



Monetary Authority of Singapore

A Review of the Core Inflation Measure for Singapore

MAS Staff Paper No. 51

Aug 2011

A REVIEW OF THE CORE INFLATION MEASURE FOR SINGAPORE

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August 2011

*** THE VIEWS IN THIS PAPER ARE SOLELY THOSE OF THE AUTHORS AND SHOULD NOT BE ATTRIBUTED TO THE MONETARY AUTHORITY OF SINGAPORE. THE AUTHORS ACKNOWLEDGE THE SUPPORT AND GUIDANCE PROVIDED BY EDWARD ROBINSON THROUGHOUT THE PREPARATION OF THIS PAPER.**

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JEL CLASSIFICATION NUMBER: C22, E31, E52

KEYWORDS: Core inflation, Trend inflation, Inflation, Singapore

ABSTRACT

Apart from the headline consumer price index, most central banks around the world are guided by some measure of core inflation in their conduct of monetary policy to ensure price stability. This paper reviews such a measure for Singapore, the MAS Core Inflation, which has been used over the past two decades. Our analyses show that the MAS Core Inflation based on the exclusion approach remains the most appropriate for measuring core inflation in terms of policy accountability, as well as usefulness for policy formulation purposes. The study also reaffirms the strong grounds for excluding the costs of accommodation and private road transport from the core inflation measure in Singapore, as these are volatile and significantly influenced by administrative policies. Moreover, changes in the costs of these two items do not translate into changes in cash expenditures for most Singaporean households, given the high homeownership rate and long intervals between new car purchases for a typical consumer. Empirical tests also establish that the MAS Core Inflation measure fulfils the various criteria of a good core inflation measure — it is less volatile than CPI inflation but co-integrated with it. Further, it is a good measure of trend inflation and a relatively robust predictor of future headline inflation. Hence, the MAS Core Inflation measure continues to be an important indicator of price developments in Singapore that are driven by changes in underlying demand conditions, thereby providing useful information for monetary policymaking.

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1 INTRODUCTION

1.1 The primary objective of monetary policy in Singapore is to promote sustainable, non-inflationary economic growth. Most central banks in the industrialised countries similarly focus on keeping inflation low, recognising that price stability provides the best foundation for sustained economic development. Indeed, a number of them, such as the Reserve Bank of New Zealand, the Reserve Bank of Australia and the Bank of England, have “inflation targeting regimes” with explicit quantitative inflation targets.

1.2 Apart from the headline consumer price index (CPI), most central banks are guided by some measure of core inflation in their conduct of monetary policy (Appendix 1). For instance, the US Federal Reserve regularly refers to its principal measure of core inflation, which is the personal consumption expenditure price index (excluding food and energy), when explaining its monetary policy decisions. The Reserve Bank of Australia also utilises various core inflation measures to supplement the overall CPI inflation in justifying its policy decisions. The Bank of Canada employs a core inflation measure to predict future changes in the CPI, although it has an explicit quantitative target for headline CPI inflation.

1.3 For the past two decades, the Monetary Authority of Singapore (MAS) has closely monitored an underlying inflation measure, the MAS Core Inflation measure, which excludes the costs of accommodation and private road transport.¹ Along with headline CPI inflation, it has been used as a gauge of price pressures in the economy. The measure was last reviewed in 1998 and was found to be less volatile than, but co-integrated with, overall CPI inflation. The MAS Core Inflation measure also provides useful information on the underlying inflation process and can be used to forecast headline CPI inflation.

1.4 Nonetheless, given the significant changes in the global environment as well as the evolution of Singapore’s economic structure, it is timely to review the relevance and effectiveness of the MAS Core Inflation measure for the purpose of monetary policy formulation in Singapore. Section 2 briefly reviews the existing literature on the concept of core inflation. In Section 3, we discuss the different empirical approaches to measuring core inflation. A framework to evaluate the suitability of the various core inflation measures in Singapore’s context is then presented in Section 4. Section 5 revisits the

¹ The MAS underlying inflation was renamed MAS Core Inflation this year to bring it in line with international norms.

assumptions made in the construction of the MAS Core Inflation measure. In Section 6, we employ a series of statistical tests to evaluate the MAS Core Inflation against various criteria, including its volatility, ability to track trend inflation and predictive capabilities for future headline CPI inflation. Finally, Section 7 concludes.

2 LITERATURE REVIEW

2.1 The concept of core inflation was first introduced by Schreder (1952)² but it was only in the 1990s that the bulk of the research in this area was built up. The academic studies first sought to establish the fundamental underpinnings and definitions of core inflation. As the appeal of the concept gained traction, the focus shifted to establishing practical methods to derive the core inflation measure. Following the widespread adoption of the concept in monetary policymaking, researchers and policymakers turned their attention towards the assessment of core inflation measures' performance.

2.2 The literature identifies two characteristics of core inflation, which are that it must reflect both *persistent* and *generalised* price changes.

2.3 Milton Friedman (1963) defined inflation as a "... *steady and sustained* increase in the general price level". He noted the distinction between "... steady inflation, one that proceeds at a more or less constant rate, and an intermittent inflation, one that proceeds by fits and starts...". This distinction led Bryan and Cecchetti (1994) as well as Blinder (1997) to define core inflation as a measure that reflects persistent rather than temporary price changes. Indeed, the core inflation measure in many countries excludes the most volatile items, typically food and energy, in the CPI basket. This is particularly relevant for monetary policy which works with long and variable lags. In Singapore's case, MAS (2009) estimated that a 1% appreciation of the Nominal Effective Exchange Rate (S\$NEER) will lead to a 0.8% decline in the domestic CPI level over eight quarters. Hence, our monetary policy is generally not suited to address short-term fluctuations in prices.

2.4 Another characteristic of core inflation was first identified in Okun's (1970) definition of inflation as "... a condition of *generally* rising prices". Thus, measured inflation is taken to encompass a generalised or core inflation component and a relative price change component. Core inflation should capture generalised price movements that are common to all items and not changes in relative prices due to sector-specific factors, such as idiosyncratic supply shocks, or non-market influences, including government price controls and taxes.

² When discussing the United States inflation outlook back in the early 1950s, Schreder (1952) wrote that "even those who tend to agree with the concept of a rough balance between supply and demand, point out that there is still a huge money supply – and that is the hard core of inflation...over the long term basic economic factors, including prices, do tend to move in line with money supply".

2.5 In most cases, generalised price changes correspond to persistent inflation, as supply-driven relative price movements should only have a temporary impact on the overall inflation rate. Thus, the two conceptual characteristics of core inflation may not be very different in substance.

2.6 By highlighting the underlying price pressures, the core inflation measure plays two broad roles in monetary policy. First, it provides *policy accountability*, as it improves the transparency and communication of the monetary policy decision. For example, in the case of a transitory shock to prices, the core inflation measure could be used to explain the factors that caused headline inflation to deviate from trend inflation temporarily. This helps to minimise the risk of the temporary shock feeding into inflation expectations.

2.7 Second, core inflation serves as an important *input for monetary policy formulation*. Monetary policy actions taken to counter the inflationary or disinflationary consequences of demand disturbances also reduce deviations of economic activity around the potential level of output. If supply shocks lead to significant temporary price changes, monetary policy responses and their consequent impact on output will not be warranted if general demand conditions remain unchanged. Thus, central banks – even those with explicit inflation targets – need to distinguish between transient and persistent price changes, and between supply and demand shocks. In the case of a generalised and persistent price shock, the core inflation measure provides guidance that headline inflation has drifted towards a new mean and hence contributes to a better assessment of prevailing demand and supply conditions and, consequently, better policy-making.

3 EMPIRICAL APPROACHES TO MEASURING CORE INFLATION

3.1 Introduction

3.1.1 There are essentially two broad approaches to measuring core inflation in the literature. The first is based on time series information (values of a variable over time) while the second uses cross-section data (values of several variables at one point in time). The most frequently used methodologies in each category are shown in Table 3.1.

Table 3.1
Empirical Approaches to the Measurement of Core Inflation

Time Series	Cross-Section
<ul style="list-style-type: none"> • Specific Adjustment • Smoothing Techniques (Moving Averages) • VARs 	<ul style="list-style-type: none"> • Variability-adjusted Measures • Trimmed Mean • Dynamic Factor Index Model • Exclusion-Based Measures

3.2 Measures Based On Time Series Information

3.2.1 This approach attempts to remove the effects of temporary shocks using smoothing techniques or other statistical models to capture the persistent component of CPI inflation.

3.2.2 **Specific Adjustment:** When price shocks are considered to be one-off in nature, specific adjustment is usually applied to remove their effects. This technique has been used to separate the impact of changes in indirect taxes, subsidies or other government policies, but has been extended to deal with extreme events such as the oil crisis in the 1970s or exceptional exchange rate movements. However, there are high levels of subjectivity in both the types of shocks to adjust for and the magnitude of adjustment, which could in turn give rise to questions on the central bank's credibility with regard to monetary policy. Such difficulties prompted the Reserve Bank of New Zealand to abandon this measurement of core inflation in 1996.

3.2.3 **Smoothing Techniques:** The most common approach to removing the effects of temporary price movements is to apply smoothing techniques on high-frequency data. This involves taking the average of current and past headline inflation rates over a certain number of time periods to obtain the trend inflation. However, such a measure is typically dominated by past inflation, making it a more backward-looking indicator that is slow to capture

new turning points and signals in the data. Cecchetti (1997) proposed that a measure of price change over a three-month horizon offers the optimal signal-to-noise ratio - it removes the volatility inherent in monthly price data and minimises the loss of signals in the latest data points.

3.2.4 Vector Autoregressive (VAR) Models: Unlike the methods discussed above, core inflation measures that are derived from structural VAR models have theoretical underpinnings. Specifically, such models are based on the assumption that inflation is a process that results from perturbations to the economy over time. Quah and Vahey (1995) attempted to separate these perturbations into those that do not affect real variables in the long run (nominal demand shocks) and those that do (supply shocks). Given that core inflation is attributed to nominal demand shocks, it should therefore be uncorrelated with real variables in the long run. This concept of core inflation is consistent with the long-run vertical Philips curve, i.e. monetary shocks have no lasting impact on real variables but will affect inflation. While such models may be robust, the results are sensitive to the model specification. Besides, for any given choice of variables, the results will vary with the sample period selected. The results are also difficult to communicate as the differences between the headline and core inflation cannot be readily explained in terms of identifiable shocks. Given this, core inflation derived from VAR models are not widely adopted.

3.3 Measures Based On Cross Section Information

3.3.1 Measures utilising cross-sectional data attempt to separate price changes that are common to all individual goods and services from relative price changes that are the result of sector-specific dynamics. This is achieved through re-weighting the items in the CPI basket based on volatility or through the exclusion of some items.

3.3.2 Variability-adjusted Measure: Under this methodology, weights are assigned to the various price components based on their variability. For instance, Diewert (1995) proposed a variance weighted index called the Edgeworth Index, which was applied by Dow (1994) and Wynne (1997) to US consumer prices. It is calculated by weighting the individual price components by their volatility such that the most volatile components have the lowest weights. Such a measure has the advantage of not discarding any information as the entire set of prices within the CPI basket is retained when computing core inflation. While this method is systematic and does not rely on arbitrary adjustments, it is limited in its use for policy decisions as it disregards the expenditure weights of the underlying CPI basket. For

example, a component with a very small weight in the CPI may get a very large weight in the Edgeworth Index if its price has been stable. Besides, it is not totally transparent, particularly if adjustments are made on highly disaggregated data that are not released to the public. The Edgeworth Index may also be inherently inferior given the backward-looking way in which it decides which prices to down-weight. Indeed, Vega and Wynne (2003) found that such a measure underperforms traditional 'ex-food and energy' core inflation measures in various statistical tests for the Euro area.

3.3.3 Trimmed Mean or Median-based Measure: This stochastic method is premised on the non-normality of the inflation distribution, which makes the arithmetic mean an inefficient estimator of average price changes. For this measure, the CPI is re-weighted on a period-by-period basis and excludes, at each point of time, the items with the largest and smallest price changes. For instance, a 5% symmetric trimmed mean excludes the upper and lower 5% of the inflation distribution. Such a measure is thus able to filter out shocks from diverse sources on a timely basis. Numerous central banks such as New Zealand, Australia, Sweden and the United Kingdom regularly report such a measure of core inflation. However, for this indicator to be robust, highly disaggregated data is required which might not be publicly available. More importantly, the trimmed mean measure is not easily understood by the general public and cannot be forecasted. Consequently, it only serves as a supplementary price indicator for most central banks.

3.3.4 Dynamic Factor Index (DFI) Model: In the DFI model developed by Bryan and Cecchetti (1993, 1997) and Dow (1994), the individual sub-indices in the CPI are assumed to share a component that is subject to common disturbances. In addition, they each have an idiosyncratic component that reflects both relative price changes, which can arise from sector-specific supply shocks, and a systematic drift from the common component. Each sub-index is weighted according to the degree in which it is determined by the common component instead of its CPI basket weight. While such a measure may be a useful indicator of the general tendency in price changes, it may not necessarily correspond to the increase in the cost of living of a typical household. Besides, the technique employed is based on statistical considerations and the measure is relatively difficult to justify on economic grounds. The measure may also not be reliable over time as the weights are sensitive to the choice of the sample period.

3.3.5 Exclusion Measure: This measure of core inflation, widely adopted by many countries, is derived by excluding the CPI items whose prices are deemed to be particularly volatile or primarily supply-driven. In the developed

economies, the most often excluded items are energy and food products, which are heavily influenced by factors such as supply disruptions, seasonality or tax changes. Items that are subject to measurement biases – due to weighting schemes, problematic sampling techniques and quality adjustments – are also often excluded. For instance, the Statistics Bureau of Japan publishes the data for CPI excluding imputed rentals for owner-occupied accommodation due to the use of possibly non-representative samples. While the exclusion measure is intuitive and can be computed easily, there are also issues of subjectivity with regard to the items to be excluded and the level of disaggregation to use. If highly aggregated data is used, important information content may be lost together with the noises, resulting in a less informative inflation measure than headline inflation. Furthermore, there is a need to ensure that price changes of the excluded items do not have second order effects on the CPI and, hence, are truly not correlated with the persistent or general tendency of inflation.

4 EVALUATING THE APPROPRIATE CORE INFLATION MEASURE FOR SINGAPORE

4.1 To assess the appropriateness of each of the above mentioned measures in Singapore's context, we have identified a set of evaluation criteria based on the twin roles of a core inflation measure of providing policy accountability and serving as input for monetary policy formulation. (See Table 4.1)

Table 4.1
Evaluation (Qualitative) Framework for Measures of Core Inflation in Singapore

		Time Series Measures				Cross Sectional Measures		
		Specific-Adjustment	Smoothing	DFI	VAR	Variability-Adjusted	Trimmed Mean	Exclusion Based
Policy Accountability	Timeliness	✓	X	✓	X	✓	✓	✓
	Credibility							
	1. Can be externally verified	✓	✓	X	X	X	X	✓
	2. Easily understood	✓	✓	X	X	X	X	✓
	Exclusion of items beyond central bank's control	✓	X	X	X	X	X	✓
Input for the Formulation of Monetary Policy	Able to be forecasted	X	✓	✓	X	✓	X	✓
	Predictive ability for overall CPI inflation	?	X	?	?	?	?	?

4.2 In theory, the approaches discussed above produce robust measures of core inflation that are based on either statistical or economic considerations. However, to be useful for monetary policy, it is important that the chosen core inflation measure contributes to the transparency and policy accountability of a central bank.

4.3 In this regard, the measure must be readily available on a timely basis and released at the same frequency as CPI inflation. Otherwise, the measure has little value in explaining current policy or inflation outcomes. This implies that measures based on VAR models are not suitable, given the models' reliance on variables such as output, for which data are only available quarterly.

4.4 In addition, the core inflation measure should be simple to understand and can be replicated and verified by the public. By this criterion, the DFI model, variability adjusted and trimmed mean measures are not ideal. Apart from the difficulty in conveying the construction of the DFI and variability

adjusted measures to the general public in a non-technical way, deviations of such core inflation measures from the headline inflation also cannot be easily interpreted. In Singapore, 36 price indices, representing over 6,500 brand items in the CPI, are publicly available. Given this relatively high degree of aggregation in the data, the DFI and variability adjusted measures are also likely to be less informative of underlying inflation trends than headline CPI. This data limitation means that the trimmed mean measure is also not suitable as it will not be possible for external parties to replicate the index, thus raising transparency and creditability issues.

4.5 Apart from the backward-looking role that the core inflation measure plays in providing policy accountability, it should also be able to reasonably predict future inflation. This rules out the use of the smoothing technique as it relies on past data and is slow to capture new trends. Measures based on specific adjustment, VAR models and trimmed mean will also not qualify as they cannot be forecasted with a reasonable degree of confidence. In Singapore, as monetary policy has a medium-term orientation, the core inflation measure needs to be forecasted beyond the immediate months.

5 RE-EXAMINING THE MAS CORE INFLATION MEASURE

5.1 Based on the evaluation in the previous section, exclusion-based measures appear to be the most useful in terms of policy accountability as well as for policy formulation purposes (See Table 4.1). Indeed, almost all the key central banks adopt some form of exclusion-based measures as their 'official' core inflation series. (See Appendix 1) In Singapore's case, the core inflation measure is a key public communication tool in explaining MAS' policy decisions.³ It is therefore important that the core inflation measure chosen is transparent and can be forecasted and disclosed in a timely manner. An exclusion-based measure that is appropriately devised will meet these criteria.

5.2 Exclusion-based measures of core inflation typically remove the items whose prices are volatile and largely determined by supply disturbances or changes in government policies. The excluded items could include (a) food and energy; (b) interest payments; and (c) tobacco products. For instance, the US Federal Open Market Committee, in its semi annual *Monetary Policy Report*, projects changes in the core personal consumption expenditure deflator (i.e. excluding food and energy), while the European Central Bank publishes the headline Harmonised Index of Consumer Price inflation and five other measures of core inflation that exclude combinations of items which are either affected by supply disturbances or changes in government policy. In some instances, the most volatile prices were excluded outright in the core inflation measure. For example, the Bank of Canada uses the CPIX, which excludes the eight most volatile items in the CPI basket and adjusts for the effects of changes in indirect taxes on the remaining components of the CPI.

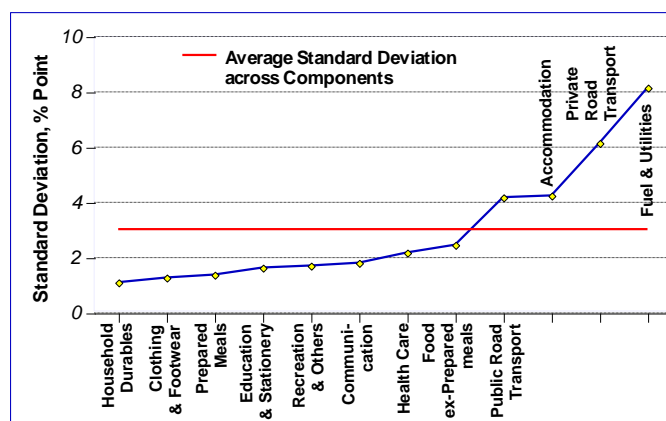
5.3 In Singapore's case, given our high degree of reliance on imported food and energy products, it will not be appropriate to exclude these items in the core inflation measure, even though they are often subject to supply disruptions. Not only do food and energy take up a fairly substantial weight in the CPI basket (27%), our exchange-rate centred monetary policy also has a direct bearing on their import prices.

5.4 Instead, the MAS Core Inflation measure excludes the costs of private road transport and accommodation. These are not only volatile but

³ This series is published on a monthly basis by the Department of Statistics (DOS) in its CPI release (www.singstat.gov.sg/pubn/catalogue.html#prices) and the MAS in its Inflation Monthly report (www.mas.gov.sg/eco_research/eco_dev_ana/Inflation_Monthly.html). A longer time series is available in the MAS' *Macroeconomic Review* (www.mas.gov.sg/publications/macro_review/index.html)

are also largely driven by administrative policies – and hence, are not always indicative of underlying demand conditions. (See Chart 5.1)

Chart 5.1
Standard Deviation of Quarterly Y-O-Y Changes of CPI Components,
Q1 1990- Q4 2010



5.5 Treatment of private road transport costs: In Singapore, a vehicle quota system is used to keep the vehicle population in check. Hence, the costs of private road transport are largely policy-driven, and particularly influenced by changes in the supply of Certificates of Entitlement (COEs). (See Chart 5.2) Indeed, as a result of the changes in the motor vehicle policy in the last two decades, private road transport costs have been among the most volatile component in the CPI basket.⁴ (See Chart 5.1) Private road transport costs also include administrative charges such as road tax and Electronic Road Pricing (ERP) charges (under other running costs). (See Table 5.1) Changes in the prices of these items are similarly motivated by other policy considerations and may not entirely reflect underlying demand influences.

⁴

The most volatile item in the CPI basket is the cost of fuel and utilities, which is highly correlated with global oil prices.

Chart 5.2
Monthly Quota of COEs for Cars and Private Road Transport Costs

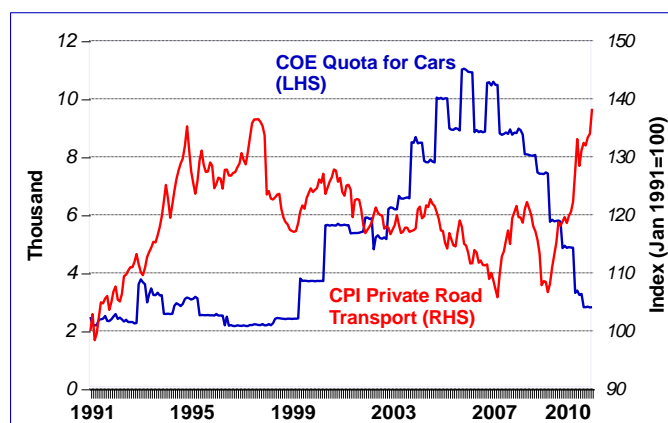


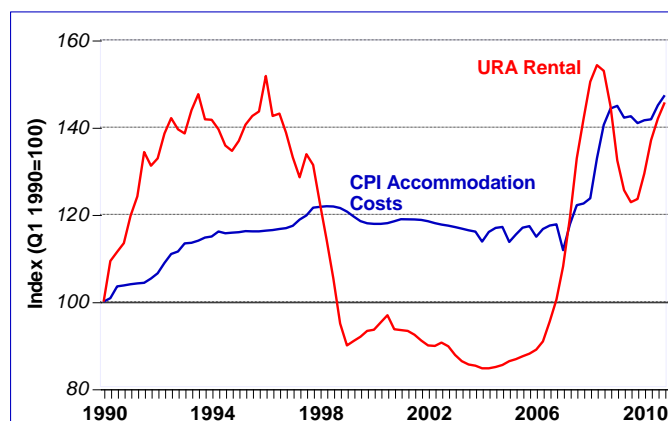
Table 5.1

Items Excluded from MAS Core Inflation (Weight)	
Accommodation (20.02%)	Private Road Transport (11.66%)
<ul style="list-style-type: none"> • Rented accommodation (1.85%) • Owner-occupied accommodation (15.64%) • Minor repairs and maintenance (2.53%) 	<ul style="list-style-type: none"> • Purchase of vehicles (6.03%) • Repairs and maintenance & purchase of spare parts (0.65%) • Other running costs (4.98%)

5.6 Treatment of accommodation costs: The exclusion of accommodation costs when the MAS Core Inflation was first introduced was due in large part to the way in which the cost of owner-occupied housing (OOH) was computed. (MAS 1998) At that time, the pricing indicator used to compute OOH cost was the Annual Values (AVs), which were estimated by the Inland Revenue Authority of Singapore (IRAS) for property tax purposes. The revisions to HDB AVs were infrequent and influenced by policy considerations. However, these issues related to the use of AVs have become irrelevant since the 2009 CPI-rebasing exercise as DOS has switched to monthly market rental data from IRAS as the pricing indicator for OOH cost in the CPI. As such, the accommodation costs in the CPI are now more reflective of current market developments.⁵ (See Chart 5.3)

⁵ DOS revised the OOH price series back to 2008 using the new methodology. For further details, please see DOS' information paper titled "The Rebasing of the Consumer Price Index (Base Year 2009 = 100)". (<http://www.singstat.gov.sg/pubn/papers/economy/ip-e36.pdf>)

Chart 5.3
CPI Accommodation Costs and URA's Private Residential Property Rental Index⁶



5.7 Nonetheless, there remains a case for the exclusion of accommodation costs from the core inflation measure given the high level of home ownership in Singapore.⁷ Thus, developments in the rental market, while impacting accommodation costs in the CPI, will not lead to changes in actual cash outlays for a large majority of households.

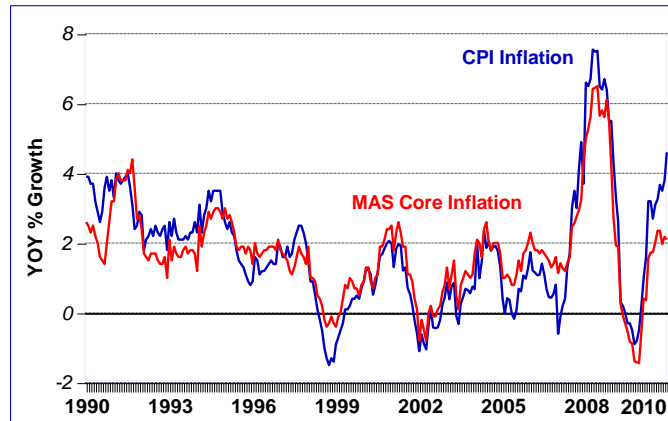
5.8 In addition, CPI accommodation costs are significantly influenced by government rebates such as those for Service & Conservancy Charges and rentals. As the amount of rebates disbursed by the government fluctuates greatly from month to month, CPI accommodation costs have been the third most volatile category within the CPI basket. (See Chart 5.1)

5.9 The MAS Core Inflation has served its purpose as a core inflation measure reasonably well, being less volatile than CPI inflation and tracking it closely over the years. (See Chart 5.4) Despite recent improvements in DOS' methodology for computing the cost of OOH in the CPI, the above qualitative arguments also suggest that there remain strong grounds for the core inflation measure to exclude the costs of accommodation and private road transport in Singapore's context. However, further statistical tests should be performed to determine whether the MAS Core Inflation measure is a truly good indicator of trend inflation and contains reasonable levels of information content for forecasting headline inflation.

⁶ CPI accommodation costs also include the costs of rented and owner-occupied HDB accommodation and minor repairs and maintenance. However, as there is no publicly available market HDB rental index over a sufficiently long time horizon, this chart only includes the URA rental index for private residential property.

⁷ 87% of resident households in Singapore own their homes in 2010. As a result, the OOH component takes up a substantial 15.6% weight in the CPI basket while rented accommodation accounts for a mere 1.9% share.

Chart 5.4
Overall CPI and MAS Core Inflation



6 STATISTICAL TESTS OF THE CORE INFLATION MEASURE

6.1 Volatility

6.1.1 In the series of empirical tests that follow, year-on-year changes of overall CPI and MAS Core Inflation were used. All the empirical tests were conducted using quarterly data over the period Q1 1990 to Q4 2010.

6.1.2 Given that core inflation should not be affected by transitory relative price movements, one would expect it to be more stable than overall headline inflation. Indeed, the standard deviation of the MAS Core Inflation measure was lower than that of the overall CPI inflation over the periods of 1990-99 and 2000-10. (See Table 6.1) In addition, the average rate of MAS Core Inflation and overall CPI inflation over these periods were similar even as the two measures diverged in the short run.

Table 6.1
Measures of Volatility

Sample Period	Inflation Measure	Standard Deviation of Quarterly Inflation Rate, % point	Average Annual Inflation Rate, %
1990-99	Overall CPI	1.3	1.9
	MAS Core Inflation	1.0	1.8
2000-10	Overall CPI	2.0	1.6
	MAS Core Inflation	1.6	1.7
1990-10	Overall CPI	1.7	1.8
	MAS Core Inflation	1.3	1.7

6.2 Co-Integrating Relationship Between Headline and Core Inflation

6.2.1 A desirable property of a core inflation measure is that it should move together with headline inflation in the long run, i.e. they have an equilibrium relationship. This is equivalent to testing for the presence of a co-integrating relation between headline and core inflation.

6.2.2 The test for co-integration involves two steps. The first step is to ascertain that the headline and core inflation measures are non-stationary, i.e.

they contain unit roots.⁸ The results of the Augmented Dickey-Fuller (ADF) test, as shown in Table 6.2, indicate that unit roots are present in both headline CPI inflation and MAS Core Inflation.

Table 6.2
Augmented Dickey-Fuller Unit Root Test Results (1990-2010)

	ADF Test Statistic	P-value
Overall CPI Inflation	-2.26	0.19
MAS Core Inflation	-2.82	0.06

The ADF test statistics are compared with the 5% critical value of -2.87 for the null hypothesis that the series contains a unit root. The null hypotheses for both overall CPI inflation and MAS Core Inflation are not rejected.

6.2.3 In the next step, we tested for co-integration between the MAS Core Inflation measure and overall CPI inflation using the Engle-Granger (1987) residual-based test procedure. It is essentially a unit root test on the residuals from equation (1) below.⁹ If CPI inflation, π_t , and core inflation, π_t^c , are individually non-stationary and are co-integrated, the residual ε_{1t} , will be stationary.

$$\pi_t = \alpha_1 + \beta_1 \pi_t^c + \varepsilon_{1t} \quad (1)$$

6.2.4 The test results, summarised in Table 6.3, show that the MAS Core Inflation and headline CPI inflation are co-integrated with a coefficient that is close to unity.

Table 6.3
Engle-Granger Co-integration Test Results (1990-2010)¹⁰

	Coefficient	t-stat	ADF test statistic for residual
MAS Core Inflation	1.19	24.05	-3.97

The ADF test statistic is compared with the 5% critical value of -3.34 . The null hypothesis that the residual series contains a unit root is rejected.

⁸ A stationary series is one with constant mean and variance and autocovariances that only depend on the distance between observations. A meaningful co-integrating relationship can only exist between two non-stationary series.

⁹ A dummy variable for 2010's quarterly observations was used. Due to the government's tightening of the vehicle population policy, COE premiums surged and caused an unprecedented divergence between overall CPI inflation and MAS Core Inflation.

6.2.5 In addition, we use the Hodrick-Prescott filter to estimate trend inflation, and then determine the divergence of core and headline inflation, i.e. root-mean-squared-errors (RMSE), from this trend. (See Table 6.4) The results show that the MAS Core Inflation measure has tracked trend inflation more closely than headline CPI inflation, especially in the recent decade.

Table 6.4
RMSE of Inflation Measures Compared with Trend Inflation Derived from Hodrick-Prescott Filter, % point

	Overall CPI Inflation	MAS Core Inflation
RMSE (1990-99)	0.69	0.67
RMSE (2000-10)	1.69	1.54
RMSE (1990-2010)	1.32	1.24

6.3 Ability to Measure Trend Inflation

6.3.1 The above tests were performed to examine whether the MAS Core Inflation measure diverges from headline inflation significantly over the long run and also whether it *tracks* trend inflation well. A more stringent test would be to assess whether the MAS Core Inflation is a good *measure* of trend inflation.

6.3.2 Based on the work of Marques et al (2003), trend inflation should satisfy the following criteria:

- a. The trend and headline inflation rates should evolve on the same path in the long run. This means that both trend inflation and headline inflation are non-stationary processes and are co-integrated with a unitary coefficient. This requirement has already been examined in section 6.2.
- b. The headline inflation rate tends to converge to the trend inflation rate. Thus, the adjustment coefficient of the error-correction term (β_2) in equation (2), which has the first difference of headline inflation as the dependent variable, should be negative and statistically significant.

$$\Delta\pi_t = \alpha_2 + \beta_2(\pi_{t-1} - \pi_{t-1}^{trend}) + \delta_i \sum_{i=1}^k \Delta\pi_{t-i} + \varepsilon_{2t} \quad (2)$$

- c. The trend inflation rate should not converge to the headline inflation rate, implying that the trend measure is exogenous. This means the adjustment coefficient of the error correction term (β_3) should be statistically insignificant in equation (3).

$$\Delta\pi_t^{trend} = \alpha_3 + \beta_3(\pi_{t-1} - \pi_{t-1}^{trend}) + \gamma_i \sum_{i=1}^k \Delta\pi_{t-i}^{trend} + \varepsilon_{3t} \quad (3)$$

6.3.3 The estimation results of using the MAS Core Inflation as the trend inflation measure are satisfactory, as shown in Table 6.5. The adjustment coefficient on the error correction term in equation (2) is negative and statistically significant while that for the error correction term in equation (3) is not statistically significant. These suggest that while headline CPI inflation converges to the MAS Core Inflation, the converse is not true.

Table 6.5
Error Correction Model for Testing MAS Core Inflation Measure

	Equation 2	Equation 3
Dependent Variable	$\Delta\pi_t$	$\Delta\pi_t^{trend}$
Coefficient on $(\pi_{t-1} - \pi_{t-1}^{trend})$ (Adjustment Coefficient)	-0.3276 (-2.504)**	-0.0417 (-0.366)
Coefficient on $\Delta\pi_{t-1}$	0.5800 (5.354)**	-
Coefficient on $\Delta\pi_{t-1}^{trend}$	-	0.5256 (4.913)**
Adjusted R-square	0.3758	0.3267

The t-statistics are in parentheses.

** indicates the coefficient is statistically significant at the 5% level.

6.4 Ability of MAS Core Inflation to Predict Headline CPI Inflation

6.4.1 This section appraises the ability of the MAS Core Inflation to forecast headline inflation over a horizon of one to three years. A univariate forecasting equation of the following form was used:

$$\pi_t^k = \alpha_4 + \beta_4 \pi_t^c + \varepsilon_{4t} \quad (5)$$

where $\pi_t^k = \frac{(\ln CPI_{t+k} - \ln CPI_t)}{k}$, with k being 1, 2 or 3 years

π_t^c = either MAS Core Inflation or headline CPI inflation

6.4.2 The forecast variable of interest, π_t^k , is the overall CPI inflation over longer horizons to remove short term “noise”. The forecast performances of the MAS Core Inflation measure and headline CPI inflation, at 1, 2 and 3-year horizons are expressed as RMSEs in Table 6.6. The MAS Core Inflation measure is shown to be a better predictor of longer-term inflation in general, compared to the overall CPI inflation.

Table 6.6
RMSE of Inflation Forecasts Generated by CPI Inflation and
MAS Core Inflation (For Forecasting Horizon of 1, 2 and 3-years), % point

	Overall CPI Inflation	MAS Core Inflation
1990-1999	<i>k</i> = 1	
	1.06	1.03
	<i>k</i> = 2	
	0.83	0.81
	<i>k</i> = 3	
	0.60	0.60
2000-2010	<i>k</i> = 1	
	1.02	0.99
	<i>k</i> = 2	
	1.34	1.28
	<i>k</i> = 3	
	1.07	1.03
1990-2010	<i>k</i> = 1	
	1.28	1.25
	<i>k</i> = 2	
	1.15	1.11
	<i>k</i> = 3	
	0.92	0.88

7 CONCLUSION

7.1 This paper reviews the usefulness of the MAS Core Inflation measure for Singapore. Our analyses show that the MAS Core Inflation based on the exclusion approach remains the most appropriate to measure core inflation in terms of policy accountability as well as usefulness for policy formulation purposes. In addition, there remains strong grounds for the MAS Core Inflation measure to exclude the costs of accommodation and private road transport, as they are volatile and significantly influenced by administrative policies. Further, the CPI accommodation costs do not represent actual cash outlays for the large majority of households which own their homes. Changes in COE premiums, and hence CPI private road transport costs, also do not affect the cash expenditures of most households unless they are buying new cars.¹¹

7.2 Furthermore, the tests conducted in section 6 established that the MAS Core Inflation measure fulfils the various criteria for a good core inflation measure. Indeed, MAS Core Inflation is less volatile than CPI inflation and is co-integrated with the latter. Further, headline CPI inflation is found to have the tendency to converge to the MAS Core Inflation, but the converse is not true. All these suggest that the MAS Core Inflation is a good measure of trend inflation. In addition, the property of headline inflation converging to the core inflation implies that price changes of the two excluded categories – accommodation and private road transport- notwithstanding the short term volatility induced by policy shifts, are similar to the underlying price developments in the rest of the CPI basket in the long run. Finally, our tests showed that the MAS Core Inflation measure is a relatively robust predictor of future headline inflation.

7.3 In conclusion, notwithstanding significant changes in the global environment and the evolution of the Singapore economy in the last two decades, the MAS Core Inflation measure continues to be an important indicator of price developments in Singapore that are driven by changes in underlying demand conditions, thereby providing useful information for monetary policymaking.

¹¹ The proportion of the annual COE quota to the number of resident households fell to 3.7% in 2010, the lowest in more than a decade.

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APPENDIX 1**CORE INFLATION MEASURES PUBLISHED BY SELECTED NATIONAL STATISTICAL OFFICES AND CENTRAL BANKS****STATISTICAL OFFICES**

Office	Core Inflation measure
Australian Bureau of Statistics	CPI less: <ul style="list-style-type: none"> • each of the category groups, • housing and financial and insurance services • hospital and medical services • 'volatile items' (fruit and vegetables and automotive fuel)
Bureau of Labor Statistics (United States)	All items less: <ul style="list-style-type: none"> • food and energy • energy • food • shelter • medical care
Department of Statistics (Singapore)	CPI less: <ul style="list-style-type: none"> • Accommodation
Japan	General excluding: <ul style="list-style-type: none"> • fresh food • imputed rent • food (excluding alcoholic beverages) and energy
Office of National Statistics (United Kingdom)	CPI excluding: <ul style="list-style-type: none"> • indirect taxes • energy • energy, food, alcoholic beverages and tobacco • energy and unprocessed food • seasonal food • energy and seasonal food • tobacco • alcoholic beverages and tobacco • liquid fuels, vehicle fuels and lubricants • housing, water, electricity, gas and other fuels • education, health and social protection RPI excluding: <ul style="list-style-type: none"> • mortgage interest rates • housing • mortgage interest rates and indirect taxes • mortgage interest payments and depreciation • energy • energy, food, alcoholic beverages and tobacco • seasonal food • food
Statistics Canada	All-items excluding: <ul style="list-style-type: none"> • food • food and energy • gasoline • eight of the most volatile components (as defined by the Bank of Canada)

CENTRAL BANKS

Agency	Core Inflation Measure
Bank of Canada	<ul style="list-style-type: none"> • Core CPI – excludes from the all-items CPI the effect of changes in indirect taxes and eight of the most volatile components identified by the Bank of Canada: fruit; fruit preparations and nuts; vegetables and vegetable preparations; mortgage interest cost; natural gas; fuel oil and other fuels; gasoline; inter-city transportation; and tobacco products and smokers' supplies • CPI excluding food, energy and the effect of changes in indirect taxes • Weighted median • 1.5 standard deviation trimmed mean • Doubled weight measure (adjusted to exclude changes in indirect taxes) • Chain price index for consumption • Chain price index for consumption excluding food and energy • Chain price index of GDP
Bank of England	<ul style="list-style-type: none"> • RPI excluding mortgage interest payments and first round effects of indirect taxes • RPI excluding import prices
Bank of Thailand	<ul style="list-style-type: none"> • CPI excluding raw food and energy
Bank Indonesia	<ul style="list-style-type: none"> • CPI excluding administered prices and volatile food
Bank Negara Malaysia	<ul style="list-style-type: none"> • CPI excluding price-volatile and price-administered items
Cleveland Federal Reserve	<ul style="list-style-type: none"> • Weighted median • 16 percent trimmed mean • CPI excluding eight components • Private consumption expenditure implicit price deflator excluding food and energy
European Central Bank	<p>Harmonised Index of Consumer Prices (HICP) excluding:</p> <ul style="list-style-type: none"> • Energy • Energy, food, alcohol and tobacco • Tobacco • Energy and seasonal food • Energy and unprocessed food <p>Persistence weighted measures of core inflation (the importance of each component of the HICP is reweighted according to its relative persistence, as measured by the sum of the autoregressive coefficients or by an indicator of mean reversion)</p>
Reserve Bank of Australia	<ul style="list-style-type: none"> • CPI excluding mortgage rates, interest charges for loans on consumer products and prices of foods like meat and fish • 30 percent trim • Weighted median
Reserve Bank of New Zealand	<ul style="list-style-type: none"> • CPI excluding commodity price shocks, government charges or taxes and interest components