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Article

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Heterogeneous provincial prices and monetary policy in South Africa: A wavelet-based quantile regression analysis

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ABSTRACT

Although economic agents in different parts of a country face heterogeneous prices, empirical literature continue to assume homogeneity in the monetary policy-inflation nexus, with dire consequences for optimal monetary policy and welfare. Using wavelet-based quantile regressions, we provide a multi-layered asymmetric exposition on provincial inflation-monetary policy relationship in South Africa. We find that whiles restrictive monetary policy delivers stability in the prices of Gauteng, Mpumalanga and North West provinces, it is destabilizing for prices in Eastern Cape, KwaZulu-Natal, Limpopo, Northern Cape and Western Cape provinces. The findings are mixed, for Free State province, depending on the time horizon and quantiles. Our findings present enormous policy and welfare implications, given the inflation targeting status of South Africa and the economic disparities among the provinces of the country.

1. Introduction

A large amount of the literature on monetary policy-inflation nexus are premised on the notion that all economic agents are confronted with homogeneous prices in the economy (Fielding and Shields, 2006) and thus situate the relationship in the context of national aggregates. Meanwhile, different people, and for that matter different cities and regions in a country face different prices (Fielding and Shields, 2006; Ceglowski, 2003; Cecchetti et al., 2002; and Engel and Rogers, 2001) and such heterogeneities present significant ramifications for the conduct of monetary policy (Fielding and Shields, 2006; and Arnold and Kool, 2004). A restrictive monetary policy, for instance, may be felt differently in different regions. While it may be mildly restrictive for some regions, it may be severely restrictive for others (Arnold and Kool, 2004). Indeed, such a monetary policy stance may even be relatively accommodative for some other regions.

The patterns of consumption in these regions, their industrial mix, the level of development of their respective financial sectors, performance of enterprises, the differences in demography, differences in capacities of production, technological differences, differences in region-specific factors, differences in the economic agents' behaviour and differences in economic policy implementations in these regions necessarily inform the differences in their structure and for which reason monetary policy changes should not be expected to have a uniform impact across these regions (Anagnostou and Gajewski, 2019; Anagnostou and Papadamou, 2016; and Carlino and DeFina, 1998). Importantly, Carlino and DeFina (1998) point out that the nature of the theories on transmission of monetary policy themselves give an indication that different regions may be affected differently by changes in monetary policy. In the interest rate channel, for instance, different firms and industries have different sensitivities to interest rates and different regions have different industrial mix. The credit channel, following the works of Bernanke and Blinder (1988) and Kashyap et al. (1996), also suggest that some firms depend more on loans from banks than other firms and regions have different mix of industries and firms. Theoretically, authors such as Gros and Hefeker (2002) and De Grauwe (2000) have demonstrated that when monetary policy rule disregards regional differentials in the face of transmission asymmetry, welfare losses would be the natural consequences (Fielding and Shields, 2006). Fratantoni and Schuh (2003) argue

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that for monetary policy efficiency, recognizing differences across regions is of great importance.

Although literature on monetary policy and asymmetric regional responses exist, they are largely focused on regional output responses to monetary policy shocks (see Anagnostou and Gajewski, 2019; Anagnostou and Papadamou, 2016; Ridhwan et al., 2014; and Carlino and DeFina, 1998, 1999); monetary policy and regional housing equity (see Beraja et al., 2017); monetary policy, credit availability and cost (see Dow and Montagnoli, 2007); monetary policy and regional housing market (see Fratantoni and Schuh, 2003); monetary policy and general macroeconomic variables (see Fraser et al., 2014; and De Lucio and Izquierdo, 1999); monetary policy and employment (see Svensson, 2012); and monetary policy and real variables (see Xiaohui and Masron, 2014). However, studies on monetary policy and responses of regional inflation remain limited in the empirical literature. Meanwhile, differential responses of regional inflation to monetary policy pose a critical challenge in the context of inflation targeting countries where such differences could potentially undermine the achievement of the publicly announced national inflation targets with dire consequences for the credibility of policymakers.

Few studies, such as Fischer et al. (2018), Aastveit and Anundsen (2017), Yang et al. (2010) and Del Negro and Otrok (2007), have considered monetary policy and regional housing prices. Meanwhile, the prices that economic agents face in the various regions of a country go beyond just the housing prices. Beck et al. (2006) studied factors that explain inflation at the regional levels of selected countries in the Euro area but fell short of an explicit relationship between monetary policy and these regional prices. Choi et al. (2015) considered the effect of the adoption of inflation targeting framework on regional inflation in South Korea as opposed to the impact of changes in monetary policy on regional inflation. Nagayasu (2010) studied factors that explain regional prices in China but not the heterogeneous responses of regional inflation to monetary policy changes. Alagidede et al. (2014) considered persistence in regional and sectoral inflation in Ghana as opposed to the responses of regional inflation to changes in monetary policy.

To the extent that we know, the only two studies that have looked at responses of regional prices to changes in monetary policy are Fielding and Shields (2006) in the context of South Africa and Fielding and Shields (2007) in the context of the United States. These studies are, however, limited in a number of ways. Fielding and Shields (2006) considered a hypothetical monetary policy as opposed to actual monetary policy changes with the limitation that the results obtained may be far from reality in terms of actual policy dynamics. Fielding and Shields (2007) considered the context of law of one price and how monetary policy itself contribute to the heterogeneity in regional prices. Moreover, the authors studied cities in the United States as opposed to full-fledged regions.

In addition, while these studies underscore the policy and welfare fatality of assuming homogeneity in the effect of monetary policy on prices that confront all agents in a country, they surprisingly assume that the relationship between each region's inflation and monetary policy is symmetric throughout the distribution of the former. Meanwhile, the fact that monetary policy behaviour and effect, and indeed macroeconomic variables, exhibit asymmetry is well known in the literature (Liu et al., 2018; Caporale et al., 2018; Ahmad, 2016; Martin and Milas, 2013). Moreover, the economic processes of the regions are not static over time nor simplistic to expect that each region's inflation's response to monetary policy remains the same across time.

Furthermore, these studies have been conducted in pure time domain that overlooks the fact that the objectives of central banks differ across long- and short-term horizons and these objectives simultaneously operate at varying scales. As argued by Aguiar-Conraria et al. (2008), different economic agents take various actions with varying objectives over different horizons and it is these varying actions and objectives that inform various economic processes. As a result, time series data on various macroeconomic variables are necessarily an amalgamation of these varying objectives and horizons of economic agents. Consequently, the effect of monetary policy, for instance, would naturally differ across different horizons and frequencies. Such intricate relationship between monetary policy and other macroeconomic variables may be difficult to unearth with econometric methods that are either exclusively frequency-domain or exclusively time-domain (Aguiar-Conraria et al., 2008). Significantly, Aguiar-Conraria et al. (2018) reckon that the effect of monetary policy across various horizons and particularly the cyclical frequencies should be of interest to policymakers as social welfare may be affected differently when fluctuations occur across distinct frequencies.

We make significant contributions to the monetary policy-regional inflation nexus. We consider a multi-faceted approach to capturing asymmetry in the effect of monetary policy on provincial inflation in South Africa as we unearth not just the relationship across time and frequency but also across distinct quantiles of the distributions of the respective provincial inflation using the wavelet-based quantile regression technique for the first time in the literature on monetary policy and regional inflation. Whiles the quantile regression enables us to examine the monetary policy-provincial inflation nexus at low, moderate and high inflationary episodes across the various provinces, the decomposition of the data using the wavelet approach enables us to capture these varying monetary policy-provincial inflation relationships in time and frequency domains. Such multi-layered asymmetric exposition provides a far more nuanced information that are invaluable in informing monetary policy stance. South Africa provides an important policy case given its inflation targeting status and a model for the African continent. Heterogeneous provincial prices pose significant challenge to policymakers in anchoring inflation expectations in the context of inflation targeting.

We find that not only are the responses of the provincial inflation to monetary policy distinct when compared to each other across scales and quantiles, but same provinces' inflation rates respond to monetary policy differently at distinct quantiles and horizons. The findings are robust to different specifications.

2. Economies of the provinces of South Africa

There are nine provinces in South Africa; namely Western Cape, North West, Northern Cape, Mpumalanga, Limpopo, KwaZulu-Natal, Gauteng, Free State and the Eastern Cape. We rely on the annual and quarterly provincial GDP data released by Statistics South Africa (StatsSA, 2019) to provide an insight into the distinctiveness of the various provinces of South Africa. Between 2000 and 2017, the Gauteng province consistently contributed more than a third of the gross domestic product (GDP) of South Africa, peaking at approximately 35% of the country's GDP in 2016. The second largest contributor to the country's GDP is the KwaZulu-Natal (KZN) province which contributed more than 15% of the country's GDP since 2000 with a peak of 16.1% in 2017. This is followed by the Western Cape province with a minimum contribution of 13% of GDP since 2000 and a peak of 13.9% in 2016 and 2017. These three provinces together contributed an average of 63% of the country's GDP since 2000 with Gauteng province alone contributing an average of 33.9% or 34% approximately to the national economy. The remaining six provinces (Eastern Cape, Northern Cape, Free State, North West, Mpumalanga and Limpopo) together contributed an average of 37% to the country's GDP since 2000 which is

only 3% more than the contribution of Gauteng province alone. Indeed, the combined economic contributions of any five provinces out of these six provinces is less than that of the Gauteng province alone. For instance, between 2000 and 2017, the *highest* combined contributions of Eastern Cape, Northern Cape, Free State, North West and Limpopo to the real GDP of South Africa was 32% in the year 2000. Meanwhile, the *minimum* contribution of the Gauteng province *alone* over the same period was 32.8% in the same year 2000 which is 0.8% more than the *highest* combined contribution of the five provinces. Similarly, the *highest* combined contributions of Mpumalanga, Eastern Cape, Northern Cape, Free State and North West was also 32% in 2000 and 2001 over the period 2000–2017 which is again 0.8% less than the *minimum* contribution of Gauteng province *alone* over the same period.

The key economic sub sectors of South Africa are finance, trade (wholesale and retail), agriculture, mining, manufacturing, transportation and construction. The concentration of these sub sectors differs from province to province. The Gauteng province controls more than 40% of the value added of the country's financial sector; more than 30% of the trade sector; more than 35% of the transportation sector; more than 30% of the construction sector; and more than 40% of the manufacturing sector. The only two sectors where the Gauteng province does not exert dominance are the agriculture and mining. In the agricultural sector, the KZN province leads the pack with an average of 28% over the period 2000–2017. KZN is followed by the Western Cape province with an average contribution of 22.2% to the national agricultural sector. Indeed, Mpumalanga and Free State provinces are ahead of the Gauteng province in terms of the agricultural sector contributions. In the mining sector, North West contributed an average of 24% to the mining sector followed by 21% from Mpumalanga; 20% from Limpopo; 12% from the Gauteng province; and 7% from the Northern Cape. The Gauteng province has witnessed a nosedive in its contribution to the mining sector over the period under review, particularly from the year 2006. Indeed, it was from 2006 onwards that Limpopo province overtook the Gauteng province in terms of contribution to the mining sector of South Africa. Since 2011, the contribution of Limpopo province to the mining sector has been more than any other province. In 2017 for instance, Limpopo's contribution to the mining sector was a whopping R86,910 million representing 37.1% of the total value added in the mining sector.

3. Differences in provincial inflation

Given the heterogeneity in the structure of the economies of the provinces, the prices that confront economic agents in them would necessarily differ. Indeed, the provinces have different weights in the national inflation basket. In Table 1, we show the various weights of the provinces in South Africa. The weight of the Gauteng province is more than a third of the national inflation basket.

As Table 2 shows, prices in the various provinces differ substantially from each other and from the national average.

Clearly, the provinces have different inflation rates and they differ from the national inflation, a fact that begs the question of why a large amount of the existing literature continue to assume price homogeneity for all economic agents in different parts of a country in dealing with the monetary policy-inflation nexus. Importantly, the conduct of monetary policy that targets a national average inflation then runs the risk of missing such a target in the face of price heterogeneity across regions with deleterious consequences for anchoring inflation expectations.

4. Methodology

4.1. Data and sources

We use data in monthly frequency from January 2006 to November 2018. The variables in our model include provincial inflation, monetary policy, transportation cost, output and weighted averages of provincial prices. The choice of these variables is informed by the literature (Fielding and Shields, 2006) although we include transportation cost to capture cost of distribution of products across provinces. We also include weighted averages of provincial prices to capture the possibility that prices in one province could be affected by prices of other provinces in the same country. We obtained the data on provincial inflation from Statistics South Africa whiles transportation cost was sourced from the quarterly bulletins of the South African Reserve Bank. The output and the monetary policy data are obtained from DataStream.

4.2. Definition of variables

Provincial inflation is in percentage, as measured by the primary source, and it represents the percentage change in the consumer price index of each province in a particular month from the same month in the previous year.

Monetary policy is measured in percentage and is represented by repo rate as that is the official monetary policy instrument in South Africa.

Output: since gross domestic product, a measure of output, is not available in monthly frequency, we rely on an alternative measure. We use the coincident business cycle indicator.

Transportation cost: Measured in percentage, as per the primary source, it represents a change in the transportation price index in a particular month from the same month in the previous year.

Weighted average of provincial inflation: Because some provinces of the same country are closer to each other and the fact that certain products are manufactured or transported from one province to the other, we envisage that the price development in a particular province may be affected by prices in other provinces. In

Table 1
Provincial weights in national inflation basket.

Province	Weight in National CPI
Eastern Cape	8.04%
Free State	5.93%
Gauteng	36.25%
KwaZulu-Natal	12.70%
Limpopo	5.7%
Mpumalanga	6.89%
Northern Cape	1.93%
North West	5.31%
Western Cape	17.25%

Weights from Statistics South Africa.

Table 2
Differences in provincial inflation.

Province	Mean	Minimum	Maximum	Std. Deviation
Eastern Cape	6.21	3.01	14.63	2.21
Free State	6.17	3.35	13.40	1.98
Gauteng	5.93	3.10	13.21	1.93
KwaZulu-Natal	6.00	2.46	14.19	2.36
Limpopo	6.19	2.41	14.24	2.54
Mpumalanga	6.15	3.03	15.04	2.48
Northern Cape	5.90	2.73	14.73	2.34
North West	6.02	2.75	15.65	2.61
Western Cape	6.17	2.61	14.14	2.07
National	**5.69**	**1.72**	**11.62**	**1.74**

estimating the monetary policy effect on the prices of a particular province, we control for the prices of other provinces. Rather than throwing prices of each of the other provinces on the right-hand side of the model as control variables with concomitant degrees of freedom challenges, we adopt a more intuitive approach. We construct weighted averages of the inflation data of the control provinces. Thus, in looking at the monetary policy effect on say the Gauteng province, the remaining eight (8) provinces are the control provinces and so we construct the weighted average of the prices of these eight (8) provinces. The weights are based on their respective weights in the national inflation basket officially provided by the Statistics South Africa.

The stationary tests, based on Dickey and Fuller (1981) and Phillips and Perron (1988), indicate that only transportation cost is stationary at the levels. The inflation rates for all the provinces are stationary after taking the first difference. Monetary policy rate and output are also stationary after first difference. However, the wavelet technique is capable of dealing with nonstationary series (see Aguiar-Conraria et al., 2008; and Crowley, 2007) (Table 3).

4.3. Estimation approaches

4.3.1. The wavelet analysis

The wavelet analysis, in addition to overcoming the inefficiencies and shortcomings of spectral analysis and the Fourier transform, is capable of dealing with nonstationary time series (see Aguiar-Conraria et al., 2008; and Crowley, 2007 for details), making it a suitable technique for time series data.

For the purposes of our study, we follow the works of Mensi et al. (2016) and Yang et al. (2018). Wavelets, across the variants, are characterized by father (ϕ) and mother (ψ) wavelets which are defined as:

$$\int \Phi(t)dt = 1 \text{ denoting father wavelet}$$

$$\int \psi(t)dt = 0 \text{ denoting mother wavelet}$$

The mother wavelets (deviations from the trend) capture the high frequency or detailed parts or components of a signal whereas the low frequency or smooth (trend) component of the signal is captured by the father wavelet.

Table 3
Test for stationarity.

Variables	ADF TEST		PP TEST	
	Level	First Diff	Level	First Diff
EC	−2.581	−9.201***	−2.883	−9.513***
FS	−2.756	−9.296***	−2.736	−9.372***
GP	−2.606	−8.726***	−2.497	−8.787***
KZN	−2.440	−8.435***	−2.470	−8.506***
LMP	−2.443	−10.360***	−2.858	−10.581***
MPU	−2.696	−8.470***	−2.374	−8.474***
NC	−2.854	−9.982***	−2.782	−10.047***
NW	−3.285*	−9.718***	−2.408	−9.810***
WC	−2.783	−8.344***	−2.398	−8.374***
MPR	−2.472	−3.364*	−1.707	−12.569***
TRANSP	−4.480***		−4.198**	
OUTPUT	−3.358*	−7.510***	−2.396	−7.856***

Note: For the ADF and the PP Tests, we include both the intercept and trend at both the levels and first difference. ***, ** and * indicate significance at 1%, 5% and 10% respectively. EC is inflation of Eastern Cape, FS is inflation of Free State, GP is inflation of Gauteng, KZN is inflation of KwaZulu Natal, LMP is inflation of Limpopo, MPU is inflation of Mpumalanga, NC is inflation of Northern Cape, NW is inflation of North West, WC is inflation of Western Cape, MPR is monetary policy rate and TRANSP is transportation inflation.

A signal, or time series in our context, given as $c(t)$ is decomposable through wavelet transformation as:

$$c(t) = \sum_k z_{J,k}\Phi_{J,k}(t) + \sum_k b_{J,k}\psi_{J,k}(t)\sum_k b_{J-1,k}\psi_{J-1,k}(t) + \ldots + \sum_k b_{1,k}\psi_{1,k}(t) \quad (1)$$

such that the wavelet functions are represented by $\Phi_{J,k}$ and $\psi_{J,k}$. Meanwhile, $z_{J,k}$ and $b_{J,k}$ up to $b_{1,k}$ represent the coefficients of the wavelet transform. In addition, the J denotes the number of levels of the multiresolution while at each level the k varies from 1 to the total coefficients. We can represent the wavelet transformation as:

$$z_{J,k} = \int \Phi_{J,k}(t)c(t)dt \quad (2)$$

$$b_{j,k} = \int \psi_{j,k}(t)c(t)dt, \quad j \text{ varies from } 1 \text{ to } J \quad (3)$$

such that J represents the highest integer where 2^J assumes a figure less than the total observations. Additionally, the trend is captured by smooth coefficient represented by $z_{J,k}$. Meanwhile, $b_{J,k}$ up to $b_{1,k}$ are coefficients that capture the deviations from the aforementioned trend. Consequently, we can approximate the initial series $c(t)$ using the wavelet series in the following expression:

$$c(t) = Z_{J,k}(t) + B_{J,k}(t) + B_{J-1,k}(t) + \ldots + B_1(t) \quad (4)$$

such that the smooth signal or trend is given by $Z_{J,k}(t)$ whiles $B_{J,k}(t)$ up to $B_1(t)$ represent the more detailed signals that deviate from the trend. The detailed and smooth signals can respectively be represented by:

$$B_{J,k} = \sum_k b_{J,k}\psi_{J,k}(t), \text{ with } j = 1 \text{ to } J-1 \text{ and } Z_{J,k} = \sum_k z_{J,k}\Phi_{J,k}(t) \quad (5)$$

4.3.2. The discrete wavelet transform (DWT)

The high frequency or detailed components $B_1(t)$ up to $B_J(t)$ can be derived by using the coefficients of the wavelet filter that scales the original signal $g = (g_{1,0}, \ldots, g_{1,L-1}, 0, \ldots, 0)^T$. Given that $h_1 = (h_{1,0}, \ldots, h_{1,L-1}, 0, \ldots, 0)^T$ signifies the Daubechies wavelet filter coefficients (Daubechies, 1992) that are supported compactly for a unit scale which is zero padded to **N** length such that for $l > L$, $h_{1,0} = 0$ subject to the following conditions:

$\sum_{i=0}^{L-1} h_{1,l} = 0; \sum_{l=0}^{L-1} h_{1,l}^2 = 1 \sum_{l=0}^{L-1} h_{1,l}h_{1,l+2n} = 0$ for all integers n which are not zero (Tiwari et al., 2013). The essence of the above condition is to the effect that a wavelet filter should possess a unit energy, have zero mean or its sum should be zero and should exhibit orthogonality to its own shifts that are even (Tiwari et al., 2013).

Table 4
Decomposed series.

Scale	Monthly scale
B1	2–4 months
B2	4–8 months
B3	8–16 months
B4	16–32 months

Table 5
Results on Gauteng province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.041	−0.007	−0.050
		(0.027)	(0.037)	(0.035)
	Transport cost	0.009	−0.003	0.004
		(0.007)	(0.009)	(0.008)
	Output	−0.008	0.013	0.014
		(0.008)	(0.012)	(0.011)
	EXGP	1.324***	1.397***	1.423***
		(0.038)	(0.052)	(0.048)
	Constant	1.612*	−0.757	−0.489
		(0.922)	(1.272)	(1.173)
	Pseudo R-squared	0.77	0.78	0.83
Decomposed series (Wavelet)				
B1	Monetary Policy	−0.11	0.069	0.093
		(0.133)	(0.09)	(0.128)
	Transport cost	0.024**	0.030***	0.031***
		(0.011)	(0.007)	(0.01)
	Output	0.027	0.023	0.013
		(0.038)	(0.026)	(0.037)
	EXGP	1.159***	1.022***	1.154***
		(0.150)	(0.10)	(0.144)
	Constant	−0.064***	−0.002	0.061***
		(0.013)	(0.009)	(0.012)
	Pseudo R-squared	0.37	0.39	0.38
B2	Monetary Policy	−0.033	0.012	−0.060
		(0.168)	(0.14)	(0.148)
	Transport cost	0.031***	0.028***	0.021***
		(0.007)	(0.005)	(0.006)
	Output	0.045	0.029	0.027
		(0.029)	(0.024)	(0.0255)
	EXGP	1.112***	1.163***	1.211***
		(0.101)	(0.082)	(0.088)
	Constant	−0.062***	−0.001	0.063
		(0.0124)	(0.01)	(0.011)
	Pseudo R-squared	0.60	0.58	0.61
B3	Monetary Policy	0.103	0.004	−0.022
		(0.067)	(0.06)	(0.099)
	Transport cost	0.029***	0.039***	0.029***
		(0.0068)	(0.006)	(0.01)
	Output	0.008	0.012	0.012
		(0.0135)	(0.012)	(0.02)
	EXGP	1.295***	1.234***	1.322***
		(0.06)	(0.053)	(0.89)
	Constant	−0.068***	0.003	0.066***
		(0.012)	(0.0103)	(0.017)
	Pseudo R-squared	0.73	0.72	0.71
B4	Monetary Policy	−0.052	−0.096	−0.114*
		(0.064)	(0.091)	(0.068)
	Transport cost	0.035***	0.036***	0.030***
		(0.007)	(0.01)	(0.007)
	Output	0.040***	0.052***	0.070***
		(0.0075)	(0.011)	(0.008)
	EXGP	1.256***	1.316***	1.373***
		(0.054)	(0.08)	(0.06)
	Constant	−0.124***	−0.019	0.113***
		(0.014)	(0.020)	(0.015)
	Pseudo R-squared	0.75	0.74	0.77
Z4	Monetary Policy	0.013	−0.008	−0.036
		(0.024)	(0.030)	(0.024)
	Transport cost	−0.019**	−0.005	0.015*
		(0.009)	(0.011)	(0.009)
	Output	−0.012	0.002	0.003
		(0.009)	(0.012)	(0.009)
	EXGP	1.296***	1.360***	1.368***
		(0.034)	(0.043)	(0.034)
	Constant	1.945**	0.447	0.684
		(0.973)	(1.255)	(0.977)
	Pseudo R-squared	0.85	0.85	0.90

Note: EXGP represents the weighted average of the inflation rates of the provinces excluding Gauteng province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 6
Results on Mpumalanga province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.024	0.081	0.109*
		(0.032)	(0.062)	(0.064)
	Transport cost	−0.055***	−0.020	−0.000
		(0.008)	(0.015)	(0.016)
	Output	0.048***	0.023	−0.032
		(0.010)	(0.019)	(0.020)
	EXMPU	1.222***	1.101***	1.024***
		(0.030)	(0.058)	(0.059)
	Constant	−6.143***	−3.458	2.982
		(1.103)	(2.127)	(2.182)
	Pseudo R-squared	0.74	0.76	0.79
Decomposed series (Wavelet)				
B1	Monetary Policy	−0.061	−0.036	−0.023
		(0.11)	(0.099)	(0.11)
	Transport cost	−0.0163*	−0.013	−0.023**
		(0.009)	(0.0082)	(0.009)
	Output	0.0032	−0.032	−0.023
		(0.031)	(0.028)	(0.031)
	EXMPU	0.975***	0.91***	0.980***
		(0.08)	(0.073)	(0.08)
	Constant	−0.065***	−0.006	0.064***
		(0.01)	(0.0097)	(0.011)
	Pseudo R-squared	0.33	0.32	0.29
B2	Monetary Policy	0.196	0.0513	0.285
		(0.22)	(0.190)	(0.190)
	Transport cost	−0.052***	−0.034***	−0.024***
		(0.009)	(0.008)	(0.008)
	Output	−0.015	−0.0285	−0.042
		(0.038)	(0.033)	(0.032)
	EXMPU	1.268***	1.156***	1.143***
		(0.087)	(0.076)	(0.075)
	Constant	−0.102***	0.0018	0.0944***
		(0.016)	(0.014)	(0.014)
	Pseudo R-squared	0.47	0.45	0.49
B3	Monetary Policy	−0.398***	−0.383***	−0.283***
		(0.140)	(0.083)	(0.1)
	Transport cost	−0.033**	−0.028***	−0.01
		(0.0145)	(0.009)	(0.01)
	Output	0.008	0.0145	0.004
		(0.029)	(0.017)	(0.021)
	EXMPU	1.101***	1.132***	1.112***
		(0.084)	(0.05)	(0.061)
	Constant	−0.103***	0.011	0.115***
		(0.024)	(0.014)	(0.018)
	Pseudo R-squared	0.54	0.57	0.58
B4	Monetary Policy	−0.315***	−0.427***	−0.427***
		(0.066)	(0.067)	(0.119)
	Transport cost	−0.025***	−0.039***	−0.035**
		(0.007)	(0.008)	(0.0135)
	Output	−0.037***	−0.032***	−0.042***
		(0.008)	(0.008)	(0.014)
	EXMPU	1.184***	1.234***	1.181***
		(0.038)	(0.0384)	(0.068)
	Constant	−0.120***	−0.0283*	0.104***
		(0.015)	(0.0153)	(0.027)
	Pseudo R-squared	0.77	0.77	0.78
Z4	Monetary Policy	0.112**	0.176***	0.092*
		(0.047)	(0.045)	(0.049)
	Transport cost	−0.050***	−0.007	0.011
		(0.018)	(0.017)	(0.019)
	Output	0.053***	0.025	−0.002
		(0.018)	(0.017)	(0.019)
	EXMPU	1.142***	1.048***	1.092***
		(0.045)	(0.043)	(0.047)
	Constant	−6.927***	−4.012**	−0.606
		(1.989)	(1.900)	(2.074)
	Pseudo R-squared	0.78	0.81	0.86

Note: EXMPU represents the weighted average of the inflation rates of the provinces excluding Mpumalanga province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 7
Results on North West province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.108*	−0.010	0.017
		(0.055)	(0.051)	(0.066)
	Transport cost	−0.062***	−0.050***	0.001
		(0.014)	(0.013)	(0.016)
	Output	0.041**	0.043***	0.029
		(0.017)	(0.016)	(0.021)
	EXNW	1.470***	1.362***	1.282***
		(0.055)	(0.051)	(0.066)
	Constant	−5.964***	−5.948***	−4.037*
		(1.890)	(1.752)	(2.272)
	Pseudo R-squared	0.71	0.74	0.78
Decomposed series (Wavelet)				
B1	Monetary Policy	−0.243	−0.158	0.024
		(0.205)	(0.142)	(0.173)
	Transport cost	0.012	0.029**	0.034**
		(0.017)	(0.012)	(0.014)
	Output	−0.072	−0.131***	−0.116**
		(0.059)	(0.041)	(0.05)
	EXNW	1.158***	0.950***	0.967***
		(0.168)	(0.116)	(0.142)
	Constant	−0.099***	−0.005	0.103***
		(0.02)	(0.014)	(0.017)
	Pseudo R-squared	0.28	0.29	0.30
B2	Monetary Policy	−0.055	0.033	−0.0008
		(0.275)	(0.199)	(0.280)
	Transport cost	−0.001	−0.014*	−0.0014
		(0.01)	(0.008)	(0.012)
	Output	−0.009	−0.003	−0.0145
		(0.048)	(0.035)	(0.049)
	EXNW	1.136***	1.147***	1.01***
		(0.119)	(0.086)	(0.121)
	Constant	−0.112***	0.002	0.0896***
		(0.02)	(0.0146)	(0.021)
	Pseudo R-squared	0.37	0.37	0.40
B3	Monetary Policy	−0.346**	−0.328***	−0.341***
		(0.147)	(0.079)	(0.121)
	Transport cost	0.035**	0.0356***	0.0346***
		(0.015)	(0.008)	(0.012)
	Output	0.0245	−0.0001	−0.009
		(0.030)	(0.016)	(0.025)
	EXNW	0.881***	0.950***	1.003***
		(0.092)	(0.049)	(0.076)
	Constant	−0.108***	−0.008	0.087***
		(0.025)	(0.014)	(0.021)
	Pseudo R-squared	0.52	0.55	0.55
B4	Monetary Policy	−0.062	0.004	0.061
		(0.168)	(0.20)	(0.186)
	Transport cost	0.051***	0.064***	0.092***
		(0.019)	(0.022)	(0.021)
	Output	−0.036*	−0.005	0.034
		(0.0198)	(0.0234)	(0.022)
	EXNW	1.196***	1.036***	0.928***
		(0.101)	(0.120)	(0.112)
	Constant	−0.235***	0.012	0.317***
		(0.038)	(0.045)	(0.042)
	Pseudo R-squared	0.54	0.58	0.63
Z4	Monetary Policy	−0.039*	−0.072**	−0.130***
		(0.022)	(0.035)	(0.016)
	Transport cost	−0.104***	−0.051***	0.001
		(0.008)	(0.013)	(0.006)
	Output	0.097***	0.077***	0.051***
		(0.008)	(0.013)	(0.006)
	EXNW	1.520***	1.500***	1.485***
		(0.023)	(0.036)	(0.016)
	Constant	−12.020***	−9.665***	−6.573***
		(0.919)	(1.450)	(0.658)
	Pseudo R-squared	0.86	0.87	0.92

Note: EXNW represents the weighted average of the inflation rates of the provinces excluding North West province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 8
Results on Eastern Cape province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.006	0.009	−0.000
		(0.042)	(0.050)	(0.062)
	Transport cost	−0.004	0.012	−0.014
		(0.010)	(0.012)	(0.015)
	Output	−0.052***	−0.065***	−0.013
		(0.013)	(0.016)	(0.019)
	EXEC	1.022***	1.051***	1.100***
		(0.043)	(0.051)	(0.062)
	Constant	5.585***	6.839***	1.996
		(1.438)	(1.719)	(2.110)
	Pseudo R-squared	0.70	0.72	0.75
Decomposed series (Wavelet)				
B1	Monetary Policy	0.086	0.134	0.119
		(0.153)	(0.165)	(0.145)
	Transport cost	−0.013	−0.002	0.015
		(0.013)	(0.014)	(0.012)
	Output	0.093**	0.0731	0.052
		(0.044)	(0.047)	(0.042)
	EXEC	1.009***	0.996***	1.063***
		(0.127)	(0.137)	(0.121)
	Constant	−0.103***	0.0181	0.102***
		(0.015)	(0.0162)	(0.014)
	Pseudo R-squared	0.25	0.24	0.305
B2	Monetary Policy	0.398**	0.371*	0.468**
		(0.190)	(0.197)	(0.22)
	Transport cost	−0.007	−0.011	−0.022**
		(0.008)	(0.0082)	(0.009)
	Output	0.045	0.013	0.010
		(0.033)	(0.034)	(0.038)
	EXEC	1.126***	1.185***	1.175***
		(0.086)	(0.09)	(0.098)
	Constant	−0.093***	−0.0001	0.093***
		(0.014)	(0.0145)	(0.016)
	Pseudo R-squared	0.475	0.471	0.483
B3	Monetary Policy	0.247**	0.280***	0.149
		(0.096)	(0.075)	(0.101)
	Transport cost	−0.031***	−0.045***	−0.04***
		(0.010)	(0.008)	(0.01)
	Output	0.009	0.0055	−0.006
		(0.020)	(0.015)	(0.021)
	EXEC	1.139***	1.225***	1.180***
		(0.064)	(0.05)	(0.067)
	Constant	−0.098***	−0.004	0.084***
		(0.017)	(0.013)	(0.018)
	Pseudo R-squared	0.63	0.65	0.67
B4	Monetary Policy	0.222***	0.229**	0.387***
		(0.065)	(0.116)	(0.126)
	Transport cost	−0.039***	−0.035***	−0.002
		(0.007)	(0.013)	(0.0144)
	Output	−0.120***	−0.11***	−0.103***
		(0.008)	(0.014)	(0.015)
	EXEC	1.278***	1.347***	1.180***
		(0.041)	(0.074)	(0.08)
	Constant	−0.182***	−0.026	0.144***
		(0.015)	(0.026)	(0.03)
	Pseudo R-squared	0.75	0.74	0.75
Z4	Monetary Policy	0.025	0.029	−0.185***
		(0.026)	(0.048)	(0.062)
	Transport cost	0.007	0.017	0.019
		(0.010)	(0.018)	(0.023)
	Output	−0.060***	−0.063***	−0.028
		(0.010)	(0.018)	(0.024)
	EXEC	1.004***	0.992***	1.191***
		(0.027)	(0.050)	(0.064)
	Constant	6.350***	6.797***	4.035
		(1.091)	(2.001)	(2.575)
	Pseudo R-squared	0.80	0.79	0.82

Note: EXEC represents the weighted average of the inflation rates of the provinces excluding Eastern Cape province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 9
Results on KwaZulu-Natal province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.110***	−0.122***	0.038
		(0.031)	(0.047)	(0.058)
	Transport cost	0.040***	0.033***	0.032**
		(0.008)	(0.012)	(0.014)
	Output	−0.040***	−0.070***	−0.068***
		(0.009)	(0.015)	(0.018)
	EXKZN	1.279***	1.274***	1.216***
		(0.033)	(0.050)	(0.063)
	Constant	3.591***	7.040***	6.468***
		(1.040)	(1.598)	(1.981)
	Pseudo R-squared	0.78	0.78	0.80
Decomposed series (Wavelet)				
B1	Monetary Policy	−0.149	−0.027	−0.107
		(0.169)	(0.125)	(0.143)
	Transport cost	0.042***	0.049***	0.038***
		(0.014)	(0.01)	(0.012)
	Output	−0.074	−0.010	−0.024
		(0.049)	(0.036)	(0.041)
	EXKZN	0.739***	0.726***	0.593***
		(0.14)	(0.102)	(0.12)
	Constant	−0.088***	0.012	0.094***
		(0.017)	(0.0123)	(0.014)
	Pseudo R-squared	0.26	0.30	0.32
B2	Monetary Policy	0.184	0.267*	0.101
		(0.171)	(0.151)	(0.195)
	Transport cost	0.009	0.015**	0.015*
		(0.007)	(0.006)	(0.008)
	Output	−0.036	−0.052**	−0.007
		(0.03)	(0.026)	(0.034)
	EXKZN	1.037***	1.031***	0.995***
		(0.079)	(0.07)	(0.09)
	Constant	−0.074***	−0.006	0.077***
		(0.013)	(0.011)	(0.014)
	Pseudo R-squared	0.52	0.51	0.52
B3	Monetary Policy	0.157	0.222***	0.104
		(0.108)	(0.084)	(0.081)
	Transport cost	−0.003	−0.0147*	−0.013
		(0.011)	(0.009)	(0.0084)
	Output	−0.002	−0.0085	−0.009
		(0.223)	(0.017)	(0.017)
	EXKZN	1.033***	1.033***	1.116***
		(0.075)	(0.058)	(0.056)
	Constant	−0.092***	0.004	0.0936***
		(0.019)	(0.015)	(0.014)
	Pseudo R-squared	0.59	0.61	0.62
B4	Monetary Policy	0.235***	0.347***	0.446***
		(0.086)	(0.104)	(0.136)
	Transport cost	0.013	0.006	0.0008
		(0.01)	(0.012)	(0.015)
	Output	−0.109***	−0.123***	−0.127***
		(0.01)	(0.0122)	(0.016)
	EXKZN	1.132***	1.066***	1.111***
		(0.057)	(0.069)	(0.09)
	Constant	−0.145***	−0.044*	0.157***
		(0.02)	(0.024)	(0.03)
	Pseudo R-squared	0.74	0.73	0.74
Z4	Monetary Policy	−0.237***	−0.194***	−0.131***
		(0.020)	(0.034)	(0.027)
	Transport cost	0.055***	0.079***	0.105***
		(0.007)	(0.013)	(0.010)
	Output	−0.068***	−0.079***	−0.070***
		(0.007)	(0.013)	(0.010)
	EXKZN	1.427***	1.342***	1.288***
		(0.022)	(0.038)	(0.030)
	Constant	6.620***	7.943***	6.984***
		(0.806)	(1.419)	(1.106)
	Pseudo R-squared	0.89	0.88	0.91

Note: EXKZN represents the weighted average of the inflation rates of the provinces excluding KwaZulu-Natal province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 10
Results on Limpopo province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.200***	−0.082	−0.030
		(0.072)	(0.066)	(0.073)
	Transport cost	0.006	0.009	−0.004
		(0.018)	(0.016)	(0.018)
	Output	0.021	0.036*	0.037
		(0.023)	(0.021)	(0.023)
	EXLMP	1.352***	1.377***	1.356***
		(0.072)	(0.066)	(0.073)
	Constant	−2.859	−4.839**	−4.626*
		(2.470)	(2.253)	(2.495)
	Pseudo R-squared	0.67	0.71	0.74
Decomposed series (Wavelet)				
B1	Monetary Policy	0.067	−0.188	−0.232
		(0.245)	(0.235)	(0.246)
	Transport cost	0.033	0.012	−0.005
		(0.02)	(0.019)	(0.02)
	Output	0.185***	0.112*	0.059
		(0.07)	(0.067)	(0.071)
	EXLMP	1.029***	0.974***	1.186***
		(0.199)	(0.191)	(0.20)
	Constant	−0.131***	0.005	0.170***
		(0.024)	(0.023)	(0.024)
	Pseudo R-squared	0.19	0.185	0.20
B2	Monetary Policy	−0.539	−0.227	−0.538
		(0.418)	(0.293)	(0.402)
	Transport cost	−0.028	−0.0201*	−0.034**
		(0.0173)	(0.012)	(0.017)
	Output	−0.043	−0.027	−0.004
		(0.073)	(0.051)	(0.07)
	EXLMP	1.351***	1.106***	1.151***
		(0.181)	(0.127)	(0.174)
	Constant	−0.137***	−0.007	0.133***
		(0.031)	(0.022)	(0.03)
	Pseudo R-squared	0.31	0.30	0.29
B3	Monetary Policy	−0.0175	0.148	−0.126
		(0.154)	(0.135)	(0.133)
	Transport cost	−0.0252	−0.028**	−0.035**
		(0.016)	(0.014)	(0.014)
	Output	0.005	−0.012	−0.045
		(0.032)	(0.0278)	(0.027)
	EXLMP	1.027***	1.02***	1.139***
		(0.1)	(0.087)	(0.086)
	Constant	−0.145***	−0.002	0.147***
		(0.027)	(0.024)	(0.023)
	Pseudo R-squared	0.48	0.46	0.50
B4	Monetary Policy	0.125	0.301*	0.507***
		(0.215)	(0.155)	(0.182)
	Transport cost	0.003	−0.002	0.022
		(0.024)	(0.017)	(0.02)
	Output	−0.05*	−0.0344*	−0.078***
		(0.025)	(0.018)	(0.021)
	EXLMP	1.143***	1.032***	1.126***
		(0.132)	(0.095)	(0.112)
	Constant	−0.239***	−0.016	0.256***
		(0.048)	(0.035)	(0.041)
	Pseudo R-squared	0.57	0.59	0.64
Z4	Monetary Policy	−0.245***	−0.172***	−0.079
		(0.031)	(0.050)	(0.048)
	Transport cost	0.028**	0.051***	0.093***
		(0.011)	(0.019)	(0.018)
	Output	0.055***	0.046**	−0.032*
		(0.012)	(0.019)	(0.018)
	EXLMP	1.537***	1.430***	1.280***
		(0.032)	(0.051)	(0.049)
	Constant	−6.930***	−5.763***	2.528
		(1.283)	(2.071)	(1.990)
	Pseudo R-squared	0.84	0.83	0.85

Note: EXLMP represents the weighted average of the inflation rates of the provinces excluding Limpopo province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 11
Results on Northern Cape province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.211***	−0.149***	−0.011
		(0.065)	(0.049)	(0.126)
	Transport cost	−0.035**	−0.012	−0.002
		(0.016)	(0.012)	(0.031)
	Output	0.040*	0.013	0.034
		(0.021)	(0.015)	(0.039)
	EXNC	1.176***	1.133***	1.143***
		(0.062)	(0.047)	(0.120)
	Constant	−3.960*	−1.211	−3.887
		(2.240)	(1.687)	(4.317)
	Pseudo R-squared	0.61	0.64	0.65
Decomposed series (Wavelet)				
B1	Monetary Policy	0.077	0.211	0.008
		(0.158)	(0.143)	(0.225)
	Transport cost	−0.008	−0.018	0.0012
		(0.013)	(0.012)	(0.019)
	Output	−0.094**	−0.077*	−0.125*
		(0.045)	(0.041)	(0.065)
	EXNC	0.845***	1.034***	0.967***
		(0.124)	(0.113)	(0.177)
	Constant	−0.097***	−0.012	0.109***
		(0.015)	(0.014)	(0.022)
	Pseudo R-squared	0.25	0.23	0.21
B2	Monetary Policy	0.367	−0.001	0.207
		(0.422)	(0.195)	(0.249)
	Transport cost	0.0005	0.002	−0.009
		(0.017)	(0.008)	(0.010)
	Output	0.0152	−0.034	−0.06
		(0.073)	(0.034)	(0.0434)
	EXNC	1.008***	1.046***	1.155***
		(0.178)	(0.082)	(0.11)
	Constant	−0.084***	0.008	0.108***
		(0.031)	(0.014)	(0.0183)
	Pseudo R-squared	0.33	0.35	0.37
B3	Monetary Policy	0.460***	0.361***	0.236
		(0.12)	(0.115)	(0.183)
	Transport cost	−0.006	−0.0045	−0.023
		(0.0124)	(0.012)	(0.019)
	Output	−0.024	−0.014	−0.056
		(0.025)	(0.024)	(0.038)
	EXNC	1.10***	1.11***	1.221***
		(0.074)	(0.071)	(0.113)
	Constant	−0.118***	−0.022	0.128***
		(0.021)	(0.02)	(0.032)
	Pseudo R-squared	0.56	0.55	0.53
B4	Monetary Policy	0.345*	0.395***	0.446***
		(0.189)	(0.103)	(0.165)
	Transport cost	−0.067***	−0.072***	−0.069***
		(0.021)	(0.012)	(0.019)
	Output	−0.041*	−0.028**	−0.047**
		(0.0222)	(0.0122)	(0.0194)
	EXNC	1.226***	1.180***	1.108***
		(0.11)	(0.06)	(0.096)
	Constant	−0.141***	−0.002	0.205***
		(0.043)	(0.024)	(0.038)
	Pseudo R-squared	0.62	0.67	0.70
Z4	Monetary Policy	−0.184**	−0.187***	−0.369***
		(0.071)	(0.065)	(0.070)
	Transport cost	−0.018	0.015	0.063**
		(0.027)	(0.024)	(0.026)
	Output	0.057**	−0.009	0.009
		(0.027)	(0.025)	(0.027)
	EXNC	1.244***	1.198***	1.391***
		(0.070)	(0.064)	(0.069)
	Constant	−6.356**	0.940	−0.491
		(2.986)	(2.739)	(2.939)
	Pseudo R-squared	0.64	0.69	0.77

Note: EXNC represents the weighted average of the inflation rates of the provinces excluding Northern Cape province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 12
Results on Eestern Cape province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	0.097	0.207***	0.389***
		(0.061)	(0.052)	(0.054)
	Transport cost	−0.037**	−0.014	0.002
		(0.015)	(0.013)	(0.014)
	Output	0.031	0.005	0.009
		(0.020)	(0.017)	(0.017)
	EXWC	1.125***	1.005***	0.781***
		(0.068)	(0.058)	(0.060)
	Constant	−3.569*	−0.702	−0.989
		(2.132)	(1.833)	(1.890)
	Pseudo R-squared	0.65	0.68	0.76
Decomposed series (Wavelet)				
B1	Monetary Policy	−0.084	−0.131	0.056
		(0.123)	(0.081)	(0.097)
	Transport cost	−0.0007	0.001	−0.005
		(0.010)	(0.007)	(0.008)
	Output	0.017	0.045*	0.044
		(0.035)	(0.0231)	(0.028)
	EXWC	1.032***	1.150***	1.066***
		(0.110)	(0.072)	(0.087)
	Constant	−0.060***	0.006	0.065***
		(0.012)	(0.008)	(0.001)
	Pseudo R-squared	0.35	0.39	0.43
B2	Monetary Policy	−0.168	−0.059	0.003
		(0.193)	(0.164)	(0.164)
	Transport cost	0.013	0.0112*	0.013*
		(0.008)	(0.007)	(0.007)
	Output	0.041	0.022	0.059**
		(0.034)	(0.029)	(0.029)
	EXWC	1.066***	1.047***	0.946***
		(0.094)	(0.08)	(0.08)
	Constant	−0.068***	−0.004	0.066***
		(0.014)	(0.012)	(0.012)
	Pseudo R-squared	0.53	0.53	0.54
B3	Monetary Policy	0.374**	−0.019	0.054
		(0.144)	(0.108)	(0.11)
	Transport cost	−0.002	0.0054	0.001
		(0.015)	(0.011)	(0.011)
	Output	0.0577*	0.044**	0.017
		(0.0293)	(0.022)	(0.022)
	EXWC	1.253***	1.154***	1.282***
		(0.107)	(0.081)	(0.082)
	Constant	−0.132***	0.0168	0.127***
		(0.025)	(0.0189)	(0.019)
	Pseudo R-squared	0.58	0.59	0.63
B4	Monetary Policy	−0.043	0.104	0.058
		(0.190)	(0.088)	(0.117)
	Transport cost	−0.038*	−0.021**	−0.0165
		(0.022)	(0.01)	(0.0134)
	Output	0.092***	0.087***	0.082***
		(0.023)	(0.011)	(0.014)
	EXWC	1.123***	0.992***	1.022***
		(0.128)	(0.060)	(0.079)
	Constant	−0.109**	0.002	0.197***
		(0.043)	(0.020)	(0.027)
	Pseudo R-squared	0.55	0.59	0.63
Z4	Monetary Policy	0.245***	0.260***	0.280***
		(0.021)	(0.040)	(0.050)
	Transport cost	−0.078***	−0.052***	−0.029
		(0.008)	(0.015)	(0.019)
	Output	0.023***	0.022	0.030
		(0.009)	(0.016)	(0.020)
	EXWC	0.971***	0.934***	0.880***
		(0.025)	(0.046)	(0.057)
	Constant	−2.615***	−2.348	−2.903
		(0.928)	(1.725)	(2.176)
	Pseudo R-squared	0.80	0.79	0.84

Note: EXWC represents the weighted average of the inflation rates of the provinces excluding Western Cape province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Table 13
Results on Free State province.

Scales	Variables	25th Quantile	50th Quantile	75th Quantile
Raw/Initial data				
	Monetary Policy	−0.008	−0.036	−0.001
		(0.028)	(0.045)	(0.051)
	Transport cost	−0.004	−0.011	−0.008
		(0.007)	(0.011)	(0.013)
	Output	−0.011	−0.009	0.010
		(0.009)	(0.014)	(0.016)
	EXFS	0.984***	1.012***	0.973***
		(0.028)	(0.044)	(0.050)
	Constant	1.411	1.566	−0.029
		(0.957)	(1.538)	(1.754)
	Pseudo R-squared	0.76	0.75	0.79
Decomposed series (Wavelet)				
B1	Monetary Policy	0.150	0.176	0.312**
		(0.158)	(0.115)	(0.152)
	Transport cost	−0.01	0.001	−0.024*
		(0.013)	(0.009)	(0.0125)
	Output	−0.036	−0.014	−0.017
		(0.045)	(0.033)	(0.044)
	EXFS	0.847***	0.734***	0.888***
		(0.126)	(0.092)	(0.122)
	Constant	−0.073	0.002	0.071***
		(0.0154)	(0.011)	(0.015)
	Pseudo R-squared	0.27	0.25	0.25
B2	Monetary Policy	−0.128	−0.015	−0.113
		(0.221)	(0.137)	(0.225)
	Transport cost	0.013	0.015***	0.016*
		(0.01)	(0.006)	(0.0093)
	Output	−0.001	−0.036	−0.019
		(0.039)	(0.024)	(0.0395)
	EXFS	0.946***	0.947***	0.936***
		(0.096)	(0.06)	(0.098)
	Constant	−0.078***	−0.005	0.086***
		(0.016)	(0.01)	(0.017)
	Pseudo R-squared	0.51	0.495	0.48
B3	Monetary Policy	−0.088	−0.140**	−0.122
		(0.062)	(0.065)	(0.11)
	Transport cost	−0.0076	−0.012*	−0.018
		(0.006)	(0.007)	(0.011)
	Output	−0.0082	−0.007	−0.016
		(0.013)	(0.0132)	(0.022)
	EXFS	1.098***	1.08***	1.057***
		(0.04)	(0.04)	(0.069)
	Constant	−0.088***	−0.0123	0.085***
		(0.011)	(0.011)	(0.019)
	Pseudo R-squared	0.69	0.68	0.67
B4	Monetary Policy	0.083	0.012	0.12
		(0.073)	(0.087)	(0.146)
	Transport cost	−0.026***	−0.025**	−0.007
		(0.0083)	(0.01)	(0.0166)
	Output	−0.027***	−0.026**	−0.004
		(0.0086)	(0.01)	(0.017)
	EXFS	1.136***	1.13***	0.953***
		(0.045)	(0.053)	(0.089)
	Constant	−0.142***	−0.05**	0.161***
		(0.017)	(0.02)	(0.03)
	Pseudo R-squared	0.70	0.71	0.71
Z4	Monetary Policy	−0.043*	0.029	0.018
		(0.024)	(0.032)	(0.043)
	Transport cost	−0.005	−0.004	−0.015
		(0.009)	(0.012)	(0.016)
	Output	−0.008	−0.008	−0.001
		(0.009)	(0.012)	(0.017)
	EXFS	1.028***	0.932***	0.913***
		(0.025)	(0.032)	(0.043)
	Constant	1.220	1.502	1.221
		(1.021)	(1.321)	(1.792)
	Pseudo R-squared	0.83	0.83	0.86

Note: EXFS represents the weighted average of the inflation rates of the provinces excluding Free State province. ***,** and * represent statistical significance at 1%, 5% and 10% respectively. Standard errors in parenthesis.

Let define $g_1 = (g_{1,0}, \ldots, g_{1,L-1}, 0, \ldots, 0)^T$ as scaling coefficients that are also zero padded with $g_{1,l} = (-1)^{l+1} h_{1,L-l-1}$ and the time series is given by $x_{0,\ldots\ldots,} x_{N-1}$. We can filter the time series with the aid of h_j that delivers the coefficients of the wavelets for scales that have $N \geq L_j$ such that $L_j = (2^j - 1)(L-1) + 1$. Thus:

$$W_{j,t} = 2^{j/2} \widehat{W}_{j,2^j(t+1)+1}, \quad \left[(L-2)\left(1 - \frac{1}{2^j}\right)\right] \leq t \leq \left[\frac{N}{2^j} - 1\right] \tag{6}$$

such that

$$\widehat{W}_{j,t} = \frac{1}{2^{j/2}} \sum_{2^{j/2}}^{L_{j-1}} h_{j,l} X_{t-1}, \quad t = L_j - 1, \ldots\ldots N - 1$$

We derive the coefficients for $\widehat{W}_{j,t}$ that are related to variations on a scale that has a length $\vartheta_j = 2^{j-1}$ through the sub sampling of each 2^jth of coefficients of $\widehat{W}_{j,t}$.

4.3.3. The maximal overlap discrete wavelet transform (MODWT)

The discrete wavelet transform (DWT) is limited in view of the requirement of dyadic length or the divisibility of sample size by 2^j and so we resort to the maximal overlap discrete wavelet transform. The maximal overlap discrete wavelet transform does not impose such requirements, thereby making it a preferred alternative. Importantly, the use of MODWT is superior since decimation operation make wavelet and the associated scaling coefficients to be sensitive to shifts of circular nature and therefore vary across shifts. In the MODWT, the coefficients of the wavelets represented by $\widehat{W}_{j,t}$ and the coefficients of the scales denoted by $\widehat{V}_{j,t}$ where j varies from 1 to J are derived by:

$$\widehat{W}_{j,t} = \sum_{l=0}^{L-1} \widehat{g}\widehat{v}_{j-1,\, t-1 \ \ modN} \text{ and } \widehat{V}_{j,t} = \sum_{l=0}^{L-1} \widehat{h}\widehat{v}_{j-1,\, t-1 \ \ modN} \tag{7}$$

We rescale the filters of the wavelet and scales ($\widehat{g}_l$ and $\widehat{h}_l$) as $\widehat{g}_j = g_j/2^{j/2}$ and $\widehat{h}_j = h_j/2^{j/2}$. The wavelet coefficients, non-decimated, signify the distinctions between the data's generalized averages using a scale of $\vartheta_j = 2^{J-1}$.

A limitation of the DWT is the fact that it is applicable only to sample sizes of multiple of 2. For the MODWT however, it is applicable to sample of any size while it preserves all of the DWT functions. In addition, it is devoid of phase-shifts that vary events' location in time (Mensi et al., 2016). Moreover, it is invariant with respect to translations since the pattern of the coefficients of the wavelet transform do not vary following a signal shift.

4.3.4. The quantile regression

Having done the decomposition using the wavelet approach, we now assess the asymmetric effect of monetary on provincial inflation across different scales and at different quantiles of the distributions of the respective provincial inflation. To estimate the quantile regression, following Iddrisu and Alagidede (2020), we define the model as:

$$g_t = x_t'\beta + \varepsilon_t \tag{8a}$$

$$E(g_t | x_t) = x_t'\beta \tag{8b}$$

$$Q_{g_t}(\tau | x_t) = x_t'\beta_\tau \tag{8c}$$

$$\beta_\tau = \beta + \vartheta \mathrm{F}^{-1}(\tau) \tag{8d}$$

where the cumulative distribution function of $\{\varepsilon_t\}$ is given by F and ϑ signifies a constant. In addition, τ denotes the specified quantiles we are considering and each province's inflation's conditional quantile function given the covariates is given by $Q_{g_t}(\tau | x_t)$. Given our total observations of 155, our data on provincial inflation is split at 25th, 50th and the 75th quantiles such that each quantile has sufficient observations for a meaningful econometric analysis. β_τ denotes the vector of parameters at the various quantiles we specified. The parameters or coefficients at the respective quantiles represent the marginal effects of the covariates on provincial inflation at a particular quantile of provincial inflation. The x_t represents the vector of these covariates whiles ε_t is the error term. A key virtue of the quantile regression analysis is that the errors can assume any distribution.

We estimate the parameters in equation (8) by minimizing the following loss function:

$$\min_{\beta_\tau \in \Re^p} \sum_{t=1}^{T} \rho_\tau \left(g_t - x_t'\beta_\tau\right) \tag{9}$$

where p = dimension (β_τ). We simplify the loss function in equation (9) by expressing it as:

$$\rho_\tau(\varepsilon) = \varepsilon(\tau - I(\varepsilon < 0))$$

Such that I represents an indicator function which takes the value 1 when $\varepsilon < 0$ or 0 otherwise.

Unlike the mean-based approaches that minimize the sum of the residuals squared, the sum of the absolute values of the residuals along with asymmetric penalties are minimized in the case of quantile regression. Thus, the minimization problem showed in equation (9) is given as:

$$\min_{\beta_\tau \in \Re^p} \sum_{t=1}^{T} \tau |\varepsilon_t| + \sum_{t=1}^{T} (1-\tau) |\varepsilon_t| \tag{10}$$

such that $\tau|\varepsilon_t|$ represents penalization for $\varepsilon_t \geq 0$ whiles $\varepsilon_t < 0$ is penalized by $(1-\tau)|\varepsilon_t|$.

5. Results

As noted by Crowley (2007), the scales produced in wavelet decomposition for any given series are necessarily a function of the number of observations. For each of the series, we have 155 observations. As a result, the decomposed series delivered four (4) scales from B1 to B4. Following the work of Crowley (2007), we define these scales in Table 4. The scale Z4 represents the trend.

For each of these scales, we estimated the monetary policy effect at specified quantiles.

We find that different provinces respond differently to changes in monetary policy in South Africa. The inflation of Gauteng province, the economic heartbeat of South Africa, responds to changes in monetary policy over the longest horizon (sixteen to thirty-two months) and at the 75th quantile as per Table 5. Specifically, a percentage tightening in monetary policy stabilizes prices in the Gauteng province by 0.114% at the 75th quantile over the sixteen-to-thirty-two-month horizon. That is, an increase in the repo rate (tightening of monetary policy) occasions a decline in the prices of goods and services in the Gauteng province. The negative response

of the province's inflation to monetary policy changes is not surprising, given the presence of large industrial and service concerns in the province. These firms are relatively more sensitive to interest rate changes.

Another province where monetary policy provides stability in the prices is the Mpumalanga province, although with distinct responses from Gauteng. In Mpumalanga, monetary policy stabilizes prices over B3 and B4 scales which correspond to eight-to-sixteen-month and sixteen-to-thirty-two-month horizons respectively as presented in Table 6. Over the eight-to-sixteen-month horizon, a percentage tightening of monetary policy delivers price stability of 0.4% at the 25th quantile, 0.38% at the 50th quantile and 0.28% at the 75th quantile. Over the sixteen-to-thirty-two-month horizon, a percentage restriction of monetary policy exacts price stability of 0.32% at the 25th quantile and 0.43% at the 50th and 75th quantiles respectively in Mpumalanga. The province's economy thrives on mining, trade (wholesale and retail) and manufacturing. Firms in these sectors are relatively more sensitive to interest rates.

For North West province where mining activities, trade and manufacturing also dominate in terms of the economic structure of the province, we find that the stabilizing effect of restrictive monetary policy manifests over the eight-to-sixteen-month horizon and across all the quantiles as per Table 7. Specifically, prices in the province stabilize by 0.35% at the 25th quantile, 0.33% at the 50th quantile and 0.34% at the 75th quantile over the eight-to-sixteen-month horizon following a percentage tightening of monetary policy.

For other provinces such as Eastern Cape, KwaZulu-Natal, Limpopo, Northern Cape and Western Cape however, we find that restrictive monetary policy is rather destabilizing. That is, a tightening of monetary policy (increase in the repo rate) leads to an increase in the prices of goods and services in these provinces. In the case of Eastern Cape, we find that the destabilizing effect of restrictive monetary policy manifests over three successive scales (B2, B3 and B4) and across different quantiles as per Table 8. Over the four-to-eight-month horizon (B2), we find that a percentage tightening of monetary policy increases prices by 0.398% at the 25th quantile, 0.371% at the 50th quantile and 0.468% at the 75th quantile. For B3, a percentage increase in monetary policy destabilizes prices by 0.247% at the 25th quantile and 0.28% at the 50th quantile. At the highest scale (B4), we find that a percentage restriction of monetary policy elicits price increases of 0.22% at the 25th quantile, 0.23% at the 50th quantile and 0.387% at the 75th quantile.

For KwaZulu-Natal province, we find that at B2, the province's prices destabilize by 0.267% at only the 50th quantile following a percentage tightening of monetary policy as per Table 9. At B3, a percentage policy restriction fuels instability in the province's prices by 0.22% at the 50th quantile. At the highest scale (B4) however, the destabilizing effect of restrictive monetary policy is felt across all the quantiles, with a percentage restriction occasioning a destabilization of 0.235% at the 25th quantile, 0.347% at the 50th quantile and 0.446% at the 75th quantile.

Turning to Limpopo province, with results in Table 10, we find that the only statistically significant monetary policy effect on the province's inflation is at the highest scale (B4) and at the 50th and 75th quantiles. At the 50th quantile, prices in the province increase by 0.3% following a percentage tightening of monetary policy. At the 75th quantile, prices in the province destabilize by 0.507% in response to a percentage monetary policy tightening.

For the Northern Cape province, we find the effect of monetary policy on prices of the province to be statistically significant at B3 and B4 scales as per Table 11. Specifically, a percentage restriction of monetary policy destabilizes prices over eight-to-sixteen-month horizon (B3) by 0.46% at the 25th quantile and by 0.361% at the 50th quantile. At B4 however, prices in the province destabilize by 0.345% at the 25th quantile, 0.395% at the 50th quantile and 0.446% at the 75th quantile following a percentage restriction of monetary policy.

To the Western Cape province, with results presented in Table 12, we find that monetary policy effect is significant only over the eight-to-sixteen-month horizon and at the 25th quantile. Specifically, prices in the province soar by 0.374% at the 25th quantile over the eight-to-sixteen-month horizon following a percentage tightening of monetary policy in South Africa.

The positive effect of monetary policy on provincial inflation rates of KwaZulu-Natal and the Western Cape provinces in particular is surprising, especially because they are relatively 'industrial' provinces with well-functioning finance, manufacturing and transportation sub-sectors. These sub-sectors house firms that are expected to have reasonable sensitivity to interest rate changes. However, the results may not be far-farfetched given that the contributions of these two provinces (KwaZulu-Natal and Western Cape) to the output of the South African economy are greatest in the agricultural sub-sector relative to the other sectors of the economy. In other words, the two provinces contribute more to the economy of South Africa through agriculture than any other sector. The two provinces combined contributed 50.2% of the value-added of South Africa's agricultural sector over the period under review. Firms in the agricultural sector are less sensitive to interest rates relative to sectors such as manufacturing and finance. Given such dominance of agriculture in these two provinces, it is reasonable to expect food prices to be key in the inflation basket of the provinces. Meanwhile, food prices are known to respond positively to interest rates (monetary policy) as per the works of Iddrisu and Alagidede (2020) and Bhattacharya and Jain (2019).

The findings for the Free State province, as per Table 13, is mixed. At the lower scale (B1) or over two to four months horizon, a restrictive monetary policy is destabilizing for prices in the Free State province at the 75th quantile. Prices in the province are destabilized by 0.312% following a percentage restriction of monetary policy. At B3 or eight-to-sixteen-month horizon however, prices in the province stabilize by 0.14% following a percentage monetary policy restriction.

In respect of transportation cost, which also reflects changes in prices of fuel and the cost of moving goods within the country, we find differential effect on overall inflation of the respective provinces. For the Gauteng province, we find that increases in the cost of transportation exert upward pressure on the overall inflation at all the scales and across all the quantiles. Thus, transportation cost is necessarily a major contributor to inflationary momentum in the province. This is not surprising given the fact that the province is the melting pot of the South African economy with significant proportion of good-paying jobs concentrated in the province. The availability of such jobs in the province attracts numerous people to the province with enormous opportunities for the transportation sub sector as workers require some form of transportation to commute between work places and homes. Indeed, the province is the most populous in the country with its attendant opportunities of high demand for food and household consumables. These food items are either transported from other provinces or from production centres in the province to the malls and shops. As a result, transportation cost necessarily plays a critical role in the price dynamics of the region. For Eastern Cape, Limpopo, Mpumalanga and Northern Cape provinces, we find that transportation cost rather exerts negative effect on their respective inflation rates across distinct scales and quantiles. Meanwhile, the findings for Free State, KwaZulu-Natal, North West and Western Cape provinces are mixed.

5.1. Robustness checks

We ascertain the robustness of our findings by considering a different specification that includes exchange rate. The idea is that some firms may be more oriented to international trade (imports and exports) than others in an economy and different provinces have different mix of these firms. As a result, movements in exchange rates are expected to impact on the operations of different firms and their pricing strategies that eventually feed into the consumer prices in the provinces. We measure the exchange rate as Rand against the United States Dollar as the dollar is the major foreign currency that is traded in the country. The findings, presented in the Appendix, indicate that our earlier findings are robust. For monetary policy in particular, the findings remain largely robust in terms of the signs and statistical significance.

6. Policy discussion

Undoubtedly, economic agents in the same country are confronted with distinct prices by virtue of their geographical locations. The flagrant disregard for such heterogeneity in many of the studies on monetary policy-inflation nexus that assume price homogeneity is a worrying empirical and policy conundrum. As our study has demonstrated, different provinces do not only face different prices, but their prices also respond heterogeneously to monetary policy. While monetary policy tightening provide stability in the prices of some provinces, other provinces witness further inflationary momentum. These findings then present implications for welfare. Monetary policy is supposed to deliver optimality in the welfare of the economic agents in the country. With these agents facing distinct prices across different locations in the same country implies that a monetary policy that focuses solely on national inflation may be welfare damaging for a substantial number of the very economic agents in whose interest the policy decisions are supposed to have been taken. This is because a restrictive monetary policy that is meant to rein in national level inflation may be too restrictive for some provinces and the economic agents therein.

Moreover, the differential responses of provincial inflation to monetary policy pose a risk to the achievement of publicly announced inflation targets in the context of inflation targeting countries. A restrictive monetary policy is destabilizing for as many as five provinces (Eastern Cape, KwaZulu-Natal, Limpopo, Northern Cape and Western Cape), and that is substantial in derailing stabilization efforts of the monetary policy authorities. The heterogeneous provincial inflation responses to the monetary policy pose even greater challenge, as such distinctive responses exacerbate the eccentricities in the provincial level inflation with spillover effect on the national price level. In the presence of such eccentricities, gauging the desired policy impact ex ante becomes even more daunting.

Monetary policy decisions should take into consideration provincial heterogeneity in prices and price developments. In forecasting inflation levels that inform monetary policy stance, monetary authorities must understand that the expected inflation outcome is heterogeneously influenced by distinct factors across provinces. Ignoring such heterogeneity is a sure recipe for welfare destruction and policy fatality.

7. Conclusion

The fact that different provinces have different economic structures and endowments is an ample reason to expect that price developments in these provinces would necessarily be distinct. Surprisingly, empirical studies assume that these economic agents in an economy face homogeneous prices in looking at the monetary policy-inflation nexus. Such homogeneous price assumption is welfare-damaging for economic agents who face prices that are substantially distinct from the target of the policy authorities. Although some studies on heterogeneous regional response to monetary policy exist, they are largely in the context of regional output response to monetary policy. Meanwhile, heterogeneous regional price response is even more germane, especially in the context of inflation targeting countries. Few studies have considered distinct regional price responses to monetary policy but suffer the limitation that they assume each region's inflation relates symmetrically to monetary policy. Meanwhile, monetary policy-inflation nexus is seldom symmetric. We provide a multi-layered asymmetric exposition on provincial inflation-monetary policy relationship by using the wavelet-based quantile regression approach for the first time in this strand of the literature. We decomposed our original series into scales using the wavelet technique whiles we apply the quantile regression technique in each scale to unearth the asymmetric relationship between provincial inflation and monetary policy.

We find that provinces respond differently to changes in monetary policy. Whiles restrictive monetary policy delivers stability in the prices of Gauteng, Mpumalanga and North West provinces, it is destabilizing for prices in Eastern Cape, KwaZulu-Natal, Limpopo, Northern Cape and Western Cape provinces. For Free State province, the effect of a restrictive monetary policy on prices is mixed, depending on the horizon and the quantile involved. Importantly, these provinces respond distinctively at various quantiles and over distinct horizons. We also find that provinces respond differently to transportation cost and output. Significantly, we find that prices in each province is necessarily a function of price developments in the other provinces. The findings are robust to different specifications.

In respect of policy, we recommend a policy framework that incorporates the heterogeneity of the economies of the provinces and the prices that agents face. It must be pointed out that the analysis of provincial inflation-monetary policy nexus in this study has been hampered by data unavailability. It would have been invaluable to control for province-specific factors such as size and distribution of firms, region-specific credit data, household income and consumption patterns. Availability of data on these factors in the future would substantially improve the discourse.

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