inflation exclude?

Dhyne, E., L. J. Alvarez, H. Le Bihan, G. Veronese, D. Dias, J. Hoffmann, N. Jonker, P. Lünnemann, F. Rumler, and J. Vilmunen (2006). Price changes in the euro area and the united states: Some facts from individual consumer price data. *The Journal of Economic Perspectives 20*(2), 171–192.

Du Plessis, S. (2014). Targeting core inflation in emerging market economies. In *Fourteen years of inflation targeting in South Africa and the challenge of a changing mandate*, pp. 53–68. South African Reserve Bank Conference Series.

Du Plessis, S., G. Rand, and K. Kotzé (2015). Measuring core inflation in south africa. *South African Journal of Economics 83*(4), 527–548.

Eckstein, O. (1981). *Core inflation*. Prentice Hall.

Friedman, M., M. Friedman, and M. Friedman (1963). *Inflation: causes and consequences*. Asia Publishing House.

Golosov, M. and R. E. Lucas Jr (2007). Menu costs and phillips curves. *Journal of Political Economy 115*(2).

Goodfriend, M. (2007). How the world achieved consensus on monetary policy. *The Journal of Economic Perspectives 21*(4), 47.

Goodfriend, M. and R. King (1997). The new neoclassical synthesis and the role of monetary policy. In *NBER Macroeconomics Annual 1997, Volume 12*, pp. 231–296. MIT Press.

Kahn, B. (2009). Challenges of inflation targeting for emerging-market economies: The south african case. *Challenges for Monetary Policy-makers in Emerging Markets*, 123.

Karadi, P. and A. Reiff (2012). Large shocks in menu cost models. Technical report, European Central Bank.

Laflèche, T. (1997). Mesures du taux d'inflation tendanciel. Technical report, Bank of Canada.

Mankikar, A. and J. Paisley (2004). Core inflation: a critical guide. *Bank of England. Quarterly Bulletin 44*(4), 466.

Millard, S. and T. O'Grady (2012). What do sticky and flexible prices tell us?

Mishkin, F. S. (2007). *Monetary policy strategy*.

Quah, D. and S. P. Vahey (1995). Measuring core inflation. *The Economic Journal*, 1130–1144.

Rangasamy, L. (2009). Inflation persistence and core inflation: The case of south africa. *South African Journal of Economics 77*(3), 430–444.

Rangasamy, L. (2011). Food inflation in south africa: Some implications for economic policy. *South African Journal of Economics 79*(2), 184–201.

Reiff, Á. and J. Várhegyi (2013). Sticky price inflation index: An alternative core inflation measure. Technical report, MNB Working Papers.

Roger, S. (1998). Core inflation: concepts, uses and measurement. *Reserve Bank of New Zealand Discussion Paper* (G98/9).

Roger, S. (2009). Inflation targeting at 20: Achievements and challenges. *IMF Working Papers*, 1–31.

Rossouw, J. and F. Joubert (2005). Supporting an inflation targeting policy with the measurement of inflation credibility. *South African Journal of Economics 73*(2), 321–336.

Rossouw, J. and V. Padayachee (2009). Measuring inflation credibility: Results of a first representative south african sample. *South African Journal of Economics 77*(2), 314–331.

Ruch, F. and D. Bester (2013). Towards a measure of core inflation using singular spectrum analysis. *South African Journal of Economics 81*(3), 307–329.

Ruch, F., N. Rankin, and S. du Plessis (2016). Decomposing inflation using micro-price-level data: South africa's pricing dynamics. *South African Reserve Bank Working Paper Series* (16/06).

Siklos, P. L. et al. (2016). Forecast disagreement and the inflation outlook: New international evidence. Technical report, Institute for Monetary and Economic Studies, Bank of Japan.

Svensson, L. E. (1999). Price stability as a target for monetary policy: Defining and maintaining price stability. *NBER Working Paper* (w7276).

Walsh, C. E. (2009). Inflation targeting: What have we learned?*. *International Finance 12*(2), 195–233.

Walsh, J. P. (2011). *Reconsidering the role of food prices in inflation*. International Monetary Fund.

Warne, A., G. Coenen, and K. Christoffel (2013). Predictive likelihood comparisons with dsge and dsge-var models. Technical report, European Central Bank.

Woodford, M. (2003). Interest and price.

Wynne, M. (1999). Core inflation: a review of some conceptual issues.

Wynne, M. (2008). How should central banks define price stability? *Available at SSRN 1734932*.