South African Reserve Bank
Working Paper Series
WP/20/07

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Authorised for distribution by Witness Simbanegavi

September 2020

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September 1, 2020

Abstract

The 'Phillips curve' is a commonly used benchmark for modelling inflation, based on the intuition that greater economic slack (i.e. a larger output gap) should be associated with decelerating inflation. But there is an ongoing debate about the usefulness of the Phillips curve to explain inflation. Explanations for an observed weakening between measures of slack and inflation have included: mismeasurement of economic slack, the influence of other factors (such as the exchange rate, foreign inflation or wages) or whether some components of the inflation basket are more sensitive to the business cycle than other. To advance this discussion, we consider an augmented Phillips curve specification that accounts for various drivers of inflation and test different measures of economic slack in forecasting inflation and GDP outcomes. We show that a Phillips curve relationship continues to exist in South Africa. We find the slack measure that performs best is one that includes labour market indicators and indicated low capacity pressure at the end of the sample (2019Q3). While the output gap-inflation channel continues to operate, the contributions to inflationary pressures of factors such as past inflation and inflation expectations have been much more important over recent years.

JEL Classification:E27,E31,E37

Keywords: Phillips curve, output gap, real-time estimation

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1 Introduction[1]

The Phillips curve is a key concept in models of inflation and captures the degree to which economic slack (measured using unemployment or the output gap)[2] affects inflation. An important puzzle in South Africa has been why a persistently negative output gap has not translated into even lower inflation after the Global Financial Crisis (GFC). Many advanced economies have recently experienced levels of unemployment below levels perceived as 'neutral' (i.e. levels consistent with inflation at the inflation target) without seeing inflation pick up as would usually be expected. The relative stability of global inflation in spite of substantial fluctuations in unemployment recently has led to questions around whether the Phillips curve has flattened and become less useful as a guide for monetary policy.[3]

In the South African context, several recent papers have pointed out that inflation has shown little response to persistently negative output gaps since the Global Financial Crisis (GFC). These papers provide a range of different explanations for why a persistently negative output gap has not translated into even lower inflation. These included: mis-measurement (Fowkes et al. 2019) or time-variation (Kabundi et al. 2016) of the output gap, non-linearity in the economic slack-inflation relationship (Nell 2018[4]), the influence of other factors (such as the exchange rate, foreign inflation or wages, see Burger and du Plessis 2014, Reid and du Rand 2015 or Fedderke and Liu 2018[5]), and that some consumer price index (CPI) components are more sensitive to the business cycle than others (Radebe 2019).

This paper compares different Phillips curve specifications to see which of these explanations provide the best fit of the data. We start by testing different measures of

[1]We thank David Fowkes and two anonymous referees for useful comments.

[2]The output gap is a measure of the degree of economic capacity pressures and is used to forecast inflation pressures.

[3]For the United States, Jorda et al. (2019) suggest that changes in economic slack have had virtually no impact on the dynamics of US inflation before and after the GFC, while inflation persistence has declined considerably (so that unanticipated spikes in inflation pass-through strongly to future inflation) and the contribution of future expectations has risen substantially. The implication for US monetary policy is that anchoring inflation expectations at the inflation target is crucially important. This is consistent with the recent experience of most OECD economies, where the Phillips curve has flattened, inflation has become more stable and inflation expectations have become more anchored over time (see Blanchard et al. 2015 for example).

[4]It is possible that the relationship between slack and inflation could change depending on the state of the economy or the level of inflation. Findings of non-linearity in the South African Phillips curve appear to be driven by a few significant inflation spikes during periods of large output gaps when inflation was also unusually high (see South African Reserve Bank 2017 for a discussion).

[5]Burger and du Plessis (2014) estimate different New Keynesian models that emphasise a relationship between marginal costs and inflation. Fedderke and Liu (2018) suggest that unit labour costs are a more important determinant of inflation pressure than indicators of demand-pressures. Reid and du Rand (2015) present results for various alternative demand proxies.

economic slack in forecasting inflation and GDP outcomes. Thereafter, we consider the ability of various augmented Phillips curve specifications to explain inflation behaviour. What sets this paper apart from previous research is that we compare several measures of economic slack, explicitly consider the influence of inflation expectations, the persistence of inflation and external factors, as well as different labour market indicators to explain inflation dynamics. Specifically, we provide an assessment of the stability of the Phillips curve relationship:

- Using several slack metrics, including a composite measure that incorporates labour market indicators;
- Using several measures of inflation, including using components of CPI instead of just the headline or core[6] series;
- Considering different specifications of the Phillips curve relationship, including inflation expectations, the exchange rate, global import prices, wages or unit labour costs (ULC).

There are also often arguments among policymakers about which measure of the output gap best describes current and historical slack in the economy and therefore should guide assessment of the appropriateness of the stance of monetary policy, both currently and historically. Revisions to GDP data also mean that output gap estimates in real time (ie. based on data available at the time of estimation) can be quite different from ex-post estimates (ie. when final data is available). Because the output gap is unobservable and must be estimated, the estimation technique used can also have a significant impact on the estimate produced. This is the first paper that compares the real-time and ex-post ability of a range of measures of slack to explain inflation outcomes in South Africa.

For forecasting GDP, the most successful measure of slack is the Comprehensive Activity Index (CAI), which includes labour market indicators (employment, unemployment and labour force participation). Strikingly, the output gap measure used for monetary policy committee forecasts is the worst-performing of the measures tested. For inflation, all measures of slack have tended to over-estimate inflation pressures since 2016, reflecting the impact of factors unrelated to slack. Nevertheless, we show that a Phillips curve relationship continues to exist in the data, and that the Phillips curve specification used in the Reserve Bank's quarterly projection model explains inflation dynamics well, particularly when using the CAI as the measure of slack in the model. The results suggest, however, that other variables in the Phillips curve (such as past inflation and inflation expectations) have been much more important drivers of inflation dynamics over recent years.

[6]Core inflation is defined as headline inflation minus fuel (petrol and diesel), electricity, and food inflation.

2 Comparison of real-time and ex-post estimates

Since the output gap is unobservable and must be estimated, the estimation technique used can have a significant impact on the estimate produced. The other output gap estimates we consider are a (pseudo)[7] real-time (ie. only latest available vintage) HP-filter, a finance-neutral real-time (ie. vintages available in each period) output gap (unadjusted for supply shocks, Anvari et al. 2014), and the ex-post (ie. final data vintage) CAI, which includes several labour market indicators and is estimated using the approach of Stock and Watson 2019 (details in Appendix A).

Revisions to GDP data mean that output gap estimates in real-time (ie. based on data available at the time of estimation) can be quite different from ex-post estimates (ie. when all final data is available).[8] For this reason, we compare the real-time official gap (summarises the latest Reserve Bank estimate of slack at each point in time) to an ex-post equivalent (summarising the current Reserve Bank view of the evolution of slack).

Figure 1 plots the official output gap (ex-post) against the real-time (unrevised) gap and alternative slack estimates. Before the GFC, the Reserve Bank under-estimated the extent of capacity pressures, compared to its current view of history, with its estimates gradually revised upwards over time. However, since the GFC, the opposite has been true: official real time output gap estimates have been much more negative post-GFC compared with the other measures and revised to be less negative over time. During the pre-GFC boom, for example, the official estimates show that Reserve Bank expected that excess demand would be eliminated over subsequent quarters, and under-estimated the persistence of the boom. With the benefit of hindsight, the Reserve Bank now estimates that the output gap peaked at about 3 percent instead of 2 percent according to the real-time estimates. Like many other central banks, the Reserve Bank assumed that potential growth was lower than it now believes it was. The Bank therefore under-estimated capacity pressures during the boom, gradually ratcheting up its estimate of the output gap.

[7] A 'pseudo' real time forecast is based on the latest vintage of data, whereas a 'true' real time forecast is based on the data vintages that were available at each forecast date.

[8] Note that inflation data is not usually revised so the distinction between ex-post and real time does not apply to inflation. There was, however, a one-off revision on 30 May 2003 which affected the inflation rate for the period January 2002 to March 2003 which is ignored in this paper.

Figure 1: Output gap estimates

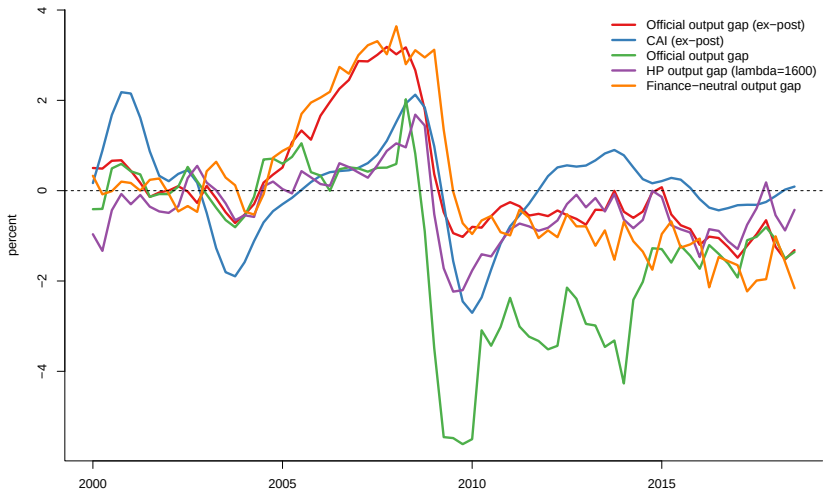
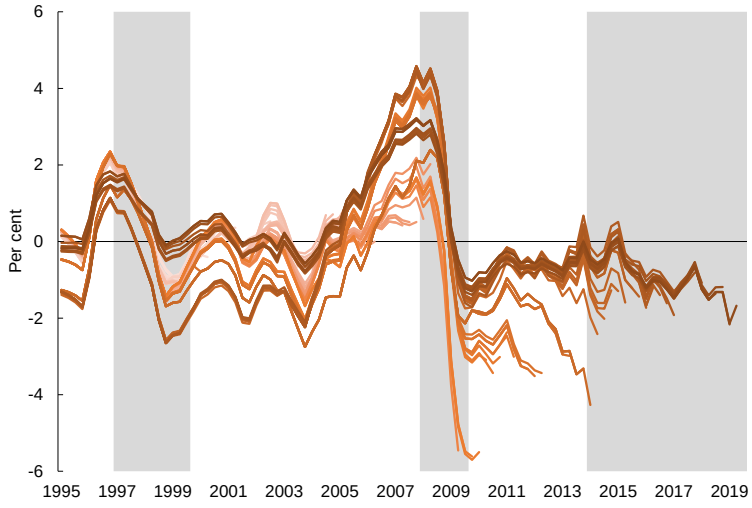


Figure 2: Vintages of real time output gap estimates



Shaded areas indicate official downward phases of the business cycle identified by the SARB.

3 The benchmark Phillips curve specifications

Output gaps estimates provide assessment of the degree of economic capacity pressures, which can be used to forecast inflation. The baseline specification for the Phillips curve that we use is that of the Reserve Bank's quarterly projection model (QPM, see

Botha et al. 2017). The current 'official' gap used by the Reserve Bank is a finance-neutral output gap, adjusted for supply shocks (based on Botha et al. 2018, although the methodology has evolved over time, see Anvari et al. 2014 for discussion of earlier approaches). The following specification is used:

$$\pi_t = a_1\hat{y}_t + a_2\pi^e_{t-1} + a_3\pi_{t-1} + a_4\pi^*_t + a_5\widehat{rulc}_t + a_6\widehat{rer}_t + \varepsilon_t \quad (1)$$

where headline inflation π_t (year-on-year) is explained by:

- the output gap ($\hat{y}_t$ in percentage deviation),
- a one-quarter lag of two-year ahead inflation expectations (π^e_{t-1}, as surveyed by the Bureau of Economic Research),
- a one-quarter lag on inflation (π_{t-1}) to capture inflation persistence,
- foreign inflation (π^*_t), summarising external price pressures from the inflation rate of imported final goods (proxied by foreign producer price inflation in rand terms),
- the real unit labour cost gap ($rulc_t$) which is based on the cyclical deviation in real wages from labour productivity and is intended to capture the impact of labour market slack,
- the real exchange rate gap ($\widehat{rer}_t$) from equilibrium (percentage deviation),[9]

The main difference to the QPM specification is that we use 2 year ahead inflation and not *blended* expectations since we use year-on-year inflation.[10]

4 A real-time forecasting exercise

One metric of the usefulness of an output gap estimate is its ability to forecast future GDP growth and inflation. The reason that this is a worthwhile exercise is that, one would expect that if the current output gap is negative, for example, GDP growth should pick up in future as the economy returns to its potential growth rate. In this sub-section,

[9]The Reserve Bank's exchange rate equilibrium is estimated using a filtering approach and tuned to be in line with a suite of satellite models.

[10]In QPM, a homogeneity requirement is applied to $\pi^e_t + \pi_{t-1}$. Our focus in this paper is on assessing whether there is a relationship between different measures of aggregate inflation and measures of economic slack, so we ignore the distinction that QPM draws between core and non-core inflation components. We also use producer price inflation instead of consumer price inflation to represent foreign inflation as we argue this better represents import prices.

we compare the ability of different slack measures to forecast GDP growth and inflation. Our comparison will be against the current (ex-post) output gap to assess whether having adopted the current view of the historical business cycle would have improved the Bank's forecasts of final vintage GDP (since this is ultimately what policymakers care about). Following Armstrong (2015), we forecast GDP growth and inflation as follows:

$$y_{t+h} - y_t = \beta_0 + \beta_1 X_t + \varepsilon_t \tag{2}$$

where y_{t+h} is either the h-quarter ahead forecast of GDP expressed in logarithmic form or the CPI inflation rate in year-on-year terms, and X_t is an output gap measure over a sample spanning 1995Q1-2019Q3 (except in the case of the CAI which starts in 1996Q1). We calculate the mean square forecast error (MSFE) and mean absolute forecast error (MAFE) relative to the performance of real-time official gap as benchmark.

Figure 3 shows that the relative MSFE and MAFE are lowest for the CAI, implying it provides an output growth forecast that is about 25 percent better at a six quarter horizon than the real time official gap. Diebold and Mariano (1995) tests confirm that the CAI's out-performance is statistically significant at a 4 quarter horizon (Table 5 in the Appendix). Nevertheless, all the measures under-estimated GDP growth in the lead-up to the GFC and over-estimated GDP growth in real time post-GFC (Figure 4).[11]

For headline inflation on the other hand, the relative MSFE and MAFE are lowest for official ex-post gap (especially over the long-term, while the real times gap performs better than the CAI (Figure 5). However, these differences are not significant at a 4 quarter horizon (Table 5). Both in the lead up to the GFC and since the GFC, the real-time gaps produced relatively large forecast errors when forecasting the change in inflation at both 1-quarter and 1-year ahead horizons (Figure 6). In the lead up to the GFC, all the gaps under-estimated the upward trajectory of inflation changes, while in the immediate aftermath of the GFC the real-time official gap produced the weakest inflation forecasts. That said, the differences in forecast performance are small and averaging across output gap measures could enhance the performance at some horizons. For core inflation, the HP gap performs best at all horizons (and significantly better than the real-time official gap at 1 quarter ahead). Lastly, we also consider the ability of the slack measures to forecast our Cyclically Sensitive Inflation (CSI) Index, which weighs components of CPI together based on their joint co-movement to the CAI measure of economic slack (see details in Appendix A). The official ex-post gap forecasts cyclical inflation best at short horizons (though all measures outperform the official real-time gap) (Table 5).

[11] GDP revisions in South Africa have generally been to the upside, but have been relatively small and may not substantially change these results. We also checked that β_1 for each regression was negative, for example that a negative real-time output gap should forecast higher future GDP growth, and vice versa. Part of the explanation for the poor forecast performance of the official output gap measures is how unusually persistent recent business cycles have been.

A striking finding is that most slack measures outperform the official real-time gap at forecasting. Overall, this exercise suggests that no single output gap provides the best assessment of the state of the economy across all relevant dimensions and there may be value in looking at a suite of estimates. This also suggests that factors unrelated to slack have had a meaningful impact on inflation outcomes post-GFC.

Figure 3: GDP growth forecasts relative to using official real-time output gap (quarters ahead)

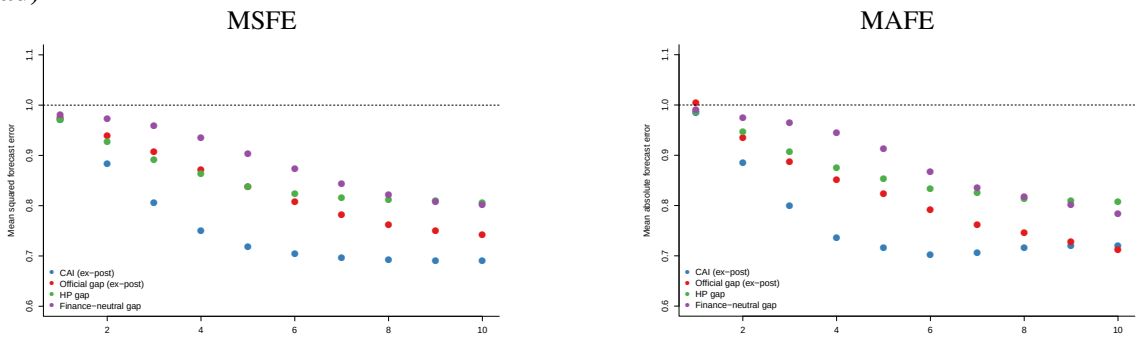
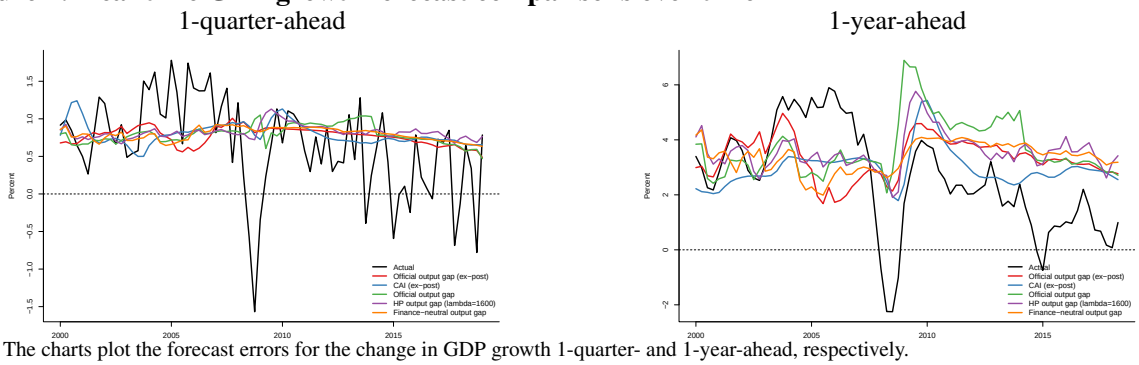


Figure 4: Real-time GDP growth forecast comparisons over time



The charts plot the forecast errors for the change in GDP growth 1-quarter- and 1-year-ahead, respectively.

Figure 5: CPI inflation forecasts relative to using official real-time output gap (quarters ahead)

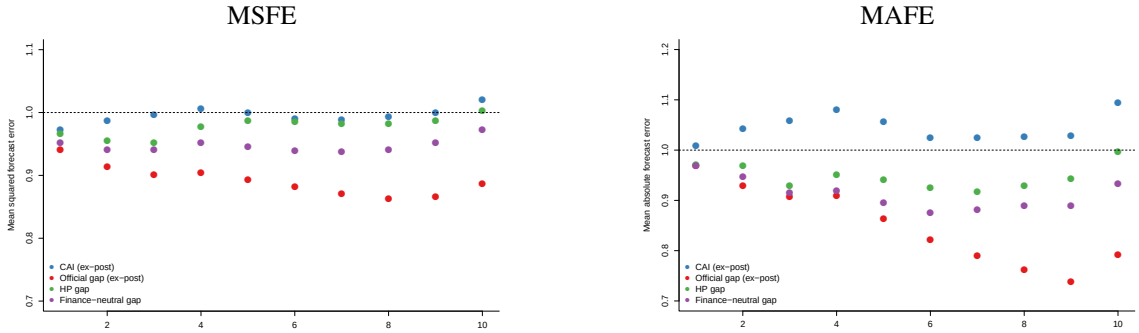
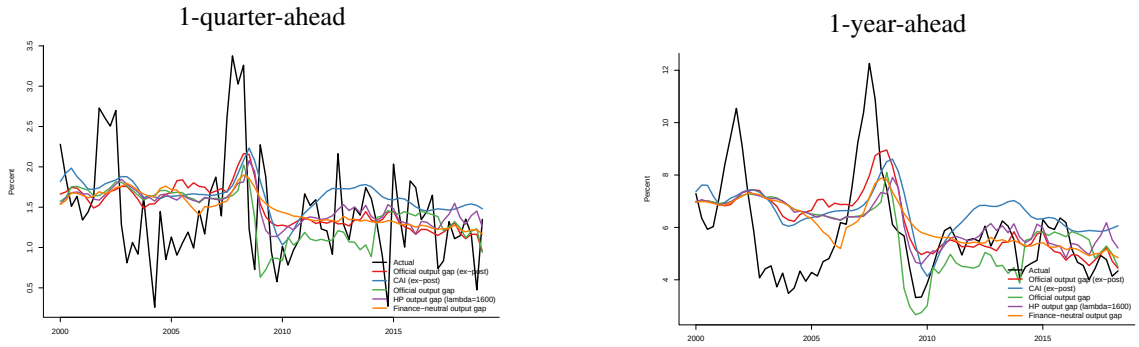


Figure 6: CPI inflation forecast comparisons over time



The charts plot the forecast errors for the change in inflation 1-quarter- and 1-year-ahead, respectively.

5 Usefulness of different output gaps in the Phillips curve

Another metric that can be used to compare output gap measures is how well they can explain the cyclical dynamics of inflation. Central bank models often use a Phillips curve relationship to model the relationship between capacity pressures, inflation expectations and inflation. We next assess which Phillips curve specification best explains the dynamics of inflation. To compare the fit of different Phillips curve specifications we replace π_t in equation 1 with alternative inflation measures, $\hat{y}_t$ with alternative output gap measures, and $rulc_t$ with the real wage gap as an alternative measure of labour market slack.[12] We also consider three measures of inflation: headline CPI inflation, core inflation and the Cyclically Sensitive Inflation (CSI) Index which weighs components

[12]The real wage gap in QPM is the deviation of the real wage from its equilibrium, where nominal wages are increasing in past wages (persistence), increasing in past inflation (wage indexing), and decreasing in the real ULC gap (cyclical real wages in excess of cyclical productivity must moderate by decreasing nominal wages to bring the system into equilibrium).

of CPI together based on their joint co-movement to slack measured using CAI. We use the $R-squared$, log-likelihood and the Akaike Information Criterion (AIC) of different specifications as measures of goodness of fit. The model with the highest $R-squared$ has the best fit in-sample, under the assumption that the model is well-specified. Likewise, the model that maximises the log-likelihood has the highest (i.e. least negative) value has the best fit, while a lower AIC is indicative of better fit.

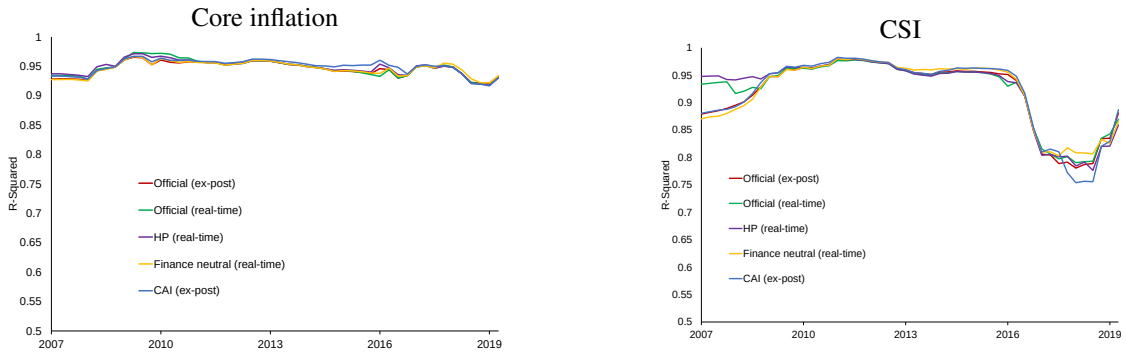
This paper assesses whether the existing Phillips curve specifications used by the Reserve Bank are appropriate for understanding inflation dynamics. Consistent with international experience (see Stock and Watson 2019 for the US, for example), Figure 7 shows that the Phillips curve relationship has been unstable in South Africa for inflation, with the ability of different measures of economic slack to explain headline inflation weakening over the last 5 years. Replacing $rulc_t$ with the wage-gap instead improves the fit of the model slightly for all specifications. However, the fit of Phillips curve models for core inflation and cyclically sensitive prices has remained more stable than for headline (Figure 8). The sections that follow provide a more detailed assessment of the fit of different Phillips curve model specifications.[13]

Figure 7: Rolling R-squared from different Phillips curve specification (Headline inflation)

R-squared is the proportion of variance in inflation that is predictable from variables on the right-hand side of equation 1 (window=30 quarters, 1 quarter steps).

[13]Figures 7 and 8 suggest that it may be useful for future research to consider using techniques that allow for parameter changes when estimating Phillips curves.

Figure 8: Rolling R-squared from different Phillips curve specification



R-squared is the proportion of variance in inflation that is predictable from variables on the right-hand side of equation 1 (window=30 quarters, 1 quarter steps).

Over the full sample, the CAI measure produces the best fit between the behaviour of the three inflation measures and the output gap measure (Table 1). For headline inflation, the real wage gap provides the best overall fit, while the ULC gap improves the fit for core inflation and the CSI. This implies that a Phillips curve model that uses a measure of slack that accounts for tightness in the labour market is best at explaining the cyclical dynamics of inflation in South Africa. Since the GFC, economic slack has been lower according to the CAI measure than suggested by the other output gap measures considered. All things equal, lower capacity pressure is consistent with higher inflation observed since the GFC, relative to what would have been expected if the output gap were instead assumed to have been more negative over this period.

Table 1: Fit of different models

	Headline		**Core**		**CSI**		**Headline**		**Core**		**CSI**	
	-LL	AIC	-LL	AIC	-LL	AIC	-LL	AIC	-LL	AIC	-LL	AIC
Output gap												
Official (ex-post)	-87	190	-31	79	-83	183	-87	190	-32	80	-81	178
Official (real-time)	-86	188	-28	73	-87	190	-84	184	-30	77	-84	184
HP (real-time)	-86	188	-28	72	-84	184	-86	188	-29	74	-80	176
Finance neutral (real-time)	-92	200	-32	80	-84	185	-92	200	-32	80	-82	180
CAI (ex-post)	**-83**	**181**	**-26**	**67**	**-81**	**178**	**-83**	**182**	**-25**	**66**	**-78**	**172**
Labour market	Real wage gap						ULC gap					

LL denotes log-likelihood. The benchmark model is the QPM specification in equation 1.

We can also compare alternative Phillips curve specifications to assess the stability of the Phillips curve relationship with different measures of inflation, economic slack and labour market conditions. Whereas Figure 7 showed that the QPM specification for headline inflation has not been stable, the fit of the specifications for core inflation and the CSI remained relatively stable over the full sample (Tables 2 and 3). The various output gap measures are statistically significant in almost all of the model specifications

with positive coefficients, consistent with excess demand being associated with an increase in inflation. The relationship between cyclical activity and the various inflation measures is strongest for the CAI, followed by the HP filter (Figure 9) and slightly more stable than between headline inflation and the official output gap. However, there has been significant variation in the slack coefficients, reflecting in part the influence of the GFC, with large deviations in inflation from the midpoint of the target accompanied by large output gap estimates (Figure 10). Lagged inflation is always significant, while inflation expectations is significant in most specifications for headline and core inflation. The ULC gap is significant in a specification for headline inflation with the official (real-time) output gap and for all CSI-based specifications, while the real wage gap is only statistically significant in three of the specifications with core inflation.[14] While foreign inflation is significant in most specifications, the real exchange rate gap is not statistically significant in most specifications.[15] Although this is consistent with other evidence of a decline in exchange rate pass-through in South Africa (see Kabundi and Mbelu 2018), an avenue for future research could be to identify a different explanatory variable to capture the impact of exchange rate changes or other global factors on inflation.

[14] Although the small direct contribution from the ULC gap for headline inflation is somewhat surprising, a larger weight is placed on ULC when using the Reserve Bank's measure of core inflation. The negative contribution from the ULC gap for core inflation is puzzling since core is a large proportion of headline inflation. Since the specifications considered produce some counterintuitive results, it may be worthwhile to consider alternative Phillips curve specifications for modelling inflation dynamics in South Africa.

[15] The exchange rate gap component plays a relatively small role since the gap is based on SARB's estimates of exchange rate misalignment relative to fundamentals, and not changes in the real exchange rate. Whereas a positive value of the exchange rate gap would be inflationary, our foreign inflation variable is the product of foreign currency global producer prices and the nominal exchange rate (with depreciation defined as a fall in the currency, consistent with the definition of the real exchange rate), representing the overall impact of two components which will have different inflationary impacts.

Table 2: Phillips Curve Estimates across specifications (with the ULC gap)

	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI
Output gap															
Official (ex-post)	**0.29**	0.03	**0.27**												
t-statistic	3.47	0.76	3.25												
Official (real-time)				**0.33**	**0.07**	**0.16**									
t-statistic				4.43	1.89	2.08									
HP (real-time)							**0.62**	**0.18**	**0.49**						
t-statistic							3.86	2.42	3.56						
Finance neutral (real-time)										**0.13**	0.02	**0.21**			
t-statistic										1.68	0.54	2.96			
CAI (ex-post)													**0.77**	**0.22**	**0.54**
t-statistic													4.70	3.72	4.08
Labour market															
ULC gap	0.01	**-0.07**	**0.12**	**0.13**	-0.04	**0.16**	0.02	-0.03	**0.16**	0.01	**-0.08**	**0.13**	-0.01	-0.04	**0.13**
t-statistic	0.17	-1.95	2.06	1.94	-0.92	2.30	0.29	-0.93	2.66	0.12	-2.05	2.19	-0.21	-1.11	2.38
Other regressors															
Inflation (t-1)	**0.67**	**0.75**	**0.75**	**0.65**	**0.75**	**0.83**	**0.58**	**0.80**	**0.80**	**0.73**	**0.74**	**0.74**	**0.43**	**0.77**	**0.74**
t-statistic	6.84	11.13	11.44	6.82	12.67	12.23	5.47	12.44	12.76	7.01	11.33	11.00	3.69	14.02	11.71
Inflation expectations (t+2)	0.35	**0.33**	0.19	**0.56**	**0.37**	0.07	**0.49**	**0.31**	0.04	0.19	**0.34**	0.17	**0.46**	**0.26**	0.03
t-statistic	1.66	3.60	0.96	2.56	4.11	0.34	2.20	3.41	0.25	0.86	3.65	0.84	2.25	2.92	0.20
Foreign inflation	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	-0.01	**-0.02**	**-0.02**	**-0.02**	**0.03**	-0.01	0.01
t-statistic	-2.26	-4.61	-2.11	-1.98	-4.49	-1.77	-1.82	-4.21	-1.35	-2.19	-4.67	-2.26	2.00	-0.97	0.90
REER gap	0.01	0.00	0.03	0.02	0.00	**0.03**	0.02	0.00	**0.04**	0.01	0.00	0.03	**0.06**	0.01	**0.05**
t-statistic	0.65	-0.42	1.65	1.28	-0.40	1.94	1.32	-0.47	2.29	0.71	-0.42	1.54	3.66	1.01	3.33
Constant	-0.30	**-0.69**	0.15	-1.08	**-0.91**	0.53	-0.35	**-0.74**	0.80	0.35	-0.65	0.33	0.48	-0.40	1.10
t-statistic	-0.33	-1.68	0.16	-1.17	-2.17	0.53	-0.39	-1.92	0.92	0.37	-1.61	0.35	0.59	-1.10	1.32
No observations	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Adj. R-squared	0.84	0.92	0.89	0.85	0.92	0.88	0.85	0.92	0.89	0.82	0.92	0.89	0.86	0.93	0.90

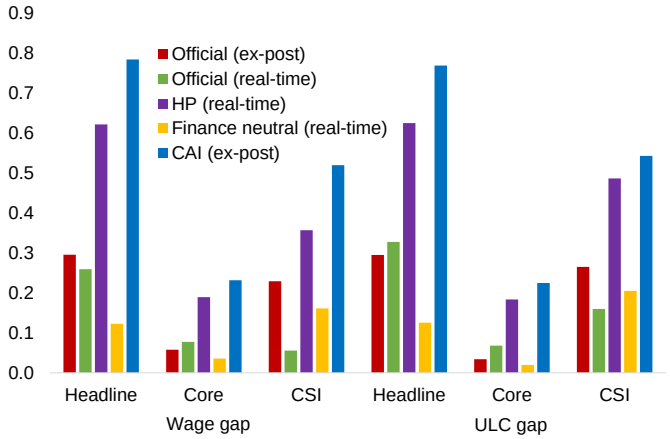
Bolded coefficients indicate significance at a 10 percent significance level.

Table 3: Phillips Curve Estimates across specifications (with the wage gap)

	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI	Headline	Core	CSI
Output gap															
Official (ex-post)	**0.30**	0.06	**0.23**												
t-statistic	3.50	1.47	2.77												
Official (real-time)				**0.26**	**0.08**	0.06									
t-statistic				3.88	2.81	0.82									
HP (real-time)							**0.62**	**0.19**	**0.36**						
t-statistic							3.87	2.91	2.59						
Finance neutral (real-time)										0.12	0.04	**0.16**			
t-statistic										1.66	1.10	2.30			
CAI (ex-post)													**0.78**	**0.23**	**0.52**
t-statistic													4.71	3.72	3.58
Labour market															
Real wage gap	-0.04	**-0.08**	-0.02	-0.03	**-0.08**	-0.02	-0.04	-0.06	0.01	-0.02	**-0.08**	-0.01	0.04	-0.03	0.07
t-statistic	-0.51	-2.17	-0.31	-0.35	-2.07	-0.28	-0.47	-1.62	0.14	-0.20	-2.11	-0.07	0.50	-0.73	0.89
Other regressors															
Inflation (t-1)	**0.64**	**0.79**	**0.75**	**0.58**	**0.76**	**0.80**	**0.55**	**0.81**	**0.79**	**0.72**	**0.78**	**0.75**	**0.45**	**0.80**	**0.74**
t-statistic	6.52	15.03	10.95	5.65	15.54	11.26	5.09	16.17	11.89	6.93	14.97	10.66	4.11	16.88	11.40
Inflation expectations (t+2)	**0.39**	**0.27**	0.22	**0.59**	**0.36**	0.05	**0.53**	**0.28**	0.09	0.21	**0.27**	0.19	**0.43**	**0.22**	0.09
t-statistic	1.88	3.24	1.11	2.60	4.11	0.23	2.42	3.49	0.49	0.96	3.20	0.91	2.25	2.79	0.53
Foreign inflation	**-0.02**	**-0.02**	**-0.03**	**-0.02**	**-0.02**	**-0.03**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.02**	**-0.03**	**0.43**	0.00	0.00
t-statistic	-2.40	-4.09	-3.00	-2.53	-4.36	-2.53	-1.98	-4.11	-2.55	-2.28	-4.07	-3.04	2.25	-0.69	0.07
REER gap	0.01	0.00	0.02	0.02	0.00	0.03	0.02	0.00	0.02	0.01	0.00	0.02	**0.06**	0.01	**0.04**
t-statistic	0.63	-0.44	0.98	1.14	-0.53	1.47	1.29	-0.50	1.46	0.71	-0.42	0.96	3.72	1.21	2.65
Constant	-0.26	-0.49	0.14	-0.82	**-0.75**	0.89	-0.32	-0.57	0.67	0.38	-0.44	0.34	0.44	-0.30	0.77
t-statistic	-0.29	-1.17	0.14	-0.86	-1.80	0.86	-0.35	-1.44	0.73	0.39	-1.04	0.34	0.54	-0.81	0.88
No observations	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Adj. R-squared	0.84	0.92	0.88	0.85	0.92	0.87	0.85	0.92	0.88	0.82	0.92	0.88	0.86	0.93	0.89

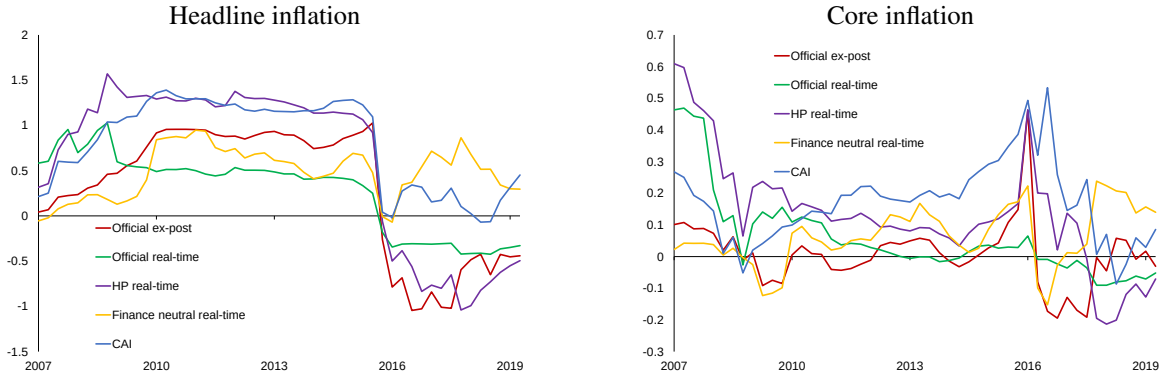
Bolded coefficients indicate significance at a 10 percent significance level.

Figure 9: Slack coefficients



Estimated coefficients on slack measures in equation 1.

Figure 10: Rolling slack coefficients



Estimated coefficients from equation 1 (window=30 quarters, 1 quarter steps).

6 Conclusion

This paper evaluates different output gap measures against two criteria: their ability to forecast GDP growth and inflation and their ability to explain inflation dynamics. For forecasting GDP, the most successful measure of slack is the CAI, which includes labour market indicators. That said, all the output gap measures underestimated GDP growth during the 2000s boom, and over-estimated it subsequently. Strikingly, the output gap measure used in actual monetary policy committee forecasts is the worst-performing of all the measures we test. It is also noteworthy that the CAI indicates that the output gap has been close to zero recently, in contrast to the other measures. For inflation, none

of the measures perform especially well, and again the official output gap used for real time monetary policy committee forecasts is the worst performing measure.

However, when using the Phillips Curve specification used in the quarterly projection model, the model fit is consistently better with an estimate of slack than without, demonstrating that a Phillips curve-relationship continues to exist in the data, even if other variables (such as past inflation and inflation expectations) are much more important over recent history. While the relationship between slack and headline inflation has weakened since 2016 for all output gap measures, the model still fits inflation data well, particularly when using the CAI as the measure of slack in the model. The fit of Phillips curve models for core inflation, on the other hand, have remained much more stable than for headline.

Overall, our findings imply that the Phillips curve remains a useful analytical framework for monetary policy in South Africa, particularly for components of the inflation basket whose prices are domestically determined. But given the poor ability of output gap measures to forecast GDP (particularly during unusually persistent up/down-turns), we argue that it might be useful to expand the suite of frameworks used to measure economic slack and use information from a suite of measures to better understand business cycle developments in real-time. Given the demonstrated importance of past inflation for future inflation, the results also suggest that anchoring inflation expectations at a lower level would help to keep inflation near the mid-point of the target range over the medium term. Lastly, we present evidence that some of the variables used in the Reserve Bank's specification of the Phillips curve do not contribute significantly to explaining the dynamics of inflation, which suggests that the Reserve Bank should consider recalibrating the Phillips curve specifications used in its models.

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A Methodology for constructing our comprehensive activity indicator and cyclically sensitive inflation measure

The key intuition from the Phillips curve is that greater slack in the labour market (i.e. higher cyclical unemployment) should be expected to be associated with lower wage pressures and decelerated inflation. Cyclical unemployment is often measured as the difference between the observed rate of unemployment and its potential level, often interpreted as the NAIRU ('Non- Accelerating Inflation Rate of Unemployment'). The NAIRU can be measured in many different ways, but is generally defined as the rate of unemployment consistent with inflation converging towards the inflation target.

Instead of estimating NAIRU, we construct a new comprehensive measure of economic slack for South Africa that incorporates labour market conditions and a new index of cyclically sensitive inflation that is based on components of headline inflation that react strongly to cyclical fluctuations in real activity (on average).[16] We argue that this measure is useful for looking at the sensitivity to cyclical pressures for different components of the inflation basket since they have various foreign and competitive price pressures; diverse market structures; and different price-setting dynamics. We show that focussing on the sub-components of the CPI basket reveals that some components react more strongly to cyclical variations than others. Using a more comprehensive measure of economic slack also helps to account for the role of the labour market in determining cyclical inflation pressure.[17] Our more comprehensive slack measure suggests that slack was closer to zero than our official measure at the end of our sample (2019Q3). Our index of cyclically sensitive inflation contains 60 percent of the components of the CPI basket (in terms of combined weight) and places the largest weights on food and non-alcoholic beverages, and relatively non-traded components of inflation such as education.

[16] There are several unusual aspects of the South African labour market that make estimation of labour market slack more challenging than in advanced economies. One is the high proportion of discouraged workers in the labour force. Kingdon and Knight (2006), for example, suggest that over 60 percent of the broadly unemployed have never had a job. Another aspect of South Africa's high rate of unemployment is its structural nature (OECD 2010). Together with a skills shortage and low labour force participation, this likely implies a weaker relationship between the unemployment rate, wages and labour demand than in an advanced economy. While there are few papers that have considered the relationship between cyclical unemployment and inflation in South Africa, there is some evidence of a relationship between cyclical output and cyclical unemployment. Marinkov and Geldenhuys (2007) finds supportive evidence, though cyclical unemployment explains a relatively small proportion of observed unemployment. Kabundi et al. (2016) show that the unemployment gap (deviation of unemployment from the NAIRU) has been positive for parts of the post-GFC sample, and that the unemployment Phillips curve has flattened since the GFC.

[17] Several papers have shown that the labour market might be important in determining inflation, see Reid and du Rand (2015) for example.

A.1 Methodology

We construct a Composite Activity Index (CAI) based on a variety of measures of capacity pressures, including several labour market indicators. We also construct a Cyclically Sensitive Inflation (CSI) Index to weight components of CPI together based on their joint co-movement to economic slack. We use the approach of Stock and Watson (2019) but use the components of CPI instead of personal consumption expenditure as in the US paper to construct the South African CSI. To do so, we standardise six measures of the economic cycle, which are then band-pass filtered before the CAI is extracted as the first principal component. The first principle component summarises the co-movement of the various measures of slack. The advantage of filtering inflation and real activity in this way is that it is not necessary to estimate trend inflation at aggregate and disaggregated levels, potential output, or the steady state value of NAIRU. The disadvantage of frequency-based filtering techniques is the frequency bands used are pre-selected, implying the correlation of cycles obtained in this way with other measures of cycles are partly dependent on researcher choices.[18]

We then construct a Cyclically Sensitive Inflation (CSI) Index to weight the 20 components of the CPI basket based on each category's joint co-movement with economic slack. We diverge from the approach of Stock and Watson (2019) by incorporating the disaggregated CPI basket instead of private consumption expenditure deflators. To derive the weights w_i for component i, non-linear least square estimation is used to maximise the correlation between y-o-y changes in the inflation sub-components and the CAI measurement for slack.

$$CAI_t = \beta_0 + \beta_1 \sum_{i=1}^{20} w_i \Delta_4 \pi_{it}^4 + u_t \tag{3}$$

Thereafter, the CSI is constructed as the weighted average of the CPI components:

$$\pi_t^{CSI} = \sum_{t=1}^{20} w_i \pi_{it}^4 \tag{4}$$

A.2 Data

We follow Stock and Watson (2019) in the selection of six real activity measures to include in the CAI. We use the logarithm of real GDP (once band pass filtered, this is interpreted as the output gap), capacity utilization rate, and a number of labour market

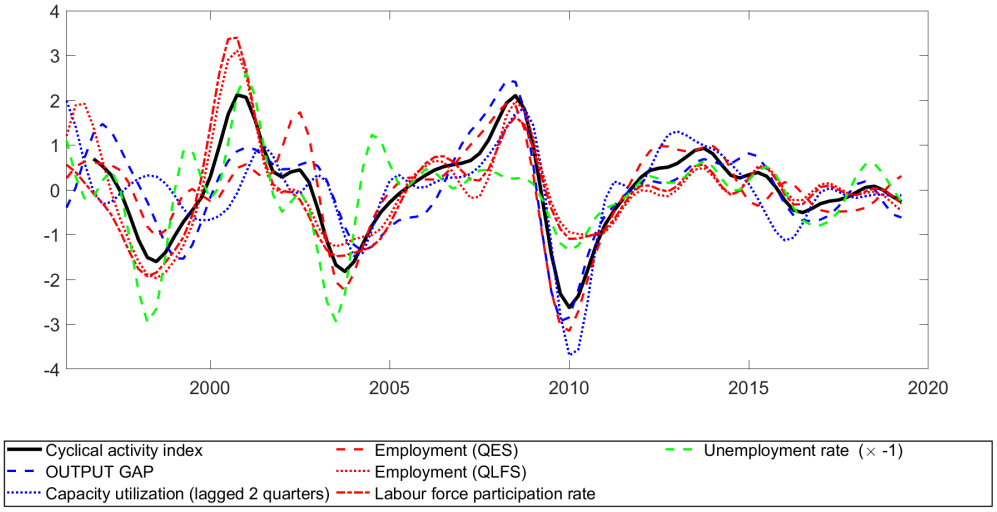
[18] In the context of South African GDP filtering, Boshoff (2010) shows that frequency range selection critically affects the volatility, persistence and co-movements obtained, although for medium-term cycles the information loss is more limited. To demonstrate how the filtering approach affects estimates of the CAI, Figure 16 compares the band pass- to applying year over year changes (specified as a four quarter moving average) to the 6 individual activity measures.

series: the labour force participation rate, two survey measures of employment, and the official unemployment rate. We use seasonally adjusted disaggregated CPI data.

A.3 Slack measurement

Figure 11 shows the six alternative measures of resource utilization considered. We invert the unemployment measure for consistency in interpretation with other output gap measures. The standardised gaps are highly correlated: the first principle component explains approximately 75 percent of the variation of the six measures. The cyclical behaviour of the components exhibit similar patterns (once band pass filtered). We find that the output gap and capacity utilization rate lead the unemployment rate, while the QLFS and labour force participation rate lag the unemployment rate. The QES unemployment moves contemporaneously with the output gap. Overall, we find that the cyclicality in the CAI is similar to that of the official output gap, but less negative over recent years, suggesting that labour indicators suggest that capacity pressures have not been as intense as the official gap has suggested.

Figure 11: Band-pass measures of cyclical activity and their first principal component for SA

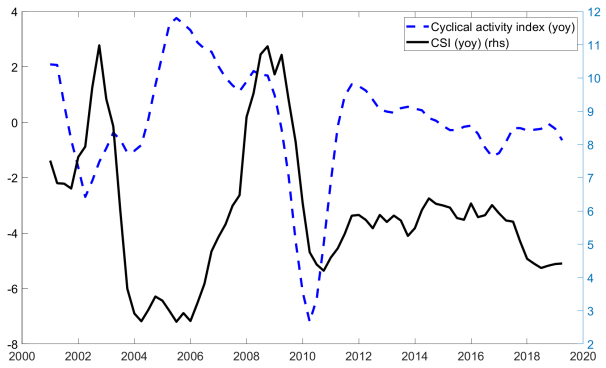


Note: Using a band of 6-32 quarters, where filtered series are standardized to have mean zero and unit variance. The unemployment rate has been multiplied by -1 to co-vary positively with the output gap estimate.

A.4 Cyclically Sensitive Inflation

While the cyclical activity indicator recovered post GFC, the CSI remained relatively stable near the top end of the inflation targeting band (Figure 12).[19] Since the end of 2017, the CSI has declined towards the midpoint of the inflation target range, even though the CAI has been suggestive of some slight weakening in inflationary pressures. Figure 13 shows that the level of CSI inflation and its cyclical behaviour has been generally consistent with headline and core CPI inflation. Lastly, we compare our results to other estimates of cyclical inflation for South Africa. Figure 14 shows that even though there are significant differences to the measure of procyclical inflation from Radebe (2019) pre-GFC, CSI cyclical inflation has been highly correlated with other measures of core since the GFC.

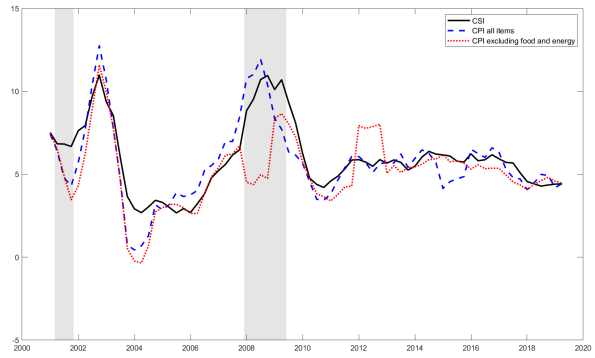
Figure 12: CAI and CSI inflation



Note: CAI rescaled to match standard deviation of $\Delta_4 \pi_t^{CSI,4}$

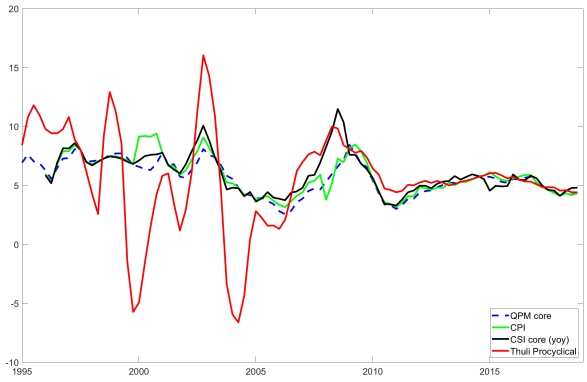
[19] To check the stability of the estimates of the CSI depending on the sample period, Figure 17 compares the full sample version of the CSI to one based on rolling estimation windows. Future work could consider using a time varying estimation technique or apply a Markov Switching approach to the non-linear maximisation estimation step.

Figure 13: Inflation rates measures and the CSI (year-on-year)



Note: Shading denotes SARB downturns, CSI transformed to be year-on-year annual terms.

Figure 14: CSI vs measures of core inflation



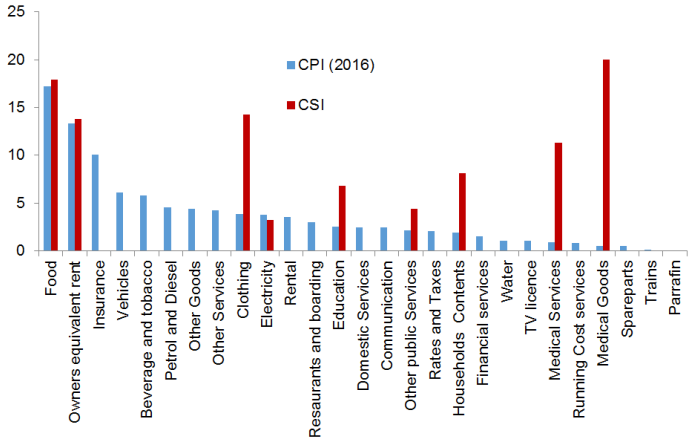
Source: Author calculations, Radebe (2019)

The weakening of the relationship between various measures of economic slack and headline inflation could reflect the recent dominance of non-cyclically sensitive components to overall dynamics of inflation. Radebe (2019) decomposed South African inflation into procyclical and acyclical measures based on their coefficients in a simple Phillips curve specification and showed only one third of core inflation is sensitive to the business cycle.

The benchmark model (band-pass based) suggests that about 60 percent of the inflation basket is strongly correlated with cyclical activity, while using year-on-year filtering instead would imply a combined weight of closer to 40 percent. Figure 15 compares the actual weights in headline CPI to the weight assignment that maximises the correlation between the CSI and the measures of slack. Using a band-pass to estimate the CAI results is a low weight on food relative to the weight in headline CPI, while year-on-year filter puts a slightly higher weight on food than CPI and higher weights on medical

goods, water, clothing and alcohol. Although the high weight on education and personal care may seem surprising, these are two relatively non-traded components that will be more reflective of domestic cyclical conditions than relatively traded components of CPI.[20]

Figure 15: CPI and CSI weights



A.5 Additional tables and charts

Table 4: Weights of CPI components

[20]Table 4 also shows the estimated weights on each component that maximises the correlation between the CSI and the official ex-post output gap.

	Weighting technique			
Components	**CPI (2016)**	**CSI & CAI (yoy)**	**CSI & CAI (bp)**	**CSI & Output gap**
Food and NAB	17.2	16.58	20.0	13.7
Petrol	3.3	0.00	0.0	0.0
Vehicles	6.1	0.00	0.0	0.0
Electricity	3.8	2.19	1.5	10.0
Furniture	0.8	0.00	0.0	0.0
Appliances	0.7	0.00	0.0	0.0
Alcohol	5.8	0.00	11.2	4.9
Clothing	3.8	0.00	8.9	2.5
Med. goods	1.4	0.00	15.5	6.7
Personal care	0.5	28.10	8.7	0.0
Other goods	5.2	7.65	2.4	4.5
Communication	2.6	0.00	10.0	0.0
Domestic	2.5	0.00	0.0	10.5
Education	2.5	36.82	18.6	24.0
OER	13.3	3.51	1.4	9.5
Med. services	0.9	0.00	0.0	0.0
Public transp.	2.3	4.73	1.8	0.0
Rent	3.5	0.00	0.0	0.0
Water	1.1	0.00	0.0	13.4
Other services	22.6	0.42	0.1	0.5

Note: Some weights were adjusted to ensure sub-indices aggregate to the headline index.

Figure 16: Alternative activity indices for SA (percent)

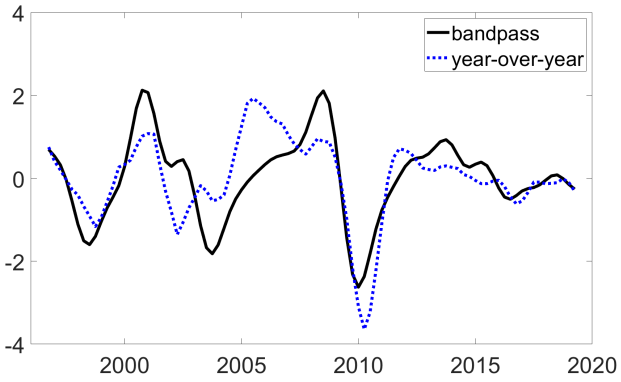
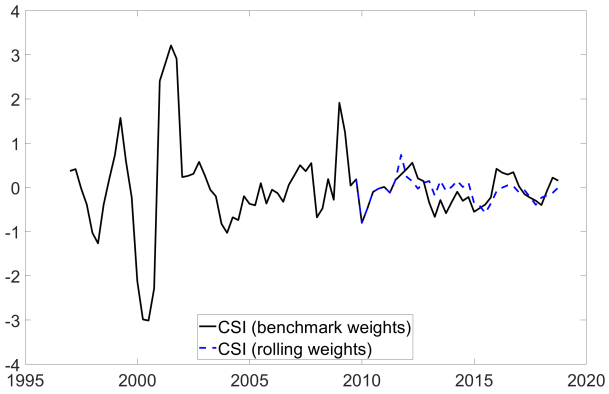


Figure 17: CSI inflation vs rolling weights (year-on-year)



Note: Solid line is the 4-quarter change in 4-quarter CSI inflation using benchmark specification and dashed line is based on rolling weights based on a 60-quarter window.

B Pairwise Diebold-Mariano tests

Table 5: Diebold-Mariano statistics (slack measure vs official real-time output gap)

	Forrecast horizon	Loss function power	test-statistic	p-value
Forecasting: GDP				
Official output gap (ex-post)	1	2	1.085	0.141
CAI (ex-post)	1	2	0.951	0.172
HP gap	1	2	1.053	0.148
Finance-neutral gap	1	2	1.018	0.156
Official output gap (ex-post)	4	2	1.097	0.138
CAI (ex-post)	**4**	**2**	**2.089**	**0.020**
HP gap	4	2	1.497	0.069
Finance-neutral gap	4	2	0.658	0.256
Forecasting: Headline CPI				
Official output gap (ex-post)	1	2	1.163	0.124
CAI (ex-post)	1	2	0.442	0.330
HP gap	1	2	0.728	0.235
Finance-neutral gap	1	2	0.997	0.161
Official output gap (ex-post)	4	2	1.127	0.132
CAI (ex-post)	4	2	-0.093	0.537
HP gap	4	2	1.236	0.110
Finance-neutral gap	4	2	0.935	0.177
Forecasting: Core CPI				
Official output gap (ex-post)	1	2	-1.111	0.865
CAI (ex-post)	1	2	-0.191	0.576
HP gap	**1**	**2**	**1.546**	**0.063**
Finance-neutral gap	1	2	-0.125	0.550
Official output gap (ex-post)	4	2	-0.438	0.669
CAI (ex-post)	4	2	-0.015	0.506
HP gap	4	2	0.913	0.182
Finance-neutral gap	4	2	-0.055	0.522
Forecasting: CSI				
Official output gap (ex-post)	**1**	**2**	**2.269**	**0.014**
CAI (ex-post)	**1**	**2**	**1.913**	**0.031**
HP gap	**1**	**2**	**2.196**	**0.016**
Finance-neutral gap	**1**	**2**	**1.818**	**0.037**
Official output gap (ex-post)	**4**	**2**	**2.134**	**0.019**
CAI (ex-post)	4	2	1.607	0.057
HP gap	**4**	**2**	**1.839**	**0.036**
Finance-neutral gap	4	2	1.664	0.051

Null hypothesis: the two indicators have the same forecast accuracy. *Alternative hypothesis*: slack measure outperforms official real-time output gap. **Bolded** results indicate significance at 5 percent significance.