Inflation Expectations in South Africa: Non-rational, Intertemporal and Idiosyncratic Heterogeneity Represented by a Term Structure Approach

by

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Declaration

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Abstract

A key factor in the inflation-targeting regime is the psychological process by which decision makers form their expectations of future inflation. Economic models often assume that on aggregate, decision makers form inflation expectations uniformly and rationally, that is, without bias or informational inefficiencies. These assumptions of rational, homogenous expectations formation are computationally convenient and allow for important model simplifications. From a monetary policy perspective, it is important to analyse and test these assumptions, since under full rationality, only unexpected changes in inflation will affect the real economy. Departures from homogeneity require monetary authorities to understand the nature of expectations formation so that the appropriate policy can be prescribed. In this study, data from both the Bureau for Economic Research (BER) Inflation Expectations Survey and the Reuters Inflation Expectations (RIE) Survey were evaluated over different forecasting horizons to assess the validity of these assumptions across different economic groups in South Africa.

This study investigates factors that likely underlie the actual decision rules whereby decision makers formed inflation expectations during the inflation targeting regime in South Africa. The results reported did not support the hypothesis of exclusively rational expectations, mainly due to the respondents' inefficient use of available information. However, the respondents were not passive or inattentive, since they did observe and respond to certain influences, though heterogeneously and mainly in the short-term. Heterogeneity was observed across different survey groups when considering adaptive behaviour, information diffusion, perceived influence of external shocks and learning behaviour. Intertemporal heterogeneity - the differences in the processes that appear to govern expectation formation at short-term horizons compared to longer-term horizons - stands out. Multiple focal points (digit preferencing) were observed in the distribution of the survey data and together with the associated heterogeneity can complicate traditional estimation approaches.

Particular attention was given to potential influences on longer-term perceived inflation expectations of the respondents to assess the heterogeneity between groups and also if these were anchored. Conventional regression analyses supported this evaluation as well as a state-space Kalman filter approach to estimate the term structure of inflation expectations. The latter was based on the Nelson-Siegel (1987) methodology for term structure estimation to estimate the perceived longer-term anchor of the respondents. None of the approaches used in this study to approximate longer-term inflation expectations provided estimates close to the midpoint of the inflation target range for any of the three BER survey groups analysed. These estimates were instead mostly clustered around the upper end of the target range.

A richer specification of South African inflation expectations formation is therefore proposed that sufficiently represent both the short- and longer-term data generating processes involved in forming inflation expectations, based on the observed non-rationality, multiple forms of heterogeneity and multi-modal distributional characteristics shown in the study presented in this thesis. Term structure analyses provide a robust, flexible and encompassing framework for facilitating a parsimonious representation of both short- and longer-term inflation expectations in South Africa and are suggested for empirical inflation expectations modelling frameworks.

Opsomming

'n Sleutel-faktor in inflasieteiken-beleidsomgewings behels die psigiese proses waardeur besluitnemers hul verwagtings oor toekomstige inflasie formuleer. Ekonomiese modelle neem dikwels aan dat besluitnemers op 'n eenvormige en rasionele wyse inflasieverwagtings vorm, dit wil sê, sonder vooroordeel of informatiewe ondoeltreffendheid. Hierdie aannames van rasionele, homogene verwagtingsvorming vergemaklik berekeninge en vereenvoudig modelspesifikasies. Uit 'n monetêre beleidsperspektief is dit belangrik om hierdie aannames te ontleed en te toets, aangesien slegs onverwagse veranderinge in inflasie die reële ekonomie sal beïnvloed gegewe 'n omgewing van uitsluitlik rasionele inflasieverwagtingsvorming. Afwykings van homogeniteit vereis dat monetêre beleids-owerhede die aard van verwagtingsvorming verstaan sodat toepaslike beleid toegepas kan word. In hierdie studie is data van die Buro vir Ekonomiese Ondersoek (BER) se inflasieverwagtings-opname asook die Reuters-inflasieverwagtingsopname (RIE) oor verskillende voorspellingshorisonne geëvalueer om die geldigheid van hierdie aannames vir verskillende ekonomiese groepe in Suid-Afrika te bepaal.

Hierdie studie ondersoek faktore wat moontlik onderliggend is aan die werklike besluitnemingsreëls waarvolgens besluitnemers inflasieverwagtings tydens die inflasieteiken-beleidsera in Suid-Afrika vorm. Die gerapporteerde resultate ondersteun nie die hipotese van uitsluitlik rasionele verwagtings nie, hoofsaaklik as gevolg van respondente se ondoeltreffende gebruik van beskikbare inligting. Die respondente was egter nie passief of onoplettend nie, aangesien hulle sekere invloede waargeneem het en daarop gereageer het, maar egter op heterogene wyses en hoofsaaklik oor die kort termyn. Heterogeniteit is waargeneem ten opsigte van die verskillende groepe wanneer aanpassingsgedrag, inligtings-diffusie, die invloed van eksterne skokke en leergedrag in ag geneem word. Intertemporale heterogeniteit – die verskil tussen verwagtingsprosesse gevorm oor kort- en langertermyn-horisonne – het voorgekom. Multimodale fokuspunte (of syfer-voorkeure) is waargeneem in die verdelings van die opname- data en dit, tesame met die gepaardgaande heterogeniteit, kan tradisionele beramingsprosedures belemmer.

Aandag is veral gegee aan moontlike invloede op die langtermyn-inflasieverwagtings van die respondente, spesifiek die heterogeniteit van die groepe asook of die verwagtings geanker was. Konvensionele regressieontledings ondersteun hierdie evaluering sowel as 'n Kalmanfilter-benadering om die termynstruktuur van inflasieverwagtings te beraam. Laasgenoemde was gebaseer op die Nelson-Siegel (1987) metodologie vir termynstruktuur-beraming om die langertermyn inflasie-anker van die respondente te beraam. Geen van die benaderings wat in hierdie studie gebruik is om die langertermyn inflasie-anker te bepaal, het ramings naby die middelpunt van die inflasieteiken vir enige van die drie BER-opnamegroepe opgelewer nie. Hierdie ramings was eerder meestal gebondel rondom die boonste limiet van die inflasieteiken.

'n Ryker spesifikasie van die vorming van inflasieverwagtings in Suid-Afrika word daarom aanbeveel om beide die kort- en langertermyn-datagenererings-prosesse vir inflasieverwagtings voldoende te verteenwoordig in ‘n modelleringskonteks, gebaseer op die waargenome nie-rasionaliteit, veelvuldige vorme van heterogeniteit en multimodale verdelingseienskappe wat uit die studie geblyk het en in hierdie proefskrif aangetoon word. Termynstruktuurontledings bied 'n robuuste, buigsame en omvattende raamwerk vir die fasilitering van 'n kernagtige verteenwoordiging van beide kort- en langertermyn-inflasieverwagtings in Suid-Afrika, en word dus voorgestel vir empiriese inflasieverwagtings-modelleringsraamwerke.

Acknowledgements

I would like to thank my family and friends for their support. I would also like to extend my gratitude to my supervisor Prof. SA du Plessis for his meticulous and most valuable advice and guidance.

Dedication

I dedicate this thesis to the Lord whose guidance and grace enabled me to complete it.

Τετελεσται (Tetelestai).

Publications

Some of the research presented in Chapter 2 builds and expands on the study by Ehlers and Steinbach (2007) called: The formation of inflation expectations in South Africa, South African Reserve Bank Working Paper, no. 07/11

A version of Chapter 2 was published internally at the SA Reserve Bank as a SARB Discussion Paper called: Inflation expectations behaviour in South Africa: bias and informational inefficiencies, SA Reserve Bank Discussion Paper, no. 18/01.

A version of Chapter 3 was published internally at the SA Reserve Bank as a SARB Discussion Paper called: South African inflation expectations: non-rational heterogeneity, SA Reserve Bank Discussion Paper, no. 18/02.

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Chapter 1

Introduction

It is often assumed (though seldom confirmed) in economic models that all decision makers form their expectations of inflation rationally, that is, without bias or informational inefficiencies. A typical example is the standard New Keynesian model, where rational representative decision makers are assumed (Galí, 2008; Woodford, 2011). The rational expectations principle is often considered to be a school of economic thought, but it is more suitably regarded to be a ubiquitous modelling technique applied widely throughout the field of economics (Sargent, 2008), where individual rationality and consistency of beliefs are two key aspects.[1] This method requires that expectations be unbiased, efficient and consistent predictors of endogenous variables such as inflation, that conform to the predictions of the applicable economic theory (Muth, 1961). From a monetary policy perspective, it is important to analyse and test this assumption, since under full rationality, only unexpected changes in inflation will affect real variables, which impacts on the efficacy of policy actions.

In the first part of the study, the rationality of inflation expectations recorded by South African respondents from the Reuters (RIE) and Bureau of Economic Research (BER) Surveys were analysed according to convention where the unbiasedness, informational efficiency and forecast accuracy properties were tested. The respondents of the RIE Survey and the financial analysts group of the BER Survey appear to have produced unbiased expectations of inflation across all reported expectation horizons. However, the business representatives and trade union officials from the BER Survey were biased, with a tendency to overestimate targeted consumer

[1] This is a requirement to restrict an otherwise unlimited number of possible model solutions.

inflation across all three forecast horizons, namely the current-year, the one-year-ahead and the two-years-ahead horizons. Furthermore, both the RIE and BER Survey respondents were inefficient in their use of available information. Biased and inefficient behaviour has policy implications, since the perceived inflation target of decision makers may be different from the announced inflation target that the authorities want to achieve, and this could impact on the efficiency of policy actions in anchoring inflation expectations (Agliari et al., 2017).

Overall, the evidence from both the RIE and BER Surveys suggests that South African decision makers do not behave in accordance with the rational expectations theory, consistent with near universal findings in the literature. The implication is that the formation of expectations in standard New Keynesian-type policy models do not match what is found in the observed economy, even though expectations are critical to the results of the New Keynesian models (Nelson, 1998; Chari et al., 2000). Researchers have explored many avenues to find more plausible approaches for modelling expectation formation processes. These include rational inattention (Reid, 2015), habit formation, adaptive learning (Evans and Honkapohja, 2001; Sargent, 2008) and heterogeneity (Branch and McGough, 2009).

Conventional rationality tests that consider the bias and informational efficiencies of decision makers are focussed on the centre of the distribution, a valid approach for normally distributed processes. Even though the properties of the centre of the distribution are important, this study extends the analysis to not only assume, or be limited to normally distributed and homogenous cases, but also to consider heterogeneous behaviour.

Decision makers in economic models are typically assumed to be homogenous with respect to the information they use, their thought and interpretation processes, and the models they use to generate their expectations about future inflation. However, demographic differences, staggered information flows and model uncertainty may well be pronounced and result in heterogeneity with regard to inflation expectations (Curtin, 2006). Such heterogeneity matters, as Agliari et al. (2017) have shown that setting the policy interest rate via the Taylor principle in a rational expectations modelling framework may not be sufficient to achieve the inflation target and may well lead to instability if expectations are heterogeneous.

Evidence of heterogeneous expectations in survey data is well documented in the literature and is considered to be a symptom of informational inefficiencies (Mankiw et al., 2004; Branch and McGough, 2009; Pfajfar and Santoro, 2010). In this study heterogeneity was observed across the different BER Survey groups, their perceptions of the persistence of inflationary shocks, information diffusion from a more financially literate group and their degree of learning. An interesting observation was the difference in the short- and longer-term processes of decision makers' formation of expectations, i.e. intertemporal heterogeneity.[2] The observed heterogeneity among South African decision makers and their inability to acquire and process relevant information are some of the impediments to rational expectation properties, and alternative modelling approaches that provide a better approximation of the formation of expectations, or expectation formation rules, are proposed. This is explored in this dissertation, as is the perceived inflation anchor of respondents.

Heterogeneity can be a symptom of many causes, and to acquire more knowledge about the properties of the responses, in particular about the mean, mode and skewness, the density functions of the responses were studied. This also enabled a comparison of these characteristics across the three BER respondent groups and provided insights into the existence of a longer-term inflation expectation anchor, or focal point. The third section of this dissertation discusses the density functions of the individual BER Survey responses for the financial analysts, business representatives and trade union officials groups across short and longer horizons to further examine the heterogeneity reported in the second section.

A tendency of respondents to provide rounded responses or favour certain digits by restricting their choices to integers or half percentages, labelled as digit preference (Fry and Harris, 2002; Curtin, 2006; Pfajfar and Santoro, 2010; Dräger and Lamla, 2014; Pfajfar and Zakelj, 2015), was observed in the survey data as multiple peaks in the density functions of the individual survey responses. Digit preference or rounding behaviour may be ascribed to uncertainty (Branch, 2007) or be related to the cost of producing more accurate forecasts. According to Pfajfar and Zakelj (2015), inattentiveness may be a source of rounding behaviour, particularly when inflation is low and stable, lowering the incentive to forecast accurately. Interestingly the density functions and focal points were not static between sub-samples, as events unfolded and respondents adapt or learn more about the inflation targeting regime. These multiple focal points in the density functions are a property associated with heterogeneity. Traditional methods for estimating a singular perceived inflation anchor can be misleading in the presence of multiple and time-varying focal points.

[2] In this dissertation when referring to the BER Survey data, the current horizon inflation expectation is considered to the short-term and the one-year-ahead and the two-years-ahead expectation horizons are considered to be longer-term.

A richer and more dynamic representation of the processes involved in forming inflation expectations in South Africa is required to separately represent the shorter- and longer-term data generating processes, based on observed intertemporal heterogeneity and multi-modal distributional characteristics. The implication of intertemporal heterogeneity is that inflation expectations should be regarded as a plural concept and not singular as is often the case in monetary models (Meeks and Monti, 2019). Drawing on some of the analogous properties between financial market (yield curves in particular) and inflation expectations data, term-structure modelling techniques were applied to dynamically differentiate and represent shorter- and longer-term expectations processes.

The term structure of inflation expectations is a continuous curve that represents different inflation expectations made at time t for different horizons in the future, analogous to the well-known yield-curve concept. This term-structure estimation approach, especially when estimated with a Kalman filter, is parsimonious, not restrictive and can handle missing data from infrequent observations, as well as the limited availability of data. It can flexibly estimate and forecast inflation expectations over any horizon, even those that are not observed, and is able to inform how inflation expectations evolve across forecast horizons and over time. Specifically, the estimation of the term structure of inflation expectations is based on the popular Nelson-Siegel (1987) approach where three latent factors were estimated to distil the longer-term trend or the perceived longer-term inflation focal point, the slope and the curvature of inflation expectations, based on the individual responses in the survey data. The economic interpretation of the trend provides information on the longer-term perceived inflation anchor, which is useful for monitoring and comparing to the announced target in a heterogeneous environment. The slope and curvature factors provide information on the expected speed of convergence of inflation expectations in reaching the announced target (Lewis, 2016). This information can usefully and timeously inform policy makers in an inflation targeting regime in order to enable efficient policy decisions.

Chapter 2

Inflation expectations behaviour in South Africa: bias and informational inefficiencies

2.1. Introduction

The primary objective of most central banks is to achieve and maintain a stable and low rate of inflation over the medium to long term, with a complementary focus on financial sector stability. Many central banks have adopted an implicit or explicit inflation-targeting framework to guide this process. Inflation targeting implies inflation forecasting or inflation expectations targeting, where the inflation forecast is the intermediate target in the policy framework (King, 1994; Svennson, 1997).

There is an important link between the prediction of future inflation and the expected path of monetary policy due to the long and variable lags in the monetary policy transmission mechanism and the dependence of both processes on the same information set (Svennson, 1997). It is often assumed (though seldom confirmed) in monetary policy models that decision makers form their expectations of inflation rationally, that is, without bias or informational inefficiencies. This simplifies model properties and reduces the number of potential model solutions, by connecting expectations formation to the process that generates the underlying variable (Sargent, 1993). This dissertation tests whether such assumptions about South African decision makers are plausible. If these assumptions are not confirmed by test results, then the conventional linkages of transmission mechanisms may be obscured, and model specifications should be sensitive to this.

Reasons why the expectations formation process matters to inflation targeting include: In an environment of non-rational expectations, contractionary monetary policy actions by a central bank, aimed at countervailing inflationary pressures can be costly to an economy, a cost which is often referred to as the sacrifice ratio, that is, the trade-off between output foregone to lower inflation. In the absence of rational inflation expectations, a credible central bank that is committed to price stability, can be confronted by an expectations trap, which could imply large losses in output and employment.[3] The threat of an expectations trap for South Africa may be real according to Kabundi et al. (2015), who analysed survey data from 2000 to 2013 and show that the South African Reserve Bank (SARB) may well have been in an expectations trap in their sample of estimation. Conversely, in a rational expectations environment, a credible central bank can reduce inflation with no output or employment losses in the long run (Chari et al., 1998; Leduc et al., 2003). In the short-run, the economy is still likely to incur output losses, also referred to as a short-run, downward-sloping Phillips curve.

To evaluate the effectiveness of policy actions, knowledge about expectation formation processes (Mishkin, 2007) and specifically the distinction between anticipated and unanticipated policy actions are important. According to the policy neutrality or policy ineffectiveness proposition (Lucas, 1972; Sargent, 1973; Sargent and Wallace, 1975; McCallum, 1980); demand management policies would be ineffective in influencing real variables if expectations were fully rational and money illusion was absent. Output would only be affected by unanticipated monetary policy changes if such a change engineered a difference between actual and expected prices, that is, created a price expectation error (Fischer, 1977).[4] These considerations imply that knowledge of the methods used by decision makers to estimate future inflation can aid the policy environment and inflation-targeting frameworks in particular, which aim to influence and anchor the longer-term inflation expectations of decision makers.

The modelling of expectations and its prominence in economic analyses has gained momentum since the sixties and was strengthened by the rational expectations revolution during

[3] An expectations trap can arise when decision makers, who doubt the commitment of the central bank to inflation, anticipate higher inflation and pre-emptively demand higher wage increases or increase prices to protect their real profits, and do not expect the central bank to raise interest rates to address the higher expected inflation. The (discretionary) central bank is then forced to adopt an accommodative policy stance, concerned about output losses that may result from the contractionary policy, which then validates the original expected increase in inflation (Chari et al., 1998).

[4] A requirement of the assumption of the policy ineffectiveness proposition of rational expectations is flexible prices, which is unlikely to be observed since many prices are slow to change or are 'sticky'. McCallum (1980) explains that the policy ineffectiveness proposition may be more than a theoretical construct, at least temporarily, since prices can temporarily be rigid and set to reflect expectations made previously about current economic conditions.

the 1970s (McCallum, 2002). Examples include the efficient market theory of stock prices, the permanent income theory of consumption, the expectations-augmented Phillips curve relationship, and the literature on bounded rationality and learning and expectations (Sargent, 1993; Evans and Honkapohja, 2001). This dissertation's corresponding research focused on analysing the formation of inflation expectations on aggregate-, sub-group- and micro-level analyses, based on survey data. Such research that emphasise the expectation formation behaviour of decision makers could contribute to mould optimal monetary policy choices into a principle that no contemporary macroeconomic model should be without (Begg, 1982; Malinvaud, 1998).

Inflation expectations are not directly observed, though, and this complicates the analysis of the processes by which such expectations are formed. Empirical proxies such as survey data, financial market expectations or model-based expectations are required for this purpose. When inflation expectations data are scarce or unreliable, macroeconomic variables are often used as proxies. Examples include past values of actual inflation (i.e. backward-looking or adaptive inflation expectations) or the rate of change in some version of a consumption-expenditure deflator. Another proxy is the difference between the yield on inflation-linked bonds and their non-inflation linked counterparts, for instance, the difference between the R157 and the R189 bond yields in the South African case. However, inflation expectations proxied by bond yield differentials may be clouded by transaction costs, risk premiums, tax considerations and the lack of long data series in some countries (Sinclair, 2010). Supply peculiarities in the issuance of bonds, due to government policies, can also cause irregularities in bond prices that are unrelated to the expectations of decision makers. Hördahl (2009) adds liquidity premiums and other technical factors to the list of strong assumptions required to isolate inflation expectations from break-even interest rates on inflation-linked bonds.

The costs, resources and information required to produce inflation forecasts are some of the constraints affecting the availability and methodological efficiency of producing such data. According to Morris and Shin (2002), decision makers are likely to reduce or even abandon their own private information collection if it is more costly to obtain relative to publicly available forecasts. When decision makers alter or reduce their own information sets to substitute for publicly available information, it is detrimental to social welfare as the economic knowledge base shrinks (Morris and Shin, 2002; Svensson, 2006). The opportunity costs associated with inefficient and neglected forecasting procedures that lead to large forecast errors and potentially detrimental decisions are also relevant, resulting in a trade-off between ignorance and efficiency.

The premise of rationality tests is based on the requirement that decision makers form expectations to minimise and avoid systematic forecast errors, and this is testable by considering the unbiasedness, efficiency and orthogonality of the data (Razzak, 1997). The research in this section builds and expands on the study by Ehlers and Steinbach (2007), by testing for rationality for not only fixed-event inflation expectation horizons, but also for the fixed-horizon inflation expectations for the BER Survey and the RIE Survey data. Pierdzioch et al. (2016a) find strong evidence against forecast rationality based on pooled and sectoral South African data. Kabundi and Schaling (2013) find that South African survey respondents do not form inflation expectations rationally, based on their analysis of aggregate BER Survey data. This study contributes by analysing the sub-groups of the BER Survey and also covers all three expectations horizons. The degree of rationality in this study was tested by considering the unbiasedness of expectations formation and the efficient use of available information.

According to the results, the financial analysts formed their expectations without bias, but the trade union officials and business representatives did show bias. This finding is consistent with the results in Du Plessis et al. (2018) who find that households persistently overestimate future inflation in the sense that they consistently believe that future inflation will be higher than past inflation. A range of reasons for the observed bias is explained in Reid and Du Plessis (2011). Furthermore, in this study, informational inefficiencies were found for all groups across all expectations horizons, similar to Reid (2015) who find informational inefficiencies due to rational inattention. Therefore, based on the results presented in this study, South African data do not conform to the principle of rational expectations formation.

In the literature, most studies for both developed and developing countries, reject unbiasedness and or efficiency and, consequently, rationality. Examples include Forsells and Kenny (2002), Mankiw et al. (2004), Gerberding (2010) and Lyziak (2012). There appears to be an almost universal failure to find empirical support for rational expectations and this has important implications for the transmission mechanisms embededed in monetary policy models, should these be designed to approximate the data generating processes in the economy.

2.2 South African inflation expectations formation

2.2.1 Wages and inflation expectations interactions

In modern monetary theory, the link between monetary policy, and prices and wages depends almost entirely on the expectations channel (Blinder, 1998; Morris and Shin, 2002). An increase in expected inflation, in the absence of any countervailing monetary policy action, can lead to a short-term increase in wage and price inflation. An increase in expected inflation will imply a decrease in the real *ex ante* interest rate, which will, in turn, provide a stimulus to the economy and more inflationary consequences in the absence of an offsetting (or higher) increase in nominal policy rates. Should policy rates not respond sufficiently to maintain the appropriate real interest rate, that is, violate the Taylor principle (Taylor, 1999), there will be a danger of economic instability, as the higher expected inflation manifests as higher actual inflation (Sinclair, 2010).[5]

The role of the inflation expectations of decision makers features in many of the macroeconomic transmission channels, one of the most prominent being the labour market. Inflation expectations influence wage negotiations and hence affect, among other factors, the prices that firms set, especially in South Africa (Kabundi et al., 2015; Fedderke et al., 2007).

The influence of trade unions plays a significant role in wage-setting processes (Azam and Rospabe, 2007; Bhorat et al., 2009). Traditionally, in wage negotiations both counterparties make use of inflation forecasts as important inputs into the formulation of their mandates, with which they enter into negotiations. Wage negotiations should, accordingly, be affected by the inflation expectations of trade unions, to the extent that they will not likely agree to a wage settlement below their inflation expectations in the absence of any other form of compensation. Evidence of such behaviour can be seen in Figure 2.1, which compares average nominal wage settlement rates, the current year's inflation expectations of trade union officials as monitored by the BER Inflation Expectations Survey, and targeted consumer inflation. [6,7] In the literature a number of papers have agreed that South African inflation expectations are to a large extent influenced by past inflation,

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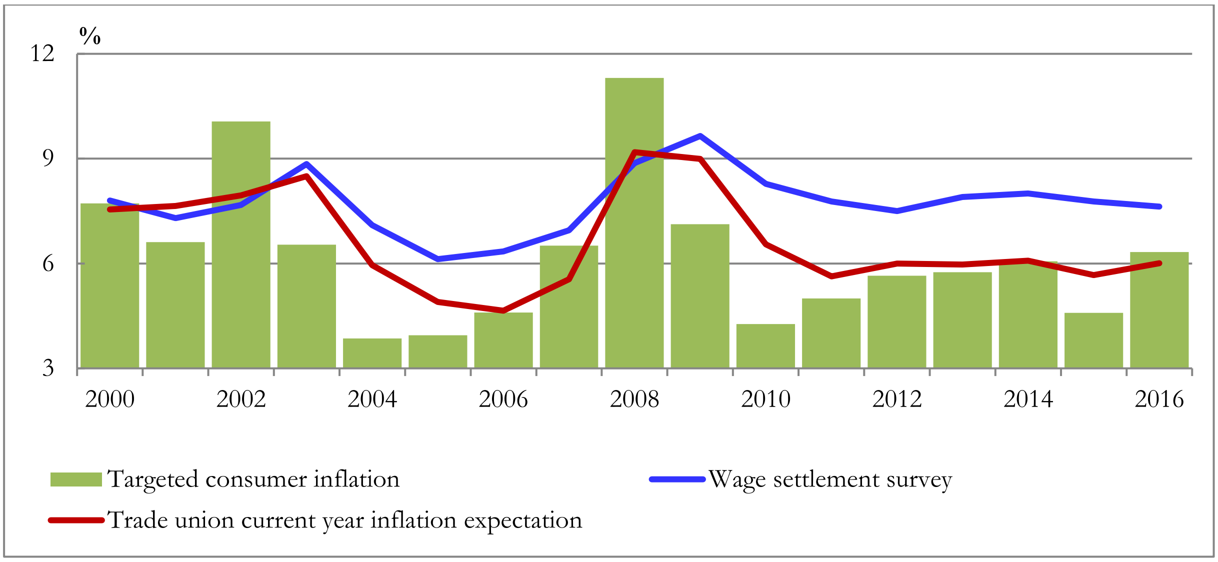
[5] According to the Taylor principle, a sustained increase in inflation should be more than offset by an increase in the nominal policy interest rate.
[6] Source: Andrew Levy Wage Settlement Surveys.
[7] A measure that reflects real-time consumer inflation that was relevant at the time when these wages were set, that is, consumer price inflation, excluding mortgage interest rates up to the end of 2007 and headline consumer prices as published by Statistics South Africa thereafter.

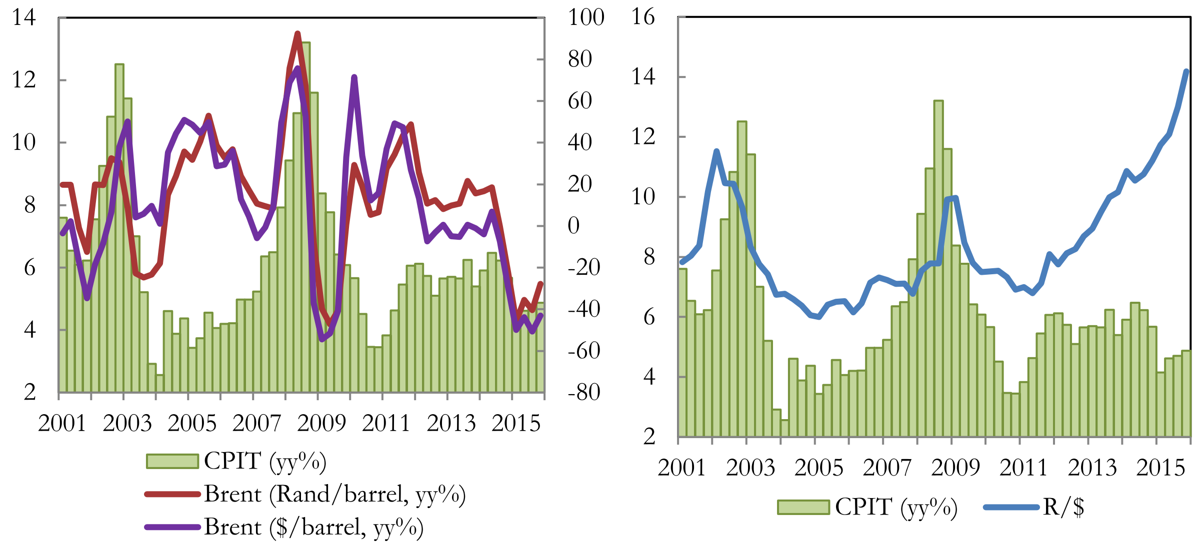
for example: Kabundi et al. (2015) and Aron et al. (2004); therefore, only the current year's expectations of the trade union officials were compared.

Figure 2.1: Inflation expectations and wage settlements in the labour market



It appears that the trade unions were successful in negotiating a wage premium (i.e. positive real wage settlements) in terms of both their inflation expectations for the current year and the targeted consumer inflation rate. Exceptions occurred in 2002 and 2008, when significant exchange rate depreciations and oil price shocks caused actual inflation to exceed expectations. The rand-dollar exchange rate depreciated by 47.4% year-on-year in the first quarter of 2002 and by 46.5% in the fourth quarter of 2008. The Brent crude oil price (in dollars) increased by 50% year-on-year in the first quarter of 2003 and by 75.7% in the second quarter of 2008. Hamilton (2009) discusses in detail the cause of these oil price increases, attributing it mainly to the inability of the supply of oil to meet increased demand at the time.

Figure 2.2: Oil price and exchange rate shocks and consumer inflation



Indications of the backward-looking formation of inflation expectations, or a degree of inflation expectations inertia, were particularly visible following these two episodes, as trade unions seem to have included some of their inflation expectations errors in subsequent wage settlement rounds. The view of backward-looking wage indexation in South Africa is supported empirically by Aron et al. (2003).

It is also noteworthy that the wage settlement rates in the period under review were recorded above the upper band of the inflation target of 6% and did not decelerate to the same extent as the trade union inflation expectations did. This downward wage settlement rigidity, especially the more recent episodes, is consistent with some allocation made for productivity gains or to address income inequality, but no other evidence is available to support this statement. From a broader perspective, the growth in nominal unit labour costs for the period 2000–2015 was 6.8% compared with CPIT inflation of 6.2% – both in excess of the upper inflation target band.[8, 9]

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[8] In this study, CPIT referred throughout to a combined price index where real-time consumer price inflation, excluding mortgage interest costs, was used up to the end of 2008 and headline consumer price inflation was used from then on. This was done to reflect real-time inflation as targeted by the SARB.
[9] As a rule of thumb, real wage growth that is accompanied by commensurate productivity growth is considered not to be problematic to inflation; otherwise it would create cost-push inflationary pressures.

2.2.2 Inflation expectations survey data for South Africa

Survey data on inflation expectations is a widely used empirical proxy and the focus of this study. Examples include the Livingston Survey of Professional Economists for the United States, the Consumer Survey for the European Union, and the Conference Board of Canada, which produces survey data on Canadian inflation expectations.

The availability of South African inflation expectations survey data is rather limited, and one of those analysed in this paper is the Reuters Inflation Expectations (RIE) Survey. This survey is conducted monthly and covers approximately 14 respondents, who are mainly market analysts. Monthly data from this survey are available from December 1999. In this survey, respondents were asked what rate of consumer price inflation they expect will be realised in the current as well as the following six quarters and what annual rate of inflation they expected for the current calendar year and the following two years.

Another source of inflation expectations survey data for South Africa is the Bureau of Economic Research (BER) Inflation Expectations Survey. The BER Inflation Expectations Survey is available at a quarterly frequency from the first quarter of 2000. This survey covers four groups of respondents, namely from the business sector (n=375), the financial sector (n=15), the trade union sector (n=12) and households (n=1898) – these sample sizes (n) are based on the number of respondents in the survey conducted in the first quarter of 2003. This survey is similar to the Livingston Survey conducted in the United States. For additional information on the Livingston Survey, see Roberts (1998) and on the BER survey, see Kershoff and Smit (2002).

The BER Survey provides insights into different decision makers' shorter- and longer-term expectations, as these surveys are conducted quarterly and report the average annual CPIT inflation expectations for the current, one-year- and two-year-ahead forecast horizons. The published expectations are in respect of calendar years. From the first to the fourth reported expectation for a particular calendar year, the expectation horizon shrinks for the current year, and progressively more observed information is available for the current year.

When analysing surveyed expectations data, a distinction should be made between fixed-event expectations (the expectation for a particular calendar date such as the BER Survey framework) and fixed-horizon expectations. The inappropriate analysis or use of fixed-event expectations when fixed-horizon expectations should be used is likely to be problematic and can adversely affect inferences drawn on such results (Yetman, 2018; Siklos, 2013; Dovern et al., 2012).

In this study both the unaltered original BER Survey data that represents the fixed-event expectations and an approximated version that attempts to represent the fixed-horizon version were analysed. [10]

To construct a fixed-horizon BER Survey dataset that attempted to account for the shrinking horizon[11] effect that emanates from fixed-event survey data, a weight structure was applied to the observations. This process delivered approximated rolling fixed-horizon expectations where the forecast horizon was kept constant to reflect the immediate next four quarters ($\pi_{t|a}^{e,rx}$) and the five-to nine-quarters-ahead horizon ($\pi_{t+4|a}^{e,rx1}$). The weight schedule was applied to the data such that the first publication of a calendar year will have weights of (1, 0) applied to the current and one-year-ahead expectations, (0.75, 0.25) for the second publication, (0.5, 0.5) for the third publication and (0.25, 0.75) for the fourth publication of the calendar year. See Equation 2.2.1 and 2.2.2 and Table 2.1 for examples of the calculation of the rolling-horizon expectations that is based on the approximations as done by Yetman (2018).

Let $\pi_{t|a}^{e,rx}$ represent the fixed-horizon expectation of annual inflation for the year, surveyed at quarter a, where a represents 1,2,3,4 for quarter 1,2,3,4 respectively for every year. Superscript rx denotes the fixed horizon current-year expectations and superscript rx1 denotes the fixed horizon one-year-ahead inflation expectations.

For the current rolling year fixed-horizon approximation:

$$\pi_{t|a}^{e,rx} = \frac{4-(a-1)}{4}\pi_{t|a}^{e} + \frac{(a-1)}{4}\pi_{t+4|a}^{e} \qquad (2.2.1)$$

where a = 1,2,3,4 for quarter 1, quarter 2, quarter 3, quarter 4 respectively for every calendar year.

For the one-year-ahead fixed-horizon approximation:

$$\pi_{t+4|a}^{e,rx1} = \frac{4-(a-1)}{4}\pi_{t+4|a}^{e} + \frac{(a-1)}{4}\pi_{t+8|a}^{e} \qquad (2.2.2)$$

where a = 1,2,3,4 for quarter 1, quarter 2, quarter 3, quarter 4 respectively for every calendar year.

For the rationality tests that follow, both the fixed-event and fixed-horizon for the BER Survey data will be analysed for comprehensiveness.

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[10] Both the RIE and BER inflation expectations data were set up to reflect the fixed- or constant-event expectations and not the fixed- or constant-horizons as they are published in each release. Careful consideration was given to ensure that the expectations observations were entered to represent the quarter (for RIE Survey) or year (for BER Survey) for which they were formed, and not when they were formed where applicable.

[11] Note that the BER Survey is conducted four times per year, but records the annual inflation expectation, and not the inflation expected for a particular quarter; hence the shrinking-horizon effect as the year progresses.

Table 2.1: Example of calculation of rolling-horizon fixed-event current-year expectations ($\pi_t^{e,rx}$)

Publication	Expectation for current year	Expectations for one-year-ahead	Rolling-horizon current-year expectation formula
2001q1	$\pi^e_{t\|q1}$	$\pi^e_{t+4\|q1}$	$(\pi^e_{t\|q1}*1) + (\pi^e_{t+4\|q1}*0)$
2001q2	$\pi^e_{t\|q2}$	$\pi^e_{t+4\|q2}$	$(\pi^e_{t\|q2}*0.75) + (\pi^e_{t+4\|q2}*0.25)$
2001q3	$\pi^e_{t\|q3}$	$\pi^e_{t+4\|q3}$	$(\pi^e_{t\|q3}*0.5) + (\pi^e_{t+4\|q3}*0.5)$
2001q4	$\pi^e_{t\|q3}$	$\pi^e_{t+4\|q4}$	$(\pi^e_{t\|q4}*0.25) + (\pi^e_{t+4\|q4}*0.75)$

The real-time consumer price inflation measure used in this paper represents the consumer inflation targeted by the South African Reserve Bank, based on its monetary policy framework. This targeted inflation definition was relevant at the time when these expectations were formed and consists of consumer price inflation excluding mortgage interest rates up to the end of 2007 and headline consumer price inflation thereafter, as published by Statistics SA (excluding the data revisions from January 2002 up to March 2003). It should be noted that the re-weighting and re-basing of consumer price inflation by Statistics SA, which was introduced from January 2009, could have had an impact on the formation of inflation expectations by decision makers just prior to its release, due to their uncertainty about the magnitude of this revision, which was published in March 2009. Furthermore, it should be noted from the outset that due to the small sample of available data, the results should be interpreted cautiously.

Using survey data to proxy inflation expectations is contentious. Thomas (1999), for example, discusses some problems inherent to survey data that undermines inferences based on them. One concern is that individual respondents might not be sufficiently incentivised to make optimal use of their resources when responding to the survey. Furthermore, some forecasters may even behave strategically by concealing their true forecasts. Such strategic behaviour is considered by Krugman, 2001 to be entirely realistic, yet inefficient to society as a whole. These problems are potential sources of statistical bias in the surveyed individual forecasts.

These biases relating to survey data should be carefully considered when rational expectations are interpreted according to Muth's (1961) definition, which states that rational expectations are informed forecasts of future events and essentially analogous to the predictions of the applicable economic theory. This translates into a model context where individuals' subjective expectations are exactly the mathematical conditional expectations implied by an economic model. The same stochastic process that generates the economic variable to be forecast should generate the rational expectation (Muth, 1961); hence no systematic forecast error bias should be observed. Expanding on Muth (1961), Keane and Runkle (1990) and Mestre (2007) maintain that the aggregation of individual expectations may conceal individual systematic differences and may to some extent, remove potential sources of bias.

According to Muth's (1961) interpretation of the rational expectations hypothesis, decision makers need not always individually be correct in forecasting variables, but the distribution of their collective forecast errors should have a zero mean and a minimum variance. From this point of view, the rational expectations hypothesis should be examined at the aggregate, and not on individual expectations processes. Even though some individuals may be ignorant or irrationally over-predict and others may under-predict, it does not imply that the expectations formation process in the economy is, on average, not rational. The objective is not to test rationality at the individual level, but rather at the aggregate level (Thomas, 1999; Mestre, 2007).

2.3. Rational expectations

The rational expectations revolution was formalised during 1971 to 1973 (McCallum, 2002) and gained momentum following the Lucas critique (Sargent, 1973; Lucas, 1976) as macroeconomic analysis was guided more towards its micro-foundations, with a particular focus on the behaviour of decision makers. Sargent (2008) classifies rational expectations as a ubiquitous modelling technique used broadly throughout the field of economics, rather than a school of economic thought. McCallum (2002) explains that the purpose of these models are to be structural (i.e. policy invariant) and these models are in some instances enhanced with explicit optimisation features where decision makers act in a dynamic and stochastic environment.

Multiple definitions and interpretations of the rational expectations principle have evolved in the literature, and a clear consensus remains elusive. Often, rationality is informally believed to refer to incredible optimising individuals who form expectations of future events using all the available knowledge and models (see Sent (2006) for an overview). Another interpretation focuses more on the information set of the aggregate group, which is assumed to have systematic unbiased forecast errors (Mankiw et al., 2004). This was motivated by Muth (1961), who showed that rational expectations should, on average, be an unbiased predictor of the actual outcome. To obtain guidance on the intended definition of rational expectations, the deliberations of the rational expectations pioneers were consulted.

According to Sargent (1993), the idea of rational expectations has two distinct components. The one component focuses on the optimising behaviour of individuals subject to some perceived constraints, and the other component focuses on the perceived constraints, which should be mutually consistent. The latter imposes consistency of perceptions across all decision makers, where a person needs to form an own expectation and also expectations of others' expectations, beliefs and processes. This in itself allows for important simplifications in economic modelling, by restricting a range of possible outcomes.

The influential paper by Muth (1961) also emphasises the idea of consistency of perceptions, which implies that decision makers need to know the perceptions of the environment, including their own and other decision makers' beliefs, decisions and thought processes (Sargent, 1993). This definition is much stronger than the requirement for bounded rationality, where decision makers are required only to behave like econometricians, who approximate and estimate the perceived true environment with modelling frameworks. By definition, rational decision makers' information sets are assumed to be superior to the representative econometrician who estimates probability distributions and parameters of laws of motion, which the rational decision makers are assumed to know (Sargent, 1993; Evans and Honkapohja, 2005). Sargent (1993) summarises the typical rational expectation model in Evans and Honkapohja (2005), where the decision maker's knowledge supersedes that of the econometrician, since the decision maker represented in the model knows the parameters of the true model, different from the econometrician who does not and needs to estimate the parameters. Muth (1961) also points out that rational decision makers' average expectations are more accurate than naïve models and just as accurate as elaborate models.

Another misconception about rational expectations according to McCallum (2002) is that it requires that all decision makers agree with the empirical analyst's approximate model of the economy. Instead it requires that decision makers form expectations to avoid systematic expectational errors, which implies that they behave as if they know the structure of the economy. If they all know the true structure, then the empirical analyst's model and the other decision makers' view of the economy would render the same expectations. Muth (1961) also advocates an arbitrage environment where individual perceptions might differ but on aggregate should match the predictions of the applicable economic theory.

The requirements of decision makers to act as econometricians and to possess knowledge about the true structure of the economy is, according to Evans and Honkapohja (2001), practically unrealistic. There are a number of factors that can interfere with rational behaviour, such as inattention, disagreement between agents (Mankiw et al., 2004) or following expert opinions (Carroll, 2003), which can protract the transmission mechanism of price channels in the economy. Heterogeneity among decision makers and their inability to access the same information at the same time also impede the concurrence of empirical data with the rational expectations theory.

The economic sciences view rationality in terms of the decisions made following thought processes, whereas other social sciences (e.g. psychology) hold the view that rationality refers rather to the processes used to make choices (Curtin, 2006). The former view focuses on an action that follows from a thought process, and the latter represents the process that leads to an action. Curtin (2006) explains that economists have therefore focused on testing the postulate of rationality in terms of the forecasting properties, the result of their action. Sargent (1993) explains that rational expectations formation is an equilibrium concept that focuses on outcomes and does not pretend to have behavioural content.

Even though the rational expectations hypothesis is methodologically sound, it does not according to Curtin (2006) appear to be empirically observed. He notes that rational expectations are costly, and the trade-off between cost and benefit can lead to the inefficient use of information. There may also be a trade-off between the cost of acquiring and analysing all available information and the cost and consequences incurred by making significant forecast errors due to inadequate forecasting processes. To gather information is costly, and decision makers may even think it is optimal to be less than fully informed. As Conlisk (1996) asks, "Why not condemn problem-solving which leads to systematic error?" He explains that due to deliberation costs, heuristics (or rule-of-thumb behaviour) often provide an adequate and cheaper solution than elaborate expensive approaches; hence the compromise between cognitive effort and judgmental accuracy (Pitz and Sachs, 1984).

The premise of rationality tests is based on the requirement that decision makers form expectations to minimise and avoid systematic forecast errors, and involve tests for the unbiasedness, efficiency and orthogonality of the data (Razzak, 1997). Passing these tests classifies the expectations as *weakly rational*. Koutsogeorgopoulou (2000) interprets weak rationality as decision makers using all the available cost-efficient information to make forecasts that are unbiased and efficient. Secondly, if the data outperform the forecasts of naïve models, such as the autoregressive moving average (ARMA) models, then expectations may be classified as *sufficiently* *rational* (Pearce, 1979;1987). Thirdly, if the predictive power of the survey data outperforms a combination of various forecasts, then expectations may be classified as *strictly rational* (Granger and Newbold, 1973). The following section reports on these tests applied to the South African inflation expectations survey data.

Studies that assess the empirical validity of the rational expectations hypothesis were conducted for both developed and developing countries. Examples include Forsells and Kenny (2002), Mankiw et al. (2004), Gerberding (2010) and Lyziak (2012). Most of these reject unbiasedness and or efficiency and, consequently, rationality. There appears to be an almost universal failure to find empirical support for rational expectations. Lovell (1986) verbalises this dichotomy between normative and positive economic theories, which can seldom be unified, by lamenting "Should the data be allowed to spoil a good story?".[12] This age-old distinction between actual versus ideal theories has received significant deliberation in the literature (Keynes, 1891; Friedman, 1994) and is empirically tested in the following section to assess the extent of rationality present in the BER and RIE survey data.

2.3.1 Weak rationality

2.3.1.1 Unbiased inflation expectations

According to Muth's (1961) principle of rational expectations, individual expectations are not necessarily the same, but they are on average and should match the predictions of the applicable economic theory. This implies that expectations should be unbiased and their mean equal to the mean of the actual inflation outcome (i.e. the average forecast error must be zero). In the literature, it has become standard practice to evaluate unbiasedness by estimating the following equation (Forsells and Kenny, 2002; Curtin, 2006):

[12] Lovell (1986) cited two reasons why, regardless of the lack of empirical support, rational expectations should not be disregarded, namely (i) measurement issues regarding expectations, and (ii) rationality may be a transient phenomenon because decision makers are learning to adapt to a regime shift.

$$\pi_t = \alpha + \beta\pi^e_{t-k|t} + \varepsilon_t \qquad (2.3.1)$$

where π_t is the inflation rate at time *t*, π^e_t is the expectation of inflation for time *t* formed at time *t-k*, α is a constant, β is a coefficient, and ε_t is a stochastic error term. A test for unbiased expectations involves testing the joint hypothesis that $\alpha = 0$ and $\beta = 1$. Furthermore, expectations of inflation should be efficient, which means that the forecast errors (ε_t) should not be serially correlated and independently distributed. When this specification was estimated using data from the RIE and BER surveys (the results are discussed in detail later on), it was found that the errors were serially correlated (even after differencing the data), which provided an early indication of possible inefficiency in the expectations formation processes.

Some authors question the validity of this form of rationality test. Granger and Newbold (1986) are of the opinion that a test of the joint hypothesis that $\alpha = 0$ and $\beta = 1$ is a necessary condition for efficiency, rather than a test for unbiasedness. The presence of measurement or sampling errors, especially in quantitative survey data sets transformed from qualitative data sets, can adversely affect the results from unbiasedness tests of this format (Hvidding, 1987; Pesaran, 1987). It is argued by Holden and Peel (1990) that a test of the joint hypothesis that $\alpha = 0$ *and* $\beta = 1$ is a sufficient but not necessary condition for the unbiasedness of expectations. They propose instead that the forecast error should be regressed on a constant and the null hypothesis that the constant of this estimated equation is zero, should be tested by a t-test. Rejection of the null hypothesis indicate that the constant term is statistically significantly non-zero and confirms the presence of bias in the forecast errors of the survey data. In the literature, other authors such as Andolfatto et al. (2002), Dolar and Moran (2002) and Pfajfar and Zakelj (2015) also concur on the correct inference concerning unbiasedness and the robustness of this formulation of this formulation of the unbiasedness test. This implies the regression:

$$\pi_{t-k|t}^{e,h} - \pi_t = \alpha + \varepsilon_t \qquad (2.3.2)$$

where π_t is the inflation rate[13] at time t, $\pi_{t-k|t}^{e,h}$ is the expectation of inflation for the h horizon category at time t formed at time $t-k$, α is a constant, k is the number of periods ago when this expectation was formed, and ε_t is a stochastic error term.

Equation 2.3.2 tests the null hypothesis of unbiasedness, that $\alpha = 0$, by means of a t-test, where $\alpha < 0$ indicates the systematic underestimation of inflation and $\alpha > 0$ indicates the systematic overestimation of inflation. Due to the existence of serial correlation in some of the tests, the standard errors produced by using ordinary-least-squares-estimation techniques will be both biased and inconsistent (Brown and Maital, 1981; Mills and Pepper, 1999), although the estimation method still yields consistent coefficients. Therefore, the covariance matrix was estimated by applying the procedure suggested by Newey and West (1987).

The null hypothesis of unbiasedness for the RIE Survey was not rejected from the current-quarter to the six-quarter-ahead forecast periods. This indicates that the RIE respondents (comprising mostly of financial analysts) formed unbiased expectations of CPIT inflation for the period from the first quarter of 2000 to the fourth quarter of 2016 (Appendix A.1, Table A.1.1).

During 2002 and 2008, the South African economy experienced significant price shocks that emanated predominantly from adverse exchange rate and oil price movements (Figure 2.2). Both the duration and magnitude of these shocks were not fully anticipated and therefore resulted in a series of underestimates of inflation, which in turn, hid some of the usual expectations formation dynamics. When these two events were controlled for by means of dummy variables, the results for the unbiasedness test across all the forecast horizons still did not detect, on average, a systematic bias in their estimation of CPIT inflation (Appendix A.1, Table A.1.1).

The BER Survey provides a unique opportunity to consider the extent of homogeneity in terms of the bias of expectations formation for the three groups surveyed (Appendix A.1, Table A.1.2). The unbiasedness tests indicate that financial analysts tend to form unbiased expectations over all five forecast horizons, even when the oil price and exchange rate shocks of 2002 and 2008

[13] Real-time actual inflation data were used (i.e. the consumer-price inflation data, excluding mortgage interest costs, were not updated with the revised figures published by Statistics SA on 30 May 2003), noting data revisions from January 2002 up to March 2003.

were controlled for, confirming the unbiasedness results from the RIE Survey, where the respondents are also financial market participants.

The trade union officials and the business representatives groups appear to have formed unbiased CPIT inflation expectations over all horizons under consideration, except for the current horizon, where the business representatives tended to be biased. However, when the oil price and exchange rate shocks were controlled for, both these groups appear to have been biased by systematically overestimating CPIT inflation over all five horizons. This result can be related to the very nature of wage negotiations on the part of trade unions, since the inflation outlook is an important point of the negotiations, and the loss incurred by underestimating inflation, and therefore accepting a lower wage increase for their members, could be problematic. Trade unions are averse to inflation surprises and motivated to increase the real wage premium of their members (Klein, 2003).

A number of studies have shown that the formation of inflation expectations among different groups is not necessarily independent, and often financial inexperienced groups tend to follow financially literate groups (Carroll, 2003; Doepke et al., 2008; Lyziak, 2012); the South African environment is no exception (Pierdzioch et al., 2016b). The biased behaviour of business representatives and trade union officials was consistent with the postulated influence of wage settlements on the resulting wage bill and the total operating costs of firms. Hence, their pricing behaviour was in contrast with the unbiased behaviour of the financial analysts group. This result highlights the degree of heterogeneity in terms of inflation expectation bias between the financial analysts group, on the one hand, and the business representatives and trade union groups, on the other. The different motives and incentives of the groups may contribute to this heterogeneity; therefore, it may be useful to analyse the financial analysts only to gain insights into their expectations formation processes.

2.3.1.2 Efficient inflation expectations

According to Mills and Pepper (1999), a sufficient condition for efficiency with respect to the information set (including the history of a particular variable) is that the forecast errors should be serially uncorrelated. A correlation between the forecast errors implies that the respondents did not utilise all available information contained in realised forecast errors to improve their expectations formation processes, and were therefore inefficient in incorporating available and relevant information.

This hypothesis involved estimating the following equation:

$$\pi^{e,h}_{t-k|t} - \pi_t = \alpha + \sum_{j=1}^{n}(\beta_j \, \pi^{e,h}_{t-k|t,t-j} - \pi_{t-j}) + v_t \qquad (2.3.3)$$

where $(\pi^{e,h}_{t-k|t} - \pi_t)$ represents the forecast error for the forecast made k time periods ago for the event at time t, h classifies the forecast horizon category (current year, one year ahead or two years ahead) α is a constant, the β 's are coefficients, representing the contribution of each lag of the forecast error included, j represent the number of lags and v_t is a stochastic error term. Selecting the model lag length j was done by minimising the Akaike and Schwarz criteria. A Wald coefficient test was performed to test the hypothesis that all the coefficients and the constant were jointly equal to zero. The intention was to ascertain whether there was any statistically significant systematic information captured in past forecast errors and the constant term that could have improved the expectations formation process.

The results for the informational efficiency tests of the RIE and BER survey respondents show that the null hypothesis of informational efficiency was strongly rejected in all cases (Appendix A.2, Tables A.2.1 and A.2.2). This suggests that past forecast errors contained useful information that was not utilised by the respondents, and therefore, these decision makers were inefficient in using the information at their disposal.

Although the RIE Survey respondents and the financial analysts group in the BER Survey appear to have formed unbiased expectations of CPIT inflation, their inefficiency in using available information leads to the conclusion that none of the groups surveyed can be considered as weakly rational. Pearce (1979),(1987) proposed that expectations data that have been classified as weakly rational (i.e. expectations that passed the tests for unbiasedness and efficiency) can subsequently be tested for sufficient rationality. Expectations survey data (i.e. forecasts) are classified as sufficiently rational if the survey data outperform forecasts of other models, such as the random walk and ARMA models.

2.3.2 Forecast accuracy

A forecast performance analysis will provide some sense as to whether naïve time series models would produce more accurate CPIT inflation forecasts than these respondents. If so, it represents information that could be supplementary to their information set and could provide additional evidence of their ineffective use of available information, as discussed in the preceding section.

The forecast performance of the BER Survey respondents was compared to a random walk model and an AR model (Figure 2.3) using quarterly data.[14] In an attempt to mimic the BER Survey data collection process and the availability of information throughout a year, CPIT inflation was forecast with the two time-series models on a quarterly basis, and for each occasion, the annual averages were calculated.

In general, the forecast error statistics analysed (Appendix A.3, Table A.3.2) indicate that, over the shorter term, the BER Survey groups outperformed the random-walk model and almost matched the AR model. However, as the forecast horizon extends, the evidence shows that the BER Survey groups' forecast performances deteriorated to such an extent that while they still outperformed the random-walk model, they performed worse than the AR model. This could be related to longer-term uncertainty about inflation and the difficulty of distinguishing between transitory and permanent shocks. The ability to correctly anticipate the magnitudes and the persistence of these shocks may also have complicated their forecasting efforts – a situation to which the AR model forecast is largely immune.

The business representatives and trade union officials groups' forecast performance were notably worse than that of the financial analysts group across all the horizons analysed, demonstrating their inefficient use of available information, which was better utilised by the financial analysts group.

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[14] See Appendix A.3 for a technical discussion and the results of these forecast-error statistics.

Figure 2.3: BER Survey forecast-error comparisons: root-mean-squared errors

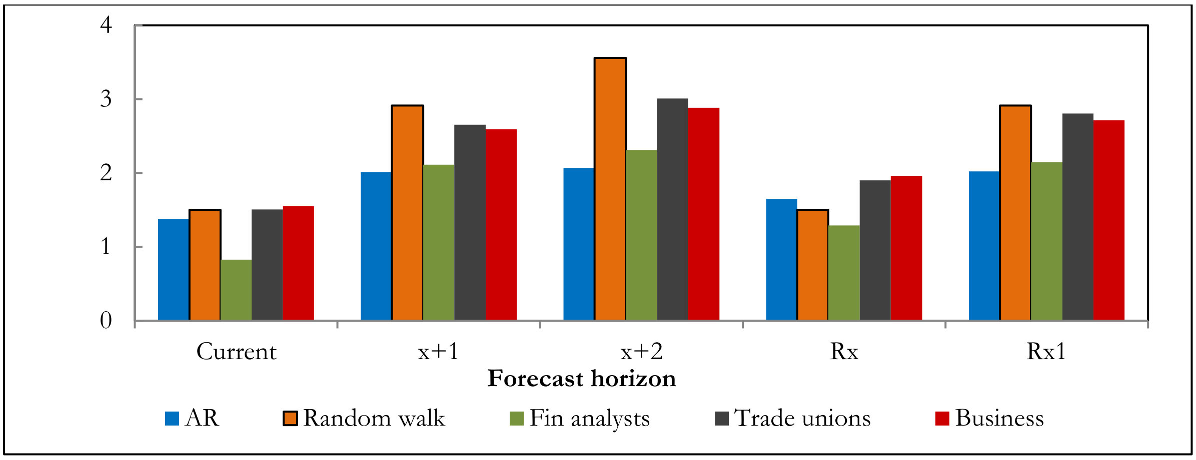
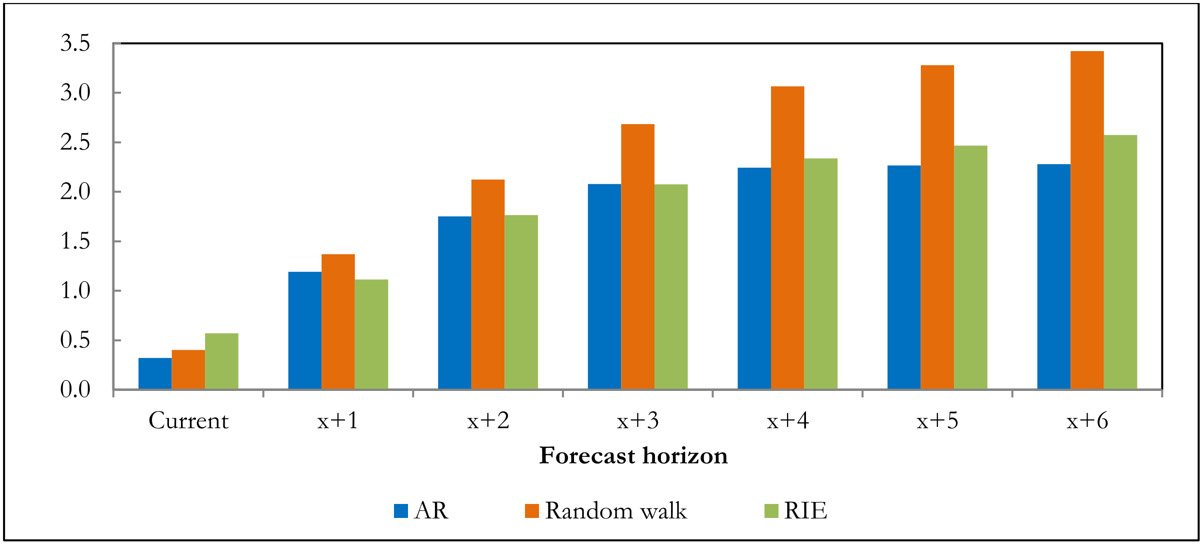


Figure 2.4 shows the root-mean-squared error (RMSE) statistics for the inflation forecasts from the RIE Survey as well as from the AR and a random walk model estimated using monthly data.[15] For expectations of inflation in the current quarter, both the RMSE and Theil inequality coefficient (Appendix A.3, Table A.3.1) indicated that the AR and the random-walk model outperformed the consensus forecast in the RIE Survey. However, for expectations of inflation one and two quarters ahead, the RIE Survey outperformed the AR and random-walk models. Over the remaining forecast horizons, the AR model outperformed both the RIE Survey respondents and the random- walk model, similar to the results from the BER financial analysts group described earlier.

[15] See Appendix A.3 for results.

Figure 2.4: RIE Survey forecast-error comparisons: root-mean-squared errors



Comparisons between the forecast-error results for the RIE Survey data and the BER Survey data should be made with caution, since the collection and reporting frequencies of the surveys differ. A more reliable comparison can be made between the BER results for the financial analysts group for their one-year-ahead (x + 1) horizon and the results of the RIE four-quarter-ahead (x + 4) horizon, where both cases show that the accuracy of the respective respondents' inflation forecasts was very similar to the accuracy of the forecasts of the AR models, though the random walk models performed much worse for both data sources.

The data from the RIE and BER Surveys show that decision makers do not form expectations rationally – the result of inefficient forecasting processes – and in some cases, they systematically overestimate inflation. However, the inflation expectations survey data consistently outperformed the forecasting capability of the random-walk process, with the exception of the current-quarter forecasts of the RIE Survey data, providing evidence that the formation of inflation expectations in South Africa cannot be classified as naïve. Notwithstanding this, there is still much improvement that can be made to efficiently analyse all the available information in order to produce more accurate forecasts than an AR model.

2.4. Conclusion

The rational expectations principle is often considered to be a school of economic thought, but it is rather regarded as a ubiquitous modelling technique applied widely throughout the field of economics (Sargent, 2008), where individual rationality and consistency of beliefs are the two key aspects.[16] Individuals need not always be correct according to Muth (1961), but their collective forecast error distribution should have a zero mean and minimum variance. The rational expectations principle therefore requires that expectations be unbiased, efficient and consistent predictors of inflation that conform to the predictions of the relevant economic theory (Muth, 1961).

In this analysis, tests were performed to evaluate these conditions in the RIE and BER Survey data for inflation forecasts. The respondents of the RIE Survey appear to have produced unbiased expectations of CPIT inflation, on average, across all expectation horizons under review. This result is supported by the analyses done on the data from the BER Survey, where the expectations of CPIT inflation by the financial analysts also appear to have been unbiased across shorter- and longer-term horizons.

Results from the BER Survey indicate that the inflation expectations of business representatives and trade union officials across all three forecast horizons were biased, to the extent that there was a tendency to overestimate CPIT inflation, on average, when the oil price and exchange rate shocks were controlled for.

The evidence from the information efficiency tests conducted on both the RIE and BER Survey data suggests that the respondents were inefficient with the use of information at their disposal. Heterogeneity among decision makers and their inability to acquire and process relevant information are some of the impediments to empirical data concurring with the rational expectations theory. This leads to the conclusion that none of the surveyed groups showed evidence of a weak form of rationality over the period under investigation.

To determine the predictive ability of the RIE and BER Survey respondents, the inflation expectations data were compared with the forecasts of a random walk model and an AR model. The RIE Survey outperformed the random walk model across all forecast horizons and outperformed the AR model's forecasts for the one-quarter- and two-quarters-ahead forecast

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[16] This is a requirement to restrict an otherwise unlimited number of possible solutions.

horizons. The forecast error statistics analysed indicate that, over the short term, the BER Survey groups outperformed the random walk model, but only the financial analysts outperformed the AR model's current-year forecasts. As the forecast horizon extends (i.e. one year ahead and two years ahead), the evidence shows that the BER Survey groups' forecast performance deteriorated somewhat, so that they performed worse than the AR model but still outperformed the random-walk model. This indicates that these longer-term expectations were not naïvely formed, yet relevant information was not incorporated into the forecasting processes.

In general, the evidence from both the RIE and BER Surveys suggest that South African decision makers probably do not form their inflation expectations rationally. The results reported here do not support the hypothesis of exclusively rational expectations in South Africa, mainly owing to the inefficient use of available information by the respondents. In a model framework that is intended to represent South African data generating processes, it does not seem appropriate to specify the inflation expectations process in a rational expectations formulation, since it does not correspond the (surveyed) data generating properties. It is suggested that a richer representation of the process of forming inflation expectations is required in a model context to enhance the approximated properties of the economic transmission mechanism and, hence, improve forecasting capabilities.

Chapter 3

South African inflation expectations: non-rational heterogeneity

3.1 Introduction

It is conventional in most economic models to assume that on aggregate decision makers form inflation expectations uniformly and rationally. This assumption of homogenous rational expectations formation is computationally convenient and allows for important simplifications in economic models. This approach originates from Muth's (1961) idea that individual persons' expectations may differ at certain times, but would converge at the aggregate level through various mechanisms. Also, it is often justified by the idea that sufficient common experiences and observations will eliminate disagreements and aid convergence in the long term (Acemoglu et al., 2006; Gnan et al., 2011).

The empirical evidence for rational behaviour based on South African survey data is at odds with the aforesaid theory and fails to confirm rational behaviour over both the short and longer horizons. This study investigated other factors that likely influenced the decision or expectation formation rule, according to which inflation expectations were formed. Consideration was given to adaptive behaviour, information diffusion from a leader group to followers, the perceived persistence of external shocks and individual learning behaviour. These results are reported in this chapter. A common observation was that inflation expectations were not formed uniformly. Heterogeneity was observed across demographic groups, information used, and methodologies applied, but more prominent were the differences in the processes that appeared to govern expectation formation over shorter-term horizons compared with longer-term horizons, i.e. intertemporal heterogeneity.

There are several reasons and practical implications why the study of heterogeneous inflation expectations decision rules is relevant. Price channels in economic transmission mechanisms can be slowed by heterogeneous behaviour and choices (Madeira and Zafar, 2015). Heterogeneous expectations can lead to disagreement among decision makers and speculative behaviour which, in turn, could delay and distort monetary policy transmission channels (Sims, 2009). Models that incorporate imperfect information (Sims, 2003; Woodford, 2001) are believed to account for some of the slow price and wage adjustments in response to monetary shocks. Mankiw and Reis (2006) attribute slow price adjustment to staggered heterogeneous information flows, where each firm is free to set prices, but only some are allowed to update their information set, resulting in a close reproduction of realised data.

Another potential consequence of heterogeneous inflation expectations is the differing *ex ante* real interest rates of decision makers, which increase both output and inflation volatility. A central bank that is too responsive in these circumstances magnifies these differences in real interest rates, especially over the short run (Fukac, 2008). In order to make appropriate policy decisions, authorities need to be aware of the degree and nature of heterogeneity present and, more importantly, what the sources thereof are.

Various sources of heterogeneity have been suggested in the recent literature, including different models of the inflation process used by agents, different information sets and different methods of interpreting information (Blanchflower and MacCoille, 2009). Macro-level respondent characteristics such as demographics, gender, age and socioeconomic differences have also been indicated by some authors (see e.g. Pfajfar and Santoro, 2009; Bryan and Venkatu, 2001; Gnan et al., 2011) as differentiating factors in the formation of inflation expectations. The existence of heterogeneity in inflation expectations may also be an indication of perceived uncertainty (Lahiri and Sheng, 2010).

Heterogeneity between groups among South African survey respondents are recognised by Miyajima and Yetman (2018) and they argue that this is related to business representatives and trade union officials being more backward looking than the financial analysts, due to inflexible labour markets. Pierdzioch et al. (2016a) also provide evidence of heterogeneity between South African survey respondents considering socio-economic categories. The contribution of this chapter is that the most important form of heterogeneity in South African survey data is the differences between short-term and longer-term inflation expectations processes, an important concept that have not been specifically identified and its relevance and consequences for monetary modelling frameworks largely overlooked in the literature, as far as could be determined.

3.2 Influences on and determinants of inflation expectations rules

As reported in the previous chapter, conventional tests indicate that South African RIE and BER respondents do not behave consistently with the rational expectations framework when forming their inflation expectations, mainly due to their inefficient use of available information. There are various possible explanations for inefficient use of available information by decision makers, including incentives to accurately forecast inflation, the ability to use information efficiently, rational inattentiveness (Reid, 2015) and the variability of inflation which has been the ultimate policy target of the central bank under the inflation targeting regime.

Furthermore, they form their longer-term expectations differently than they do their short-term expectations, and the former are likely not anchored to the inflation target.[17] There are several approaches in the literature that attempt to define and test for anchored inflation expectations (see Dräger and Lamla (2014) for an overview of these). In this study, expectation formation behaviour is considered anchored if changes in the information set have a negligible impact on it.

This section evaluates alternative approaches or influences that can affect expectation behaviour. The behaviour patterns and rules relating to the formation of decision makers' expectations can take different forms, including adaptive behaviour, correction of recent errors, extrapolation of recent trends or information diffusion (Curtin, 2006). Their approach may be influenced by the associated costs involved in the collecting and processing of information and the benefits realised from producing an accurate inflation forecast.

It has been noted by Branch (2004) that respondents choose a forecasting methodology by considering forecast accuracy, sophistication and the costs of maintaining such processes. Changes between methodologies are unlikely to be implemented often and immediately, and Branch (2004) provides evidence of inertia in the use of forecasting methodologies, where a change

[17] Kabundi et al. (2015) analysed BER survey data and confirm that South African two-years-ahead inflation expectations were not anchored within the target range of 3 to 6 percent.

between methodologies is slowed down by preferences and habits. There may also be a cost associated with switching between methodologies.

The complexity and costs of information processing may well deem it rational for decision makers to select methods other than rational expectations methodologies (Evans and Ramey, 1998; Branch, 2004). Instead of using a single method to form inflation expectations, decision makers might well use a combination of approaches, of which the rational expectations formation model could be a part, especially in uncertain economic environments (Pfajfar and Zakelj, 2015). Knowledge could also be a constraining factor that influences the choice of approach.

Granger and Jeon (2004) label the use of multiple modelling approaches as thick modelling, and show that for portfolio forecasting, it is sub-optimal to use only one model specification, as opposed to combining many approaches. Even though thick modelling estimates may be vulnerable to model misspecification, the omission of useful information may also lead to poor outcomes. Approaches where a model is selected using specific criteria enables thick modelling to be a very useful approach (Castle, 2017).

Brock and Hommes (1997) and Branch (2004) developed a model named Adaptively Rational Equilibrium Dynamics (ARED) whereby decision makers choose an expectation approach from a set of alternatives where costs increase with sophistication and the choice of decision makers' approaches depends on their relative net benefit. Decision makers in the ARED framework switch between approaches, determined by their desired forecast accuracy. Branch (2002) also contrasts different expectation formation approaches, namely a VAR representation, adaptive expectations and naïve expectations.

The following section of the dissertation provides a discussion on the potential influences on inflation expectations rules, to ascertain whether South African decision makers do apply a combination of rules or approaches. The pioneering specifications of rational expectations were tested to determine whether survey respondents behaved as such or whether they behaved heterogeneously. The influence of perceived financial experts or information diffusion on the formation of expectations also received attention, and the impact of information surprises emanating from sudden exogenous shock events, proxied by exchange rate movements, was also tested.

3.2.1 Extrapolative and adaptive behaviour

One of the first key models of expectations based on Alfred Marshall's work was introduced by Ezekiel (1938), whereby he formulated naïve expectations based on the cobweb model of price adjustment, such that inflation expectations were functions of past inflation. Other early forms of expectation formation rules were introduced by Hicks (1946), Cagan (1956) and Nerlove (1958).

Many factors can influence the formation of expectations and Hicks (1946) isolated three categories of expectations, namely non-economic (such as the weather or politics), economic (such as market superstitions) and actual experience of past and present prices. The latter serves as the basis for his expectations rule, where adjustments to inflation expectations are proportionally related to current inflation and an adjustment for the change in inflation or inflation momentum. This formulation is known as the extrapolative expectations hypothesis, which states that expectations about inflation are changed or revised based on distributed lag functions of realised inflation. A limitation of the class of extrapolative expectations rules is that these are naïve and do not make much allowance for decision makers to include their own expectations or to learn from forecast mistakes, since these are formulated as lagged representations of past inflation outcomes.

An expectations formation rule that does allow decision makers to incorporate their own judgement is the adaptive expectations rule. This rule was formalised by Cagan (1956) and Nerlove (1958) and states that inflation expectations are revised proportionally to past forecast errors. Support for adaptive behaviour is found if inflation forecast errors impacts significantly on expected inflation such that the expectation is revised or changed. Even though this type of rule was formulated about half a century ago, it is still relevant and used. More recent studies by Evans et al. (2001) and Adam (2007) tend to reject rational expectations formation in favour of adaptive behaviour based on aggregate data.

The extrapolative expectations rule based on Hicks (1946) and the adaptive rule of Cagan (1956) and Nerlove (1958), where the rule is a function of past forecast mistakes, were tested on the South African RIE and BER Survey data, and the results are reported in Appendix B.1. The approach followed is based on Figlewski and Wachtel (1981), who used data from the Livingstone Inflation Expectations Survey to estimate the adaptive expectations rules.

The extrapolative expectations rule was estimated as follows:

$$\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \gamma\left(\pi_{t-1}^{h} - \pi_{t-2}^{h}\right) + v_t \qquad (3.2.1)$$

Where $\pi_t^{e,h} - \pi_{t-1}^{e,h}$ denotes the change or revision in inflation expectations made for horizon category *h*, from period t-1 to t, α is a constant, γ the extrapolative coefficient of decision makers with respect to the change in realised inflation. The intuition of γ in Equation 3.2.1 is that decision makers revise their inflation expectations proportionally by the change in realised inflation.

The adaptive expectations rule was estimated as follows:

$$\pi_t^{e,h} - \pi_{t-1}^{e,h} = \delta + \beta\left(\pi_{t-k}^{e,h} - \pi_{t-k}^{h}\right) + \varphi_t \qquad (3.2.2)$$

To reduce the impact of any systematic measurement or specification errors on the estimated coefficients, each rule was specified with an intercept (α and δ). In Equation 3.2.2, β is the adaptive coefficient related to the previous forecast error made when realised by the respondent.

The intuition behind these coefficients (γ and β) is that decision makers adjust or revise their expectations about future inflation by some proportion of the momentum of realised inflation (Equation 3.2.1) or by every percentage point forecast error (Equation 3.2.2) they had made in estimating inflation. A statistically significant non-zero adaptive coefficient indicates the respondents' perceived persistence of the inflation momentum or expectations mistakes. The terms v_t and φ_t represent the stochastic error terms, and *h* refers to the specific forecast horizon. The results are reported in Appendix B.1: Tables B.1.1 to B.1.11.

This chapter reports the conventional test of extrapolative and adaptive behaviour which was extended to distinguish between different behaviour over shorter- and longer-term forecasting horizons. This distinction in terms of intertemporal heterogeneity, i.e. the different behaviour when forming expectations in the short versus the longer term has, as far as could be determined, not been addressed in recent papers, though it was acknowledged many years ago by Keynes (1936). One of the important contributors to the development of the theory of expectations was the seminal work by Keynes (1936). In his model he made the distinction that short-term expectations were driven by psychological factors, and long-term expectations were determined exogenously. It is important to note that Keynes considered expectations to be exogenously determined, which challenges cohesion in his theory (Mikołajek-Gocejna, 2014) and its compatibility with the ensuing theoretical developments and empirical observations.

In the results that follow, a co-movement between shorter- and longer-horizon adaptive coefficients was observed. In general, the estimated adaptive coefficients have the same sign, with the shorter-term impact being more pronounced than the longer-term, similar to Dräger and Lamla (2014), who find that short-term adaptive behaviour is more pronounced than the longer-term for USA micro-level inflation expectations data. If a particular homogeneous group's longer-term adaptive coefficients are statistically significant, and not notably smaller than the short-term adaptive coefficients, it might indicate respondents' uncertainty and unanchored longer-term inflation outlook as they incorporate persistence.

Decision makers are unlikely to be passive or inattentive, since they do observe and respond to changes in inflation momentum or to forecast errors. The behaviour, or expectation rules, of respondents are probably not static, and it is likely that they adjust their rules following major information set adjustments. The analysis was also expanded to test whether a major economic event such as the global financial crisis of 2008 did effect a notable change in the adaptive behaviour of the respondents.

3.2.1.1 RIE Survey [18]

According to the extrapolative expectations rule, decision makers adjust their expectations about future inflation by some proportion of the momentum of recently realised inflation. This specification does not allow decision makers to respond to their forecast error: they can adjust only the proportion of observed inflation momentum that they deem relevant in order to change their expectations.

To test for extrapolative expectations formation by the RIE respondents, Equation 3.2.1 was estimated for the seven forecast horizons and the results reported in Figure 3.1. The respondents projected almost half of the change in actual inflation into their current and one-quarter-ahead expectations. Over longer-term horizons, this effect appears muted. Observed inflation momentum appears to have impacted shorter-term expectations, but did not affect the

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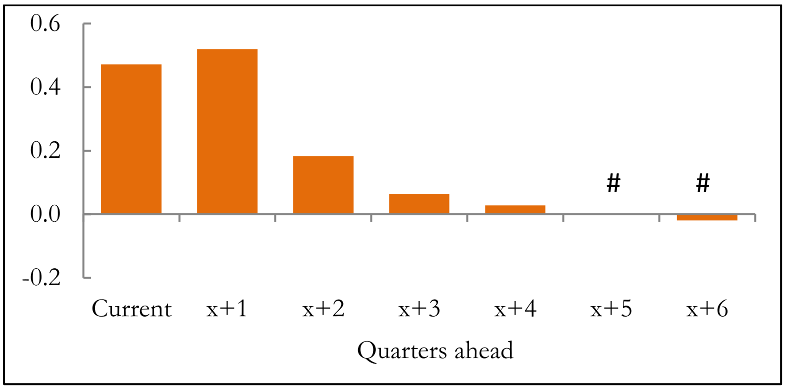
[18] The estimated results and accompanying diagnostic test results are reported in Appendix B.1. The respondents were affected by information surprises during 2003 and 2009. These unexpected affects were accounted for in the estimation of the extrapolative and adaptive expectations coefficients, where such dummy variables were found to be statistically significant. The information surprises were related to significant exchange rate depreciations and oil price shocks, which caused inflation to exceed expectations. The dollar/rand exchange rate depreciated by 47.4% year-on-year in the first quarter of 2002 and by 46.5% in the fourth quarter of 2008. The Brent crude oil price (in dollars) grew by 50% year-on-year in the first quarter of 2003 and by 75.7% in the second quarter of 2008. Hamilton (2009) discusses in detail the causes of these oil price increases, attributing them mainly to the inability of the suppliers of oil to meet the increased demand at the time.

longer-term expectations, which is indicative of intertemporal heterogeneity in the expectations formation processes.

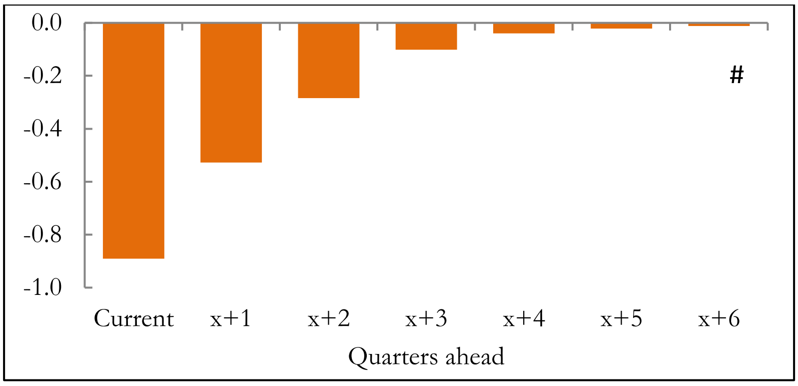
Figure 3.1: Extrapolative expectations impacts based on the RIE Survey



Note: # = not statistically significant

The adaptive behaviour of the respondents with respect to the forecast error they had made in the previous period was estimated over all reported forecast horizons for the RIE Survey. Figure 3.2 presents the magnitudes of the adaptive expectations coefficients estimated using equation 3.2.2 for the RIE Survey over the seven forecast horizons. For every percentage point error made in their previous quarter's expectations, the RIE Survey respondents adjusted their expectations for inflation in the current quarter and for one-quarter-ahead by -0.9 and -0.5 percentage points on average, respectively. The adaptive coefficients for the two-quarters- to five-quarters-ahead expectations declined over the longer-term horizons, and the six-quarters-ahead adaptive expectation coefficient is insignificant, since in terms of the diagnostic tests, it is not statistically significantly different from zero.

Figure 3.2: Adaptive expectations impacts based on the RIE Survey



Note: # = not statistically significant

The decay of the adaptive coefficients from the shorter-term to the longer-term horizons indicates that respondents did not think that short-term inflation surprises would persist over longer-term horizons. It appears that their longer-term views were not necessarily affected by forecast mistakes, but rather by other factors in their information set. This result corresponds with Madeira and Zafar (2015), who found that US survey respondents did not believe that short-term surprises were persistent over longer periods.

Intertemporal heterogeneity was observed with the Reuters respondents, who exhibited different processes governing the formation of their expectations over shorter-term horizons compared with longer-term horizons. They were potentially influenced by differing degrees of uncertainty or persistence for the short-and longer-term horizons.

In an inflation targeting framework, longer-term expectations should ideally be anchored on the inflation target. Distributional analyses of longer-term (in this instance the two-years-ahead expectation horizon, see Figures 4.6, 4.8 and 4.10) inflation expectations conducted over certain sub-samples show that South African respondents had an inflation expectations focal point at the mid-point of the inflation target range during 2004q1-2008q4, which has subsequently moved upwards towards the upper end of the inflation target range where the expectation of 6 percent became the most widespread for business representatives and trade union officials and 5.5 percent was the most widespread for the financial analysts (see Chapter 4; Figures 4.6, 4.8 and 4.10).

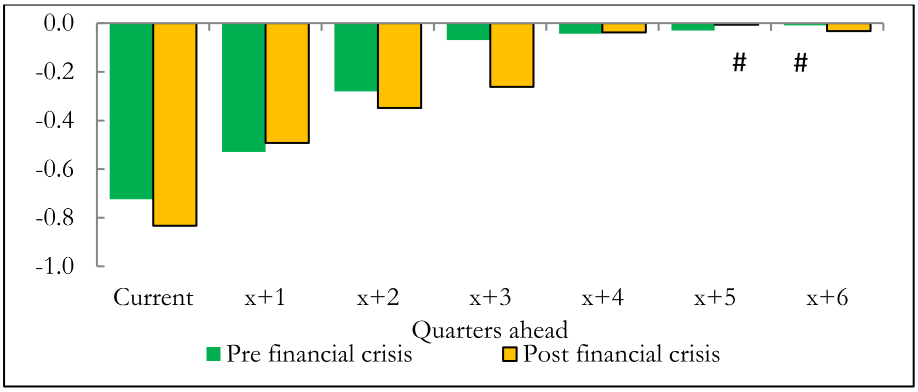
The focal point of inflation expectations may have been impacted not only by the global financial crises, but another potential cause is that the central bank implemented its inflation targeting regime rather flexibly during this period in South Africa, given the pressure on the real economy with the consequence that the implicit target of the central bank moved to the upper end of the target range. This interpretation is consistent with evidence reported in Kabundi et al. (2015).

This observation is supported by Kabundi et al. (2015) who found that the focal point for inflation expectations moved to the upper band of the inflation target band. This change of the focal point may have been impacted by the global financial crisis, which emerged during the second half of 2008. The impact of the global financial crisis on monetary policy has yielded the interesting hypothesis that policy may have been more accommodative to support the troubled economy, since the expectations data is consistent with behaviour associated with an accommodative environment.

The global financial crisis caused great uncertainty in the international economy. The onset of unconventional monetary policies and the impacts thereof, coupled with threatening zero lower bound interest rate environments, made decision makers cautious, risk averse and uncertain, as unemployment increased, some economies entered into recession and market illiquidity became a constraint severely impacting consumer and business confidence. The global financial crisis is not the only influence that affected inflation dynamics post 2008. Kabundi et al. (2015) suggest that the central bank was faced with an expectations trap, stating that the central bank was faced with a slowing growth environment that provided limited scope for policy decisions to lower inflation to the midpoint of the target range. Hence, inflation was tolerated at the upper end of the inflation target range. Despite the exchange rate depreciation post 2008, the trend in inflation remained fairly stable due to muted pass-through and improved communication by the central bank according to Kabundi and Mlachila (2019).

To evaluate whether South African respondents' sensitivity to inflation surprises was altered after the crisis, the adaptive behaviour prior to the global financial crisis (2000-2008q4) and afterwards (2009-2016q4) were compared. The results show that the adaptive behaviour of respondents appears to have been somewhat more sensitive post the global financial crisis, and the decay over time remained present in both sub-samples (Figure 3.3 and Appendix B.1, Table B.1.2, B.1.3). In particular, the average adaptive coefficient for the first four expectation horizons (i.e. first four quarters) was -0.40 pre-crisis and -0.48 post-crisis. The respondent disagreement, or average standard, error increased only marginally from 0.09 in the pre-crisis period to 0.13 post-crisis. Therefore, it appears that the adaptive behaviour of the Reuters respondents was marginally more responsive (more negative) to inflation surprises and slightly more uncertain post the global financial crisis.

Figure 3.3: Pre- and post-financial crisis impacts of adaptive expectations based on the RIE Survey



Note: # = not statistically significant

When both the extrapolative and adaptive effects are accounted for in an estimated equation (Appendix B.1: Table B.1.5), it appears that the adaptive effect overshadows the extrapolative effect. It seems, therefore, that the respondents were more sensitive to forecast mistakes than to inflation momentum when formulating their expectations.

The RIE respondents were not passive when forming their short-term inflation expectations, since they incorporated information from their forecast mistakes as well as momentum, to a smaller extent, in observed inflation. Over the longer-term horizons, these impacts were not persistent, and other factors in their information set were likely guiding their longer-term behaviour.

3.2.1.2 BER Survey [19]

Even though the results for the RIE Survey respondents are similar to those of the BER Survey financial analysts group, there are differences in the dynamics of these two surveys.[20] Firstly, the RIE Survey respondents report their expectations regarding average quarterly inflation once per month, and the BER respondents report their annual average expectations once per quarter.

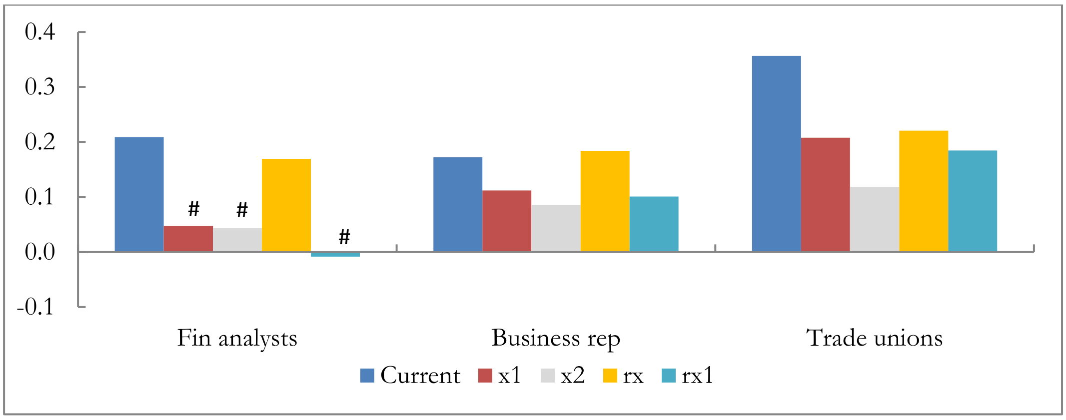
[19] The BER respondents were affected by an information surprise during 2003 and 2009, most likely related to the exchange rate volatility observed at the time. This adverse effect was accounted for in the estimation of the adaptive expectations coefficients, where such a dummy variable was found to be statistically significant.

[20] It is highly likely that some of the respondents of the RIE Survey (sample around 15) are also included in the BER Survey financial analysts group (sample more than 20), however it is not possible to confirm, since the BER Survey respondents' identities are confidential.

Therefore, the respective information sets used when reporting their expectations differ. Secondly, individual forecasts of the RIE Survey are identified by the institution that produced them, thereby adding an element of accountability, contrary to those of the BER Survey, where the respondents, and their forecasting reputations, remain anonymous. A feature of the BER Survey is that it enables inference about intra-group and intertemporal expectations heterogeneity. Expectations for annual inflation are published for three groups and also for different horizons, including the current year (x), the one year ahead (x+1) and two years ahead (x+2) horizons.

Decision makers may change or adjust their expectation rules due to changes in their information sets, such as new information about actual inflation or realised mistakes of either short-term errors or h^{th} horizon errors. In the part of the study covered in this section the BER Survey respondent expectation rules were tested according to the previously described extrapolative expectations rule and the adaptive expectations rule.[21]

Figure 3.4: Extrapolative expectations impacts based on the BER Survey



Note: # = not statistically significant

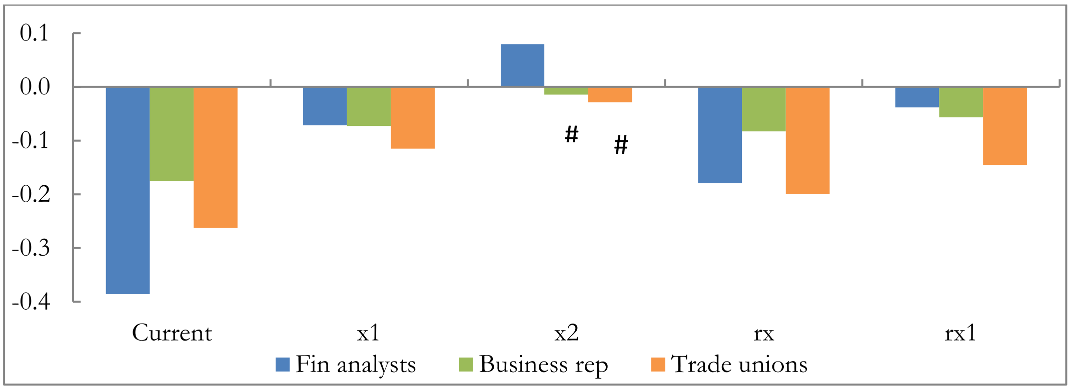
The Hicks expectations rule allows for inference about the impact of published inflation numbers, particularly, how the inflation momentum from the previous print affects respondents' views of future inflation. The financial analysts appear to have been cognisant of inflation momentum, but mainly in the short term (Figure 3.4). The business representatives and trade union officials tended to extrapolate current inflation momentum into their longer-term expectations, albeit somewhat lower over the longer term.

[21] To analyse these, careful consideration was given to the discrete time when the expectation was made, when the information was available.

These results show that for trade union officials and business representatives, inflation surprises in previous periods extended to the present as they adjusted their inflation expectations. This extension of past surprises to the present is an example of non-rational heterogeneity in expectations formation. It appears that these two groups showed more persistence than the financial analysts in their adaptive behaviour. This may indicate that the financial analysts were less influenced than the other two groups in adjusting their longer-term outlook following inflation surprises. The decay in the extrapolative behaviour of all three groups from the short-term to the longer-term horizons following an inflation surprise suggests that intertemporal heterogeneity was present and other factors were likely guiding their longer-term views.

The Cagan-Nerlove expectations rule tests the sensitivity of respondents to forecast mistakes. According to this specification, for every one percentage-point error made on the short-term expectation, respondents adjusted their inflation expectations for the current-year, one-year-ahead and two-years-ahead horizons (Figure 3.5) by β percentage points (β as estimated by Equation 3.2.2). For every one percentage-point forecast error that the financial analysts made, they adjusted their expectations for the current year, one year ahead, two years ahead, the current-year rolling horizon and one-year-ahead rolling horizon by -0.39, -0.07, 0.08 (not statistically significant), -0.18 and -0.04 percentage points. This indicates their sensitivity to incorporating information surprises over the short-term horizon, yet the results show limited persistence over the longer-term horizons.

Figure 3.5: Adaptive expectations impacts based on the BER Survey



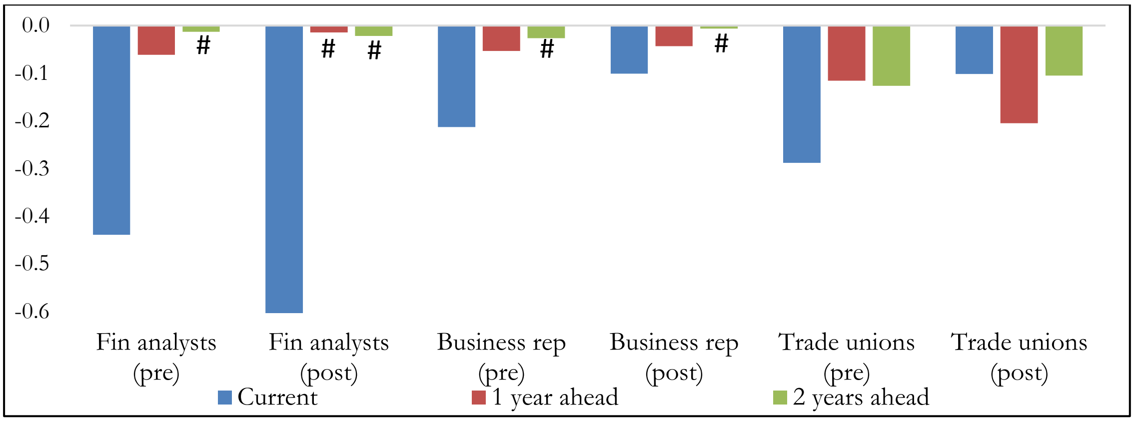
Note: # = not statistically significant

The results for the BER-surveyed financial analysts corresponded to those of the RIE Survey, in the sense that the average for the adaptive coefficients for the first four quarters for the RIE Survey was -0.45 compared with the -0.39 for the financial analysts' current-year expectation. Both groups portrayed almost no adaptive behaviour over the longer-term horizons. This indicates that they expected inflation surprises to have a notable short-term impact, though they expected very little persistence over the longer-term horizons. These respondents' longer-term views may have been determined by other factors in their information set, which guided them to a particular inflation rate.

Expectation formation processes are not static, and it would be of interest to investigate respondents' sensitivity to inflation surprises, especially following a major unanticipated event such as the global financial crisis. Therefore, the data was divided into two sub-samples, i.e. pre- and post-2009q1, to contrast the resulting adaptive coefficients. The results indicate that following the global financial crisis, the adaptive behaviour of the financial analysts group appears to have been much more sensitive to short-term horizon forecast errors, by revising their short-term inflation expectations by more post the global financial crisis than what they did prior. Their adaptive behaviour for longer-term horizons was however largely unchanged between the pre and post global financial crisis periods. The financial analysts made notable changes by increasing their short-term adaptive behaviour post the global financial crisis, where the other two groups decreased their adaptive behaviour slightly for short-term horizons (Figure 3.6).

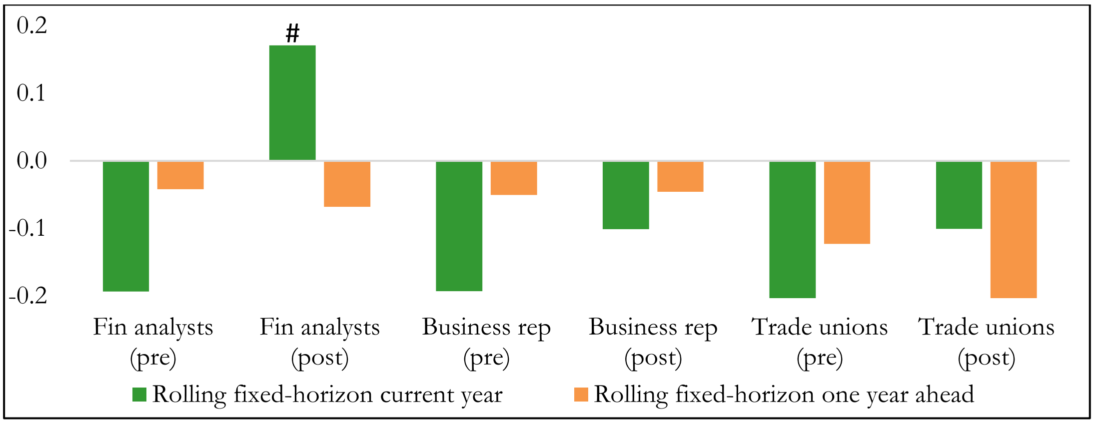
The trade union officials group increased their sensitivity to inflation forecast errors (or adaptive behaviour) for longer-term horizons by almost double the pre-crisis magnitude according to the fixed-horizon data. This indicates their increased sensitivity or uncertainty about the longer-term inflation outlook following realised expectation errors.

Figure 3.6: Pre- and post-financial crisis adaptive expectations impacts for the BER Survey: fixed-event expectations



Note: # denotes not statistically significant

Figure 3.7: Pre- and post-financial crisis adaptive expectations impacts for the BER Survey: fixed-horizon expectations



Note: # denotes not statistically significant

The financial analysts and business representatives showed notable declines in their adaptive behaviour from the short-term to the longer-term horizons, which indicates that they did not adjust their longer-term expectations as much as they did their short-term expectations following inflation surprises. Therefore, their expectations appear to have been more anchored over the longer forecast horizons. This behaviour was not as pronounced in the trade union official group, who appear to have been less anchored, particularly following a major shock such as the global financial crisis.

When both the extrapolative and adaptive effects are accounted for in an estimated equation (Appendix B.1: Table B.1.9), it appears that the adaptive rule was more prominent than the extrapolative rule when both these effects were estimated simultaneously. In most cases the extrapolative effect was not statistically significant where the adaptive effect was. This result was similar to that for the RIE Survey data, where respondents appear to have been more sensitive to forecast errors than to inflation momentum over the short-term horizon.

3.2.2. Heterogeneous information diffusion

The evidence given in the preceding section indicates that the longer-term inflation expectations behaviour was not largely influenced by information on inflation momentum or forecast mistakes. Therefore it was relevant to investigate other potential drivers of expectations. Decision makers may choose to draw on the available information and forecasts from entities who are perceived to be financially literate leaders. The degree of financial literacy is an important source of heterogeneity in inflation expectations according to Gnan et al. (2011). In an environment with varying degrees of financial literacy, the question is to what extent one group could be considered to be a leader or to anchor and the remaining groups as followers. Such a leader should be observed and regarded by the followers to have superior financial literacy and forecasting performance, hence their behaviour. Of additional interest is whether the followers incorporate information from a perceived leader heterogeneously.

In some cases even such leaders or experts find it difficult to outperform naïve-type forecasting processes. Atkeson and Ohanian (2001) show that the one-year-ahead inflation forecasts from the Federal Reserve's Greenbook have not been superior to naïve-type forecasts in the form of the previous year's forecasts. However, evidence for South Africa shows that inflation expectations of both the BER and Reuters respondents, in general do outperform naïve random walk models (see Chapter 2: Section 2.3.2). This may be in part due to the higher volatility of South African consumer inflation relative to that of the United States.[22] Naïve models such as the random walk types are difficult to outperform especially when the data is volatile like exchange rate data (Rossi, 2013).

[22] The standard error for SA consumer inflation (2.3) was almost double that of US consumer inflation (1.3) over the sample period, 2000q1 to 2016q4.

The BER Survey reports on three groups with likely differentiated levels of financial literacy where the presence of heterogeneous information diffusion can be tested. Respondents in the financial analysts group of the BER inflation expectations survey are the most likely candidate group to have superior financial literacy, compared with the other two groups.

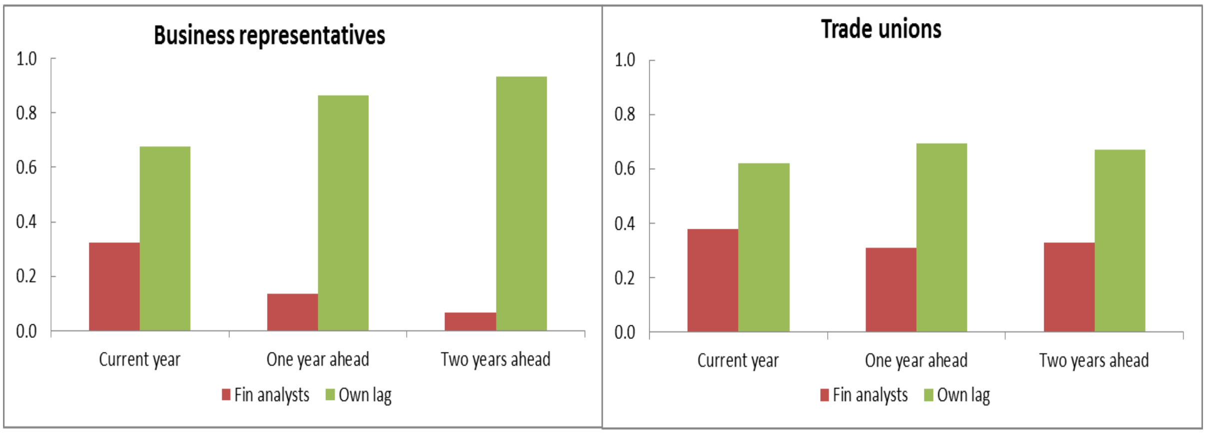
The diffusion concept engineered by Carroll (2003), where agents adopt experts' forecasts, rather than their own, with a certain probability was applied to test the diffusion of information from one group that was considered to be more financial literate, to the other groups. For this purpose, the following equation format was estimated.

$$\pi_{j,t}^{e,h} = \alpha_0 + \alpha_1 \pi_{fin,t}^{e,h} + (1 - \alpha_1)\pi_{j,t-1}^{e,h} + \epsilon_t \qquad (3.2.3)$$

Where $\pi_{j,t}^{e,h}$ denotes the inflation expectation of group *j* (where *j* = 1 for business representatives and 2 for trade union officials) for *h* year(s) ahead at time *t*, $\pi_{fin,t}^{e,h}$ denotes the inflation expectations of the financial analysts for *h* year(s) ahead at time *t*, $\pi_{j,t-1}^{e,h}$ denotes the own inflation expectations of group *j* for *h* year(s) ahead at time *t-1*.

The coefficient a_0 represents the constant term, which is omitted in the work done by Carroll (2003). In the South African case, where systematic bias in inflation expectations is often present, it is relevant to include a constant term in the estimation. The constraint imposed on the nominal coefficients relates to the notion that the equilibrium inflation rate should be equal to its expectation (Curtin, 2006). Relaxing the estimation constraint yields very similar results and does not alter the main inferences (see Appendix B.1: Table B.2.2). The following figure shows the results of the effects of expert input and own input, which were compared between the two groups and also over time.

Figure 3.8: Information diffusion from financial analysts to other BER Survey groups



Although not prominent, the information diffusion from the financial analysts is non-negligible. The results indicate that both groups tended to rely more on their own previous period's inflation expectations, i.e. possibly a naïve and inexpensive method of forecasting, than on those of the assumed expert group, namely the financial analysts (Figure 3.8). This finding is in accordance with those of Lombardelli and Saleheen (2003), Malmendier and Nagel (2009) and Ehrmann et al. (2015), i.e. that an important determinant of inflation expectations is the individual's own inflation experience over their lifetime. Expanding on this, Madeira and Zafar (2015) find that lifetime experience of inflation contributes much more to near-term expectations than to longer-term expectations. This strengthens the case for the backward-looking or adaptive behaviour among decision makers, where they tend to rely on their own inflation experiences rather than on following experts or even published past inflation outcomes.

The influence of the expert group decays from short-to longer-term horizons; more so for the business representatives than for the trade union officials. Even over the longer horizons when faced with more uncertainty, the two groups appear to have preferred to draw on their own previous inflation expectations. This behaviour is in contrast with the studies of Carroll (2003) and Ehrmann et al. (2015), who found that respondents in the United States tended to converge towards professional forecasts over time. Heterogeneity was noted where the trade union officials group appeared to have been influenced much more by the expert group than by the business representatives group over the longer horizon. It appears that these groups were inclined not to use available information, as can be seen in these results.

The evidence reported indicates that the business representatives and trade union groups were not motivated or convinced that expert forecasts may enhance their information sets and ultimately their forecast accuracy. The lack of convergence of inflation expectations on one particular expert group also contributed to the heterogeneity between these groups.

3.2.3. Heterogeneous impact of open economy effects on inflation expectations

It has been established that the RIE and BER Survey respondents do not use available information efficiently when forming their inflation expectations. One of the most prominent influences on an open economy's inflation is the exchange rate, since it impacts directly on the price of imports, transport costs and indirectly on various price categories. Indifference by decision makers to the exchange rate effect when formulating their inflation expectations could support the information inefficiency finding.

The survey respondents' interpretation and use of available macroeconomic data when formulating their inflation expectations provides insights into the potential divergence or heterogeneity between different demographic groups about their use and interpretation of such information (Mankiw et al., 2004). Open economies, such as that of South Africa, are vulnerable to trade-related and asset-market shocks, especially through the impact of volatile exchange rates on domestic prices. To analyse the impact of such shocks on the process of forming inflation expectations over different expectation horizons, and per survey group separately, the following equation was estimated:

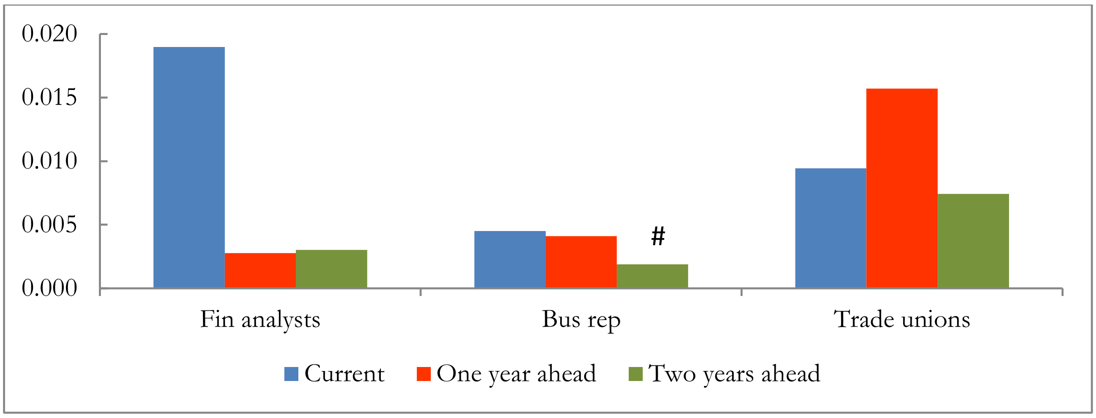
$$\pi_{j,t}^{e,h} = \alpha_0 + \alpha_1 exd_t + (1 - \alpha_1)\pi_{j,t-1}^{e,h} + \epsilon_t \qquad (3.2.4)$$

Where $\pi_{j,t}^{e,h}$ refers to expected inflation; h refers to the expectation horizon category (current year, one year ahead or two years ahead); j refers to the BER survey group (where $j = 0$ for financial analysts, 1 for business representatives and 2 for trade union officials) (separately) at time t; *exd* refers to the year-on-year rate of change in the dollar/rand exchange rate at time t and a_0, and a_1 represent estimated coefficients[23]. The results are shown in Figure 3.9 (see also Appendix

[23] The restriction in Equation 3.2.4 ensures dynamic homogeneity since all the coefficients of nominal variables of the equation is restricted to add to one. This principle is commonly applied in monetary models to ensure stability in price channels and to avoid money illusion. The equation is specified such that it is relatable to those equations often used in monetary policy models (see Westaway, 2000). Relaxing the constraint on the estimated coefficients yielded very similar results – see Appendix B.3: Table B.3.1.

B: Table B.3.2). The size of the impacts appears to have been small; however, it should be noted that the dependent variable was the BER Survey annual average inflation expectation, and it appears that the respondents were aware that initial inflationary impacts from an exchange rate change is temporary, and second-round inflationary impacts will persist for longer, which will influence their inflation expectations behaviour.

Figure 3.9: Exchange rate impact on inflation expectations over horizons per BER Survey groups



Note: # = not statistically significant

When confronted with exchange rate shocks, the three groups behaved heterogeneously. The financial analysts group appears to have adjusted their inflation expectation for the current year more than the other two groups, yet they discounted these shocks more in the one-year- and two-years-ahead horizons than the other two groups did. It is interesting that the trade union group appears to have handled exchange shocks quite differently, by adjusting their one-year-ahead inflation expectations by more than the current year, and only slightly lowering their two-years-ahead inflation expectation, displaying more persistence than the other groups.

It seems reasonable to conclude that the financial analysts group considered exchange rate shocks to be more prominent, yet less persistently so when compared with the business representatives and trade union officials. The trade union officials and business representatives behaved similarly in the current year's expectation horizon, but the former group tended to compensate more by increasing their perceived exchange rate impact for the one-year-ahead horizons, where the business representatives decreased theirs.

The notable decay in the exchange rate impact for the financial analysts and business representatives groups from the short-term to the longer-term horizons suggests that intertemporal heterogeneity was present i.e. they followed different expectation formation processes for different time horizons. In addition, it appears that following an exchange rate change, the financial analysts and business representatives groups were more anchored over the longer-term horizons than was the trade union representatives group, another source of heterogeneity.

Considering the size of the impact the exchange rate on inflation expectations, it appears that the respondents favoured their own lagged expectation and did not considerably incorporate exchange rate news in their annual inflation outlook. This supports the information inefficiency finding and that the rational expectations assumption is not likely relevant for South African decision makers.

3.3 Adaptive learning

Contemporary monetary theories propose learning and adaptive learning in particular (see Evans and Honkapohja, 2001; Bullard and Mitra, 2002; Pfajfar and Zakelj, 2015) as alternative approaches to the rational expectations formation framework. Evans and Honkapohja (2001) present adaptive learning where decision makers are allowed to adjust their forecast rule when they receive new information.

The process of forming inflation expectations involves estimating an initial expectation, but also involves opportunities for revising these during the year for appropriate reasons, such as newly acquired relevant information. It has been shown by Anderson et al. (2010) that the forming of expectations by United States (US) agents is done by heterogeneously engaging learning processes. The authors indicate that individual forecast accuracy is less diverse at the re-interview than at the initial interview, implying that the process of learning may reduce the initial heterogeneity.

Expectations formation by agents via learning is done heterogeneously according to Anderson et al. (2010), who tracked respondents' choices when surveyed twice, but at different dates, for the same inflation forecast event.

To investigate whether the BER Survey respondents followed a process of learning, the approach by Anderson et al. (2010) was followed. During the course of a calendar year, the respondents are approached four times, once per quarter, to submit forecasts for the current-year, one-year- and two-years-ahead annual average consumer inflation numbers. Subsequent to the initial interview conducted during the first quarter of the year, the following three quarterly interviews provide respondents with the opportunity to revise their previously reported expectations, especially since new information is available for them to include in their information sets. As a result, these four instances ask respondents for overlapping forecasts, but on each subsequent occasion, more information is available, which the respondents may use to improve their forecast errors. The subsequent interviews are considered to be re-interviews.

An observed forecast change by the individual respondent upon subsequent re-interview alone does not imply learning. Respondents should incorporate the additional information such that their realised forecast error is smaller compared with the previous interview, to indicate successful learning. These re-interviews provide opportunities to examine whether individual respondents update and reconsider their information sets and hence meaningfully update their forecasts such that their absolute forecast errors are smaller from the first to the fourth interview of the year. Hence, the test aimed to observe whether learning behaviour has improved their forecast accuracy.

The following equation was estimated:

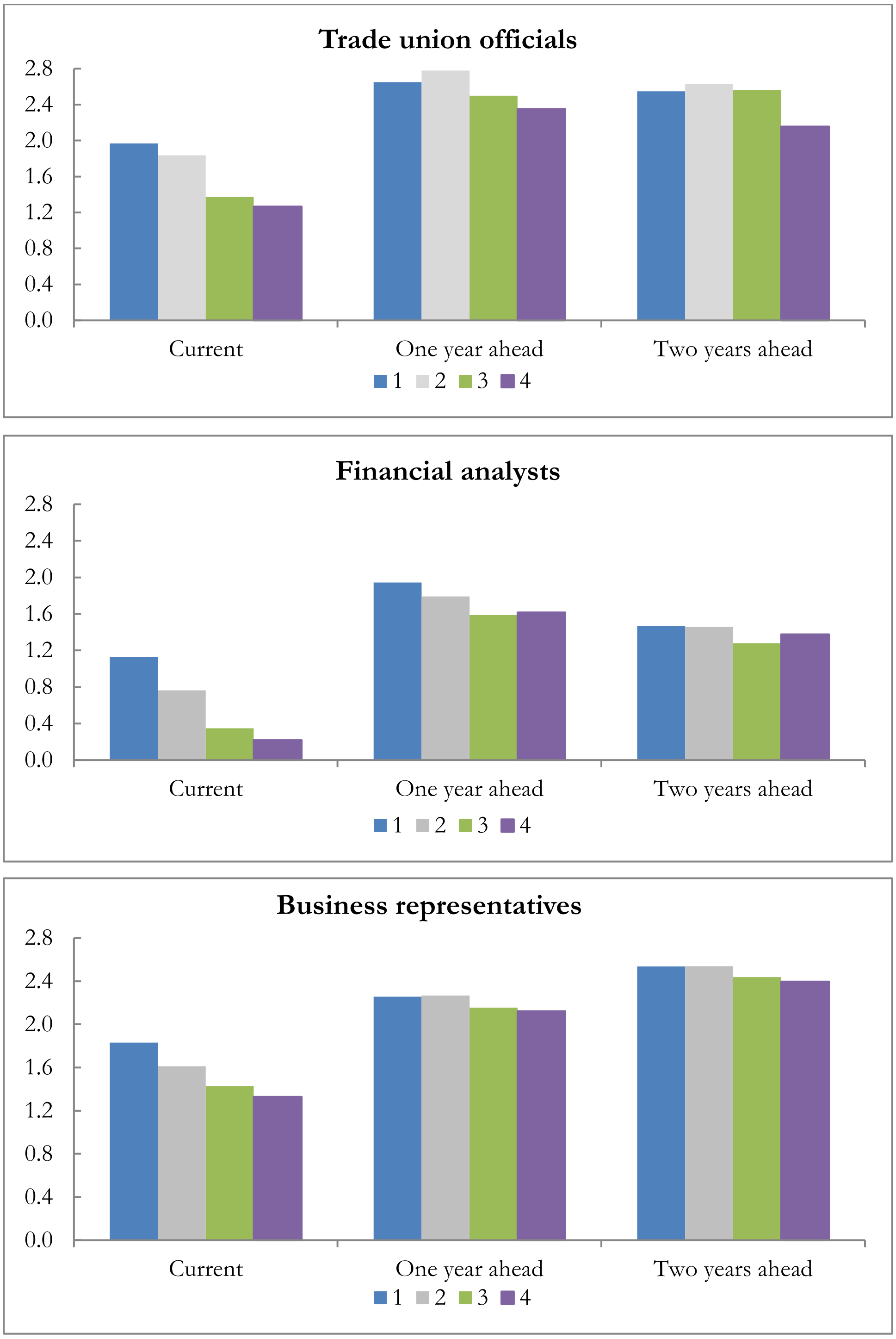
$$\left|\pi_{i,t|t+k}^{e,h,q} - \pi_{t+k}\right| = \alpha_0 + \alpha_1\ Interview^q + \varepsilon_t \qquad (3.3.1)$$

Where q = interview number (1,2,3,4), h = forecast horizon classifier (current year, one year ahead, two years ahead), k = the quarter for which the forecast was made, i = respondent 1,…,N and t = time. The parameter α_0 denotes the intercept, α_1 the average individual-specific adaptive learning parameter and ε_t the stochastic error term. In this equation individual respondents were tested to establish whether they do exhibit learning characteristics where the absolute forecast error per consecutive quarterly interview per individual decreases from their first to their fourth interviews. Where an individual did not provide all four expectations for a particular year, the incomplete data were discarded from the dataset.

The average absolute errors of the individual respondents per group and per interview number are shown in Figure 3.9. It appears that the mean absolute errors of the respondents did decline over the four interviews. According to maximum likelihood estimations, only the current year's forecast horizons have a statistically significant decay for all of the three groups considered. The financial analysts tended to have the biggest improvement in their forecast errors, by declining by 0.31% from the first to the fourth quarter on average. The trade union officials improved their absolute forecast errors by 0.26%, and the business representatives improved by 0.17% on average per consecutive quarter. The one-year- and two-years-ahead horizons do show slightly lower absolute errors over the four interviews, but these are not statistically significantly different from each other according to F-tests (Appendix B.4).

From the individual respondent analyses, the short-term expectation formation processes of the respondents indicate that learning was present in the short-term; however, this was not the case for the one-year- and two-years ahead forecast horizons. Therefore, intertemporal heterogeneity was present with regard to how these decision makers applied learning processes.

Figure 3.10 Average absolute forecast errors per group and interview for BER Survey



3.4 Policy considerations

An inflation targeting central bank needs to understand the nature and behaviour of inflation expectations in its economy so that it can influence it to achieve price stability that promotes economic growth and stability at the lowest cost to society possible. The role of monetary policy in a heterogeneous expectations environment is complex. Departures from homogeneity require monetary authorities to understand their nature so that they are able to take appropriate policy actions. In the cases where heterogeneity exists between groups, such as between private agents and the central bank, Fukac (2008) shows that it is optimal for the central bank not to respond aggressively to inflation deviations from the target, in an attempt to improve economic stability and lower output variability in the short run. Such a recommendation is in contrast with the cases of heterogeneous and imperfect knowledge, where more vigilant monetary policy responses are suggested (Orphanides and Williams, 2004).

Heterogeneous inflation expectations cause subjective disagreements about *ex ante* real interest rates among agents (Fukac, 2008; Malmendier and Nagel, 2009). When a central bank responds aggressively in such an environment, the divergence in subjective real interest rates becomes even more pronounced. A consequence of this is increased volatility in both inflation and output, since these rates are relevant to the consumption and investment decisions of agents.

In a heterogeneous expectations environment, it may be prudent for policy authorities to try to address some of the sources of heterogeneity, such as the informational inefficiencies of decision makers, by enhancing communication strategies. The provision of a clear inflation target in a credible environment may also assist in converging the longer-term inflation expectations of all decision makers to this anchor.

In an inflation targeting regime, it is important for the central bank to anchor inflation expectations at an explicit inflation target, to achieve price stability (Bernanke, 2007). When inflation expectations are anchored, it facilitates an environment where the central bank can achieve greater output stability in the short term and price stability in the long term (Orphanides and Williams, 2007). Well-anchored longer-term inflation expectations essentially should not be influenced by new economic news or inflation surprises, but should remain relatively stable at their original estimates (Bernanke, 2007; Nautz and Strohsal, 2014).

In this study there appears to have been different inflation expectation rules between short- and longer-term forecast horizons. In the short-term, respondents were motivated to change their expectations when they realised their forecast errors. They also considered inflation momentum, exchange rate effects and they learned from their forecast mistakes. Information diffusion from the financial analysts to the other two groups was also observed. However, over the longer-term horizons, it appears that mainly their own expectations mattered when they formed their expectations. Economic news, forecast mistakes and information diffusion had almost no influence. The respondents were certainly not naïve when forming their expectations, but their intertemporal heterogeneity can be challenging when formulating policy, especially when central banks focus on influencing longer-term expectations.

3.5 Conclusion

It is often assumed in economic theory that decision makers are homogenous with respect to the information used, interpretation processes and models used to generate expectations about future inflation. However, staggered information and model uncertainty may well be present and result in the heterogeneity of inflation expectations (Curtin, 2006). The South African respondents analysed did demonstrate heterogeneity, but more importantly, in multiple forms. The results from this study showed that South African inflation expectations were not formed uniformly in terms of respondents, forecast approaches, respondents' use of information, and across forecast horizons.

Heterogeneity was observed between the groups surveyed in the BER Survey. The financial analysts and the business representatives showed notable declines in their adaptive behaviour from the short-term to the longer-term horizons, indicating that they did not adjust their longer-term expectations by as much as they did their short-term expectations following inflation surprises. Therefore, they appear to have been more anchored over longer forecast horizons. This behaviour was not as pronounced in the trade union official group, who appear to have been less anchored, particularly following the global financial crisis.

Over the short-term forecast horizons, the business representatives and trade union officials groups seemed to prefer their own past inflation experience rather than fully accepting the view of a more financially literate group, when forming their inflation expectation for the current year. Even though this information diffusion effect was not dominant, the respondents relied even less on the knowledge and experience of the financially literate group over longer forecast horizons.

The short-term expectation formation processes of the individual BER Survey respondents indicate that they did learn and improve their forecast errors when re-interviewed for the same forecast event. However, this was not the case with the longer forecast horizons. Therefore, intertemporal heterogeneity was present with regard to how these individual respondents learnt. The respondents analysed here appear to have followed a process of adaptive learning only in the short term and seem to have been anchored to their own past inflation experiences in the longer term. It remains to be investigated whether longer-term expectations formation is nested within other or a combination of macroeconomic phenomena such as the inflation target, decision makers' own perceived inflation or other presumed economic experts' published forecasts.

In this study, several elements of the inflation expectations processes of decision makers were investigated. Heterogeneity was observed across different groups, their perceptions of the persistence of inflationary shocks, their information diffusion from a more financially literate group and the degree of their learning. A common observation found in all the areas considered was the difference in the short- and longer-term processes of agents' expectation formation processes, i.e. intertemporal heterogeneity.

Chapter 4

The term structure of inflation expectations

4.1 Introduction

It is widely accepted in the monetary policy literature that to maintain price stability over time, inflation expectations must be anchored (Bernanke, 2007; Trichet, 2009; Yellen, 2015; Kuroda, 2016). For inflation targeting central banks, this means that inflation expectations should ideally be anchored to the announced inflation target (Kuroda, 2016). The processes that govern the formation of inflation expectations typically differ between short- and longer-term expectation horizons. Longer-term inflation expectation-formation processes can also differ from short-term ones. This distinction is relevant for South Africa, as intertemporal heterogeneity exists in the South African survey data, as shown in the previous chapter. The focus of this chapter is on the longer-term expectations formation processes, since this is the operational horizon over which monetary policy can influence the economy.

Whether longer-term inflation expectations are anchored on a particular focal point is not a binary matter, but rather a question of degree. Many central banks target a particular inflation rate, but a tolerance band around this rate is permitted. According to Bernanke (2007), long-term inflation expectations vary over time and are not perfectly anchored, given changes in economic developments and the conduct of policy. The expectations should, however, be relatively insensitive to new data releases, i.e. variations in short-term information. The extent of this sensitivity causes differing degrees of inflation expectations anchoring. The degree to which South

African longer-term inflation expectations have been anchored was investigated further, using approaches that draw on the financial economics literature, and is covered in this chapter.

In practice, there is often some link between surprises driving changes in short-term expectations and those driving changes in longer-term inflation expectations. Castelnuovo et al. (2003) analysed inflation expectations for Japan and found that longer-term expectations are sensitive to short-term expectations. To the extent that longer-term expectations are influenced by variations in short-term expectations, the longer-term expectations are not anchored.

In the previous chapter, intertemporal heterogeneity is reported for South African survey respondents for both fixed-horizon and fixed-event expectations, in that variations in short-term expectations did not notably influence longer-term expectations, with the exception of the trade union officials group. It is also shown that longer-term inflation expectations were not systematically influenced by exchange rate changes or led by the financial analysts group (herd behaviour). This could imply that longer-term expectations are anchored. But further analysis is required to uncover at what growth rate or focal point.

Among the studies that have estimated the longer-term inflation expectations anchor for South Africa, Kabundi et al. (2015) found that the financial analysts' expectations are well anchored inside the target band. But they also found that the inflation expectations of the business representatives and trade union officials fell outside the upper end of the target level for their sample of 2000Q3 to 2013Q1, based on a reduced-form ordinary-least-squares estimation. Miyajima and Yetman (2018) also found that the financial analysts were anchored at the upper level of the target range and that the business representatives and trade union officials were anchored above the target range. According to Miyajima and Yetman (2018), wage demands presented during wage bargaining negotiations reflect the inflation anchors of trade unions, which subsequently influenced the business representatives' inflation outlook; hence the difference between them and the financial analysts group. Most of these studies were conducted on aggregated inflation expectations data, whereas in this study, and discussed in this chapter, the individual responses of the BER Survey were analysed to obtain a better representation of the respondents. According to Keane and Runkle (1990) and Mestre (2007), the aggregation of individual expectations may conceal systematic individual differences and thereby, to some extent, remove potential sources of information.

In view of the South African expectations-formation inefficiencies and the intertemporal heterogeneity observed (see the preceding chapter), as well as the multi-modal distributions shown in this chapter, a richer and more dynamic representation of these processes is required. Analyses extended to inflation expectations at the level of survey respondents that specifically separate the short- and longer-term data generating processes, will enhance an understanding of the processes underlying their choices.

Financial market yield curves and inflation expectations across different horizons share analogous properties; hence, the techniques applied to modelling yield curves could be used for estimating inflation expectation curves. One such approach is the term-structure modelling technique, which dynamically differentiates between short- and longer-term data generating processes. This technique is also able to determine whether longer-term expectations are anchored, and if so, at what focal point, without the estimation necessarily being adversely affected by multi-modal distributions when estimated with state-space techniques.

The estimation of the term structure of inflation expectations was based on the interpretation of Diebold and Li (2006) and Diebold et al. (2006) of the popular Nelson-Siegel (1987) approach. In this approach three latent factors were estimated to distil the longer-term level – interpreted as the longer-term inflation expectations focal point – the slope and the curvature from the survey data. The latter two factors provide an indication of the expected speed of convergence of inflation to its anchor. This provides useful information about the idiosyncrasies of South African inflation expectations formation and its role in the policy transmission mechanism.

Considering the idiosyncrasies identified in the previous sections of the study such as digit preference and intertemporal heterogeneity it is clear that inflation expectations should be regarded as a plural concept and not singular as is often the case in monetary models (Meeks and Monti, 2019). The presence of digit preference in South African survey data has also as far as could be determined, not been identified in the literature, not has the intertemporal heterogeneity. To estimate a longer-term perceived inflation expectations target in such an environment, an alternative approach is proposed. The resulting estimated perceived longer-term inflation expectations anchors using the proposed term structure approach are consistent with the estimates from Kabundi et al. (2015) who also find that these estimates are close to upper end of the inflation target range. There are a number of influences that can affect the longer-term inflation expectations anchor and these may be different for heterogeneous groups as shown by Du Plessis et al. (2018). Therefore the sources of heterogeneity is important to identify in South African survey data and will be analysed in this section so that an appropriate method can be followed to represent inflation expectations formation as a plural concept and not as a singular concept (Meeks and Monti, 2019).

4.2 Descriptive micro-level statistics of the BER Survey data

The individual responses of the BER Survey – rather than a summary statistic such as the mean, discussed in the preceding chapters – were analysed and are discussed in this section. The dataset was trimmed to include only those responses that contained observations for the current-year, one-year- and two-years-ahead horizons per survey round. Incomplete responses and outliers, here defined as observations less than 2 percent and larger than 15 percent, were excluded from the dataset, since these responses were regarded as *ad hoc* and unrealistic in light of South Africa's inflation experience over the sample period. For the purposes of this study, these outliers were treated as having been generated by different thought processes from the expectations in the realistic range.

The focus of this chapter is not only on determining the perceived longer-term anchor of the respondents, but also on attempting to capture their behaviour, as it changes across different expectation horizons. This was done by modelling the term structure of the BER inflation expectations. Though the BER Survey included only five-years-ahead expectations from the second quarter of 2011 onwards, they were incorporated into the dataset to enable a comparison with the properties of the two-years-ahead expectation horizon, which is available from 2000 onwards. Both the two-years-ahead and five-years-ahead horizons were treated as proxies for the perceived longer-term focal point of the inflation expectations in the BER Survey.

To give a general overview of the characteristics of the individual responses within the BER's three survey groups, descriptive statistics are shown in Table 4.1 and Figures 4.1, 4.2 and 4.3. The frequency distributions confirm the observed intertemporal and between-group heterogeneity discussed in the previous section. For the full sample from 2000q2 to 2017q4, the modal or most frequently reported expectation for the financial analysts was at 5 percent for the current-horizon expectation, 5.5 percent for the one-year- and two-years-ahead horizons and 6 percent for the five-years-ahead horizon. The business representative and trade union official groups both had a modal expectation of 6 percent, the upper end of the target band, across all the recorded horizons.

If the width of the distribution of inflation expectations is interpreted as a measure of uncertainty, the respondent groups appear less uncertain and more focussed as groups about their expectations as the expectation horizon extends. The distributions appear to be narrowing (smaller tails) and closer to the target range as the expectations horizon extends.

Table 4.1: Summary of descriptive statistics of BER Survey inflation expectations

BER group	Horizon	Obser-vations	Mean	Median	Mode	Std dev.
Financial analysts	Current year	1085	6.26	6.00	5.00	1.64
	One year ahead	1085	5.74	5.70	5.50	0.89
	Two years ahead	1085	5.47	5.50	5.50	0.75
	Five years ahead	344	5.53	5.60	6.00	0.58
Business representatives	Current year	22182	6.79	6.50	6.00	1.81
	One year ahead	22182	6.84	6.50	6.00	1.70
	Two years ahead	22182	6.85	6.50	6.00	1.79
	Five years ahead	6086	6.45	6.00	6.00	1.25
Trade union officials	Current year	909	6.58	6.20	6.00	1.80
	One year ahead	909	6.60	6.20	6.00	1.72
	Two years ahead	909	6.56	6.10	6.00	1.77
	Five years ahead	279	6.08	6.00	6.00	1.19

Note: sample 2000q2-2017q4

Another interesting observation seen in Figures 4.1, 4.2 and 4.3 is that the inflation expectations of the business representatives and trade union officials are concentrated at increments of 0.5 percentage points, a phenomenon known as digit preference. Even though the financial analysts do not show strong evidence of such behaviour over the current calendar year horizon, the distributions show evidence of digit preference over longer horizons. The concept of digit preference is discussed in more detail in a following section.

The mid-point of the target band of 4.5 percent does not appear to be a dominant choice among any of the groups or across any of the horizons. However, it may well be that these distributions and accompanying characteristics have changed over time, and therefore, subsamples are covered in the following section.

Figure 4.1: Histograms of inflation expectations by financial analysts of the BER survey: Full sample 2000q2-2017q4, calendar year horizons

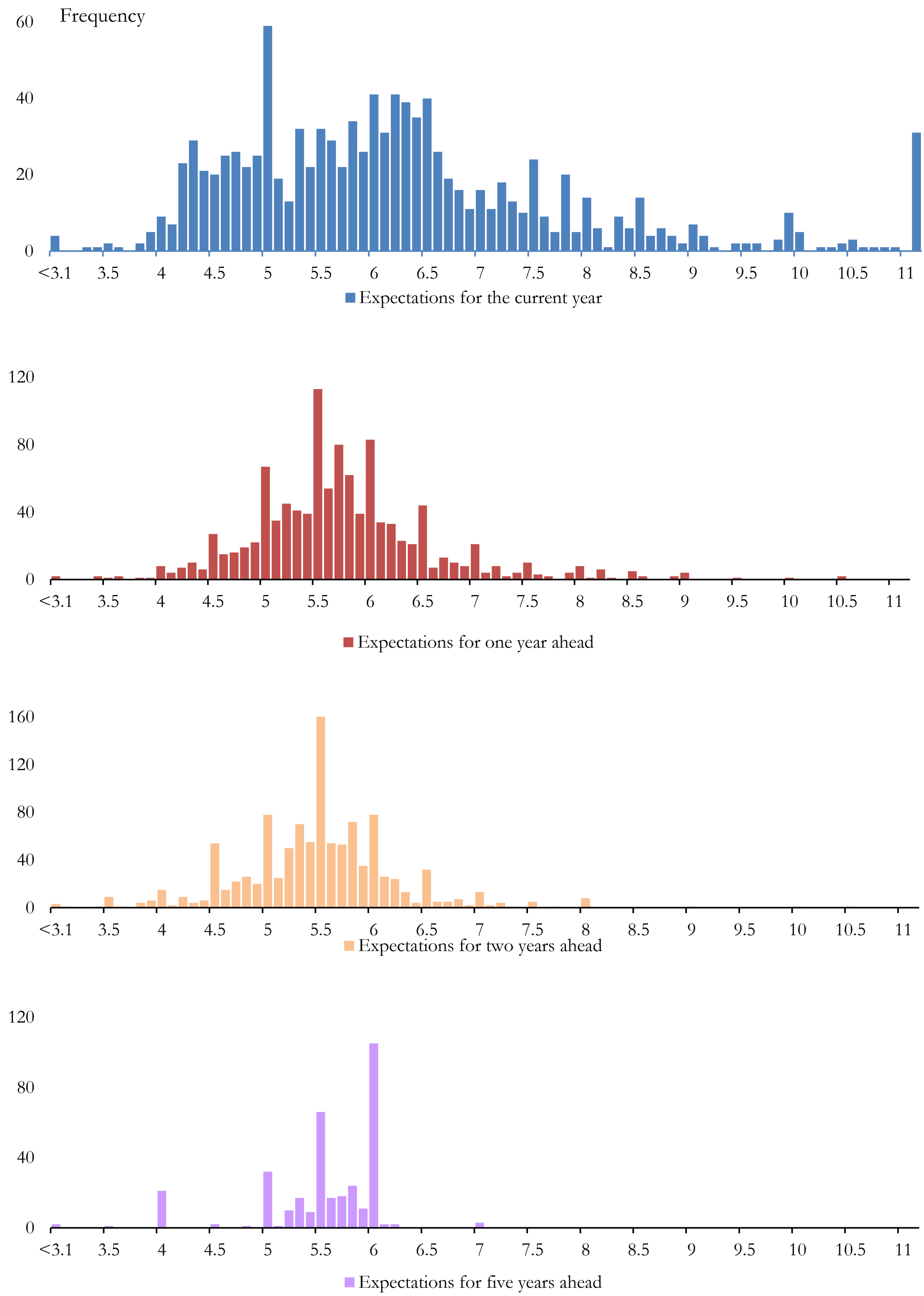


Figure 4.2: Histograms of inflation expectations by business representatives of the BER survey: Full sample 2000q2-2017q4, calendar year horizons

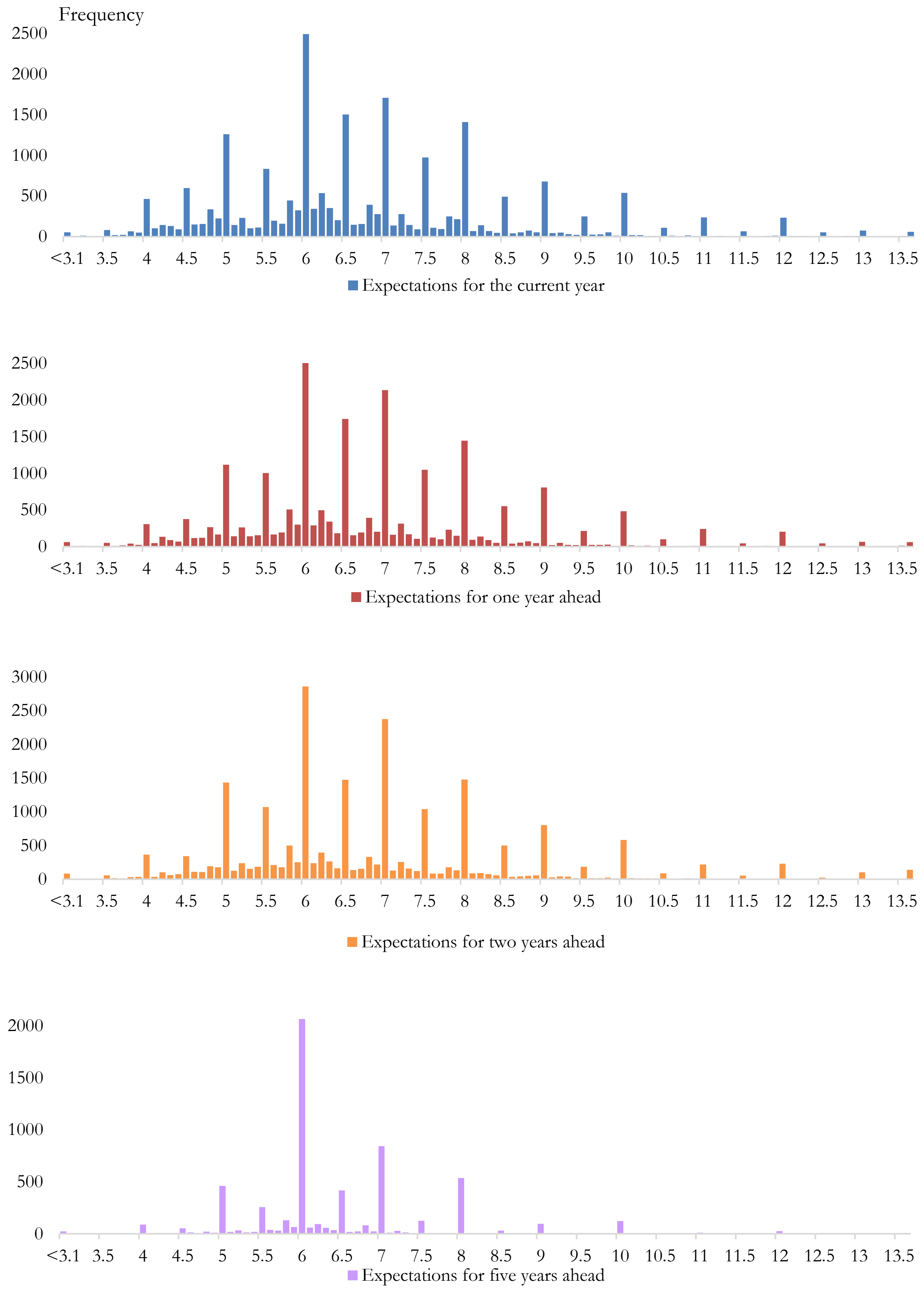
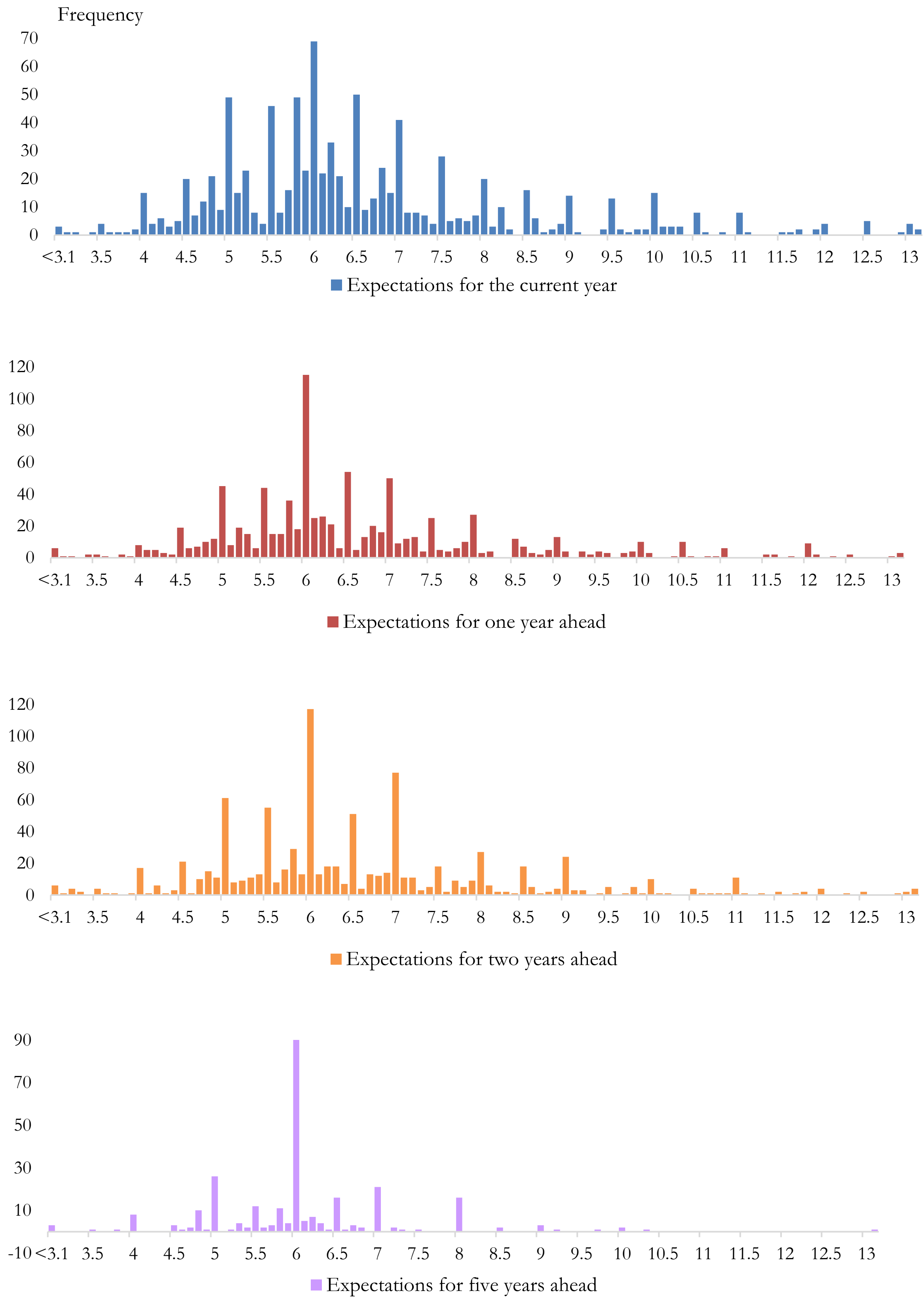


Figure 4.3: Histograms of inflation expectations by trade union officials of the BER survey: Full sample 2000q2-2017q4, calendar year horizons



4.2.1 Influence of the evolution of realised inflation rates on inflation expectations: subsample analyses

Behaviour and accompanying decision-making processes can change over time in response to a large number of possible factors, including enhanced knowledge, realisation of judgement errors and increased availability of relevant information. This section considers potential distributional changes in the BER inflation expectations survey data for three different samples as decision makers gained more familiarity and experience of the inflation targeting regime, which was introduced in South Africa during February 2000. Particular attention will be given to any changes in the modal choice and the digit preference behaviour identified in the previous section.

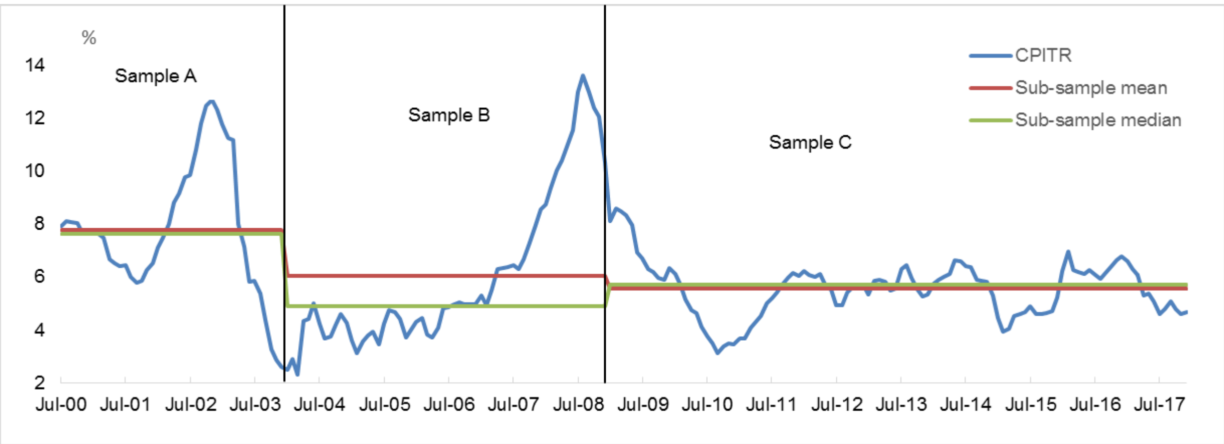
In the previous chapter, it is shown that decision makers paid attention to their inflation forecasting errors and, by implication, to observed actual inflation. Consequently, the evolution of observed inflation since the commencement of inflation targeting in 2000 was investigated. The full sample was divided into three subsamples, each with different characteristics. The first two sub-samples represent different cyclical phases in actual inflation, a downward and an upward phase and the third represents the inflation environment following the global financial crisis.

The first sub-sample represents the disinflation environment, from the introduction of the inflation targeting regime, i.e. from July 2000 to the end of 2003 (sample A). During this period, CPIT inflation averaged 7.8 percent, the median was 7.7 percent and the standard deviation was 2.5 percent. Inflation slowed from high single-digit numbers initially, to end 2003 at just above 2 percent.

The second period represents a gradual rise in CPIT inflation from January 2004 to March 2008 (sample B), where inflation rates initially remained within the target band, but exceeded the upper target band from April 2007. During this period, CPIT inflation was influenced by a combination of price shocks, including high global food inflation, high oil prices and strong domestic demand. This resulted in inflation of 6 percent on average, with a median of 4.9 percent and a standard deviation of 3 percent. While the average and median numbers are lower than in sample A, the direction of movement was from lower to higher inflation over sample B.

The last period ranges from July 2008 to December 2017 (sample C), to capture the environment from the global financial crisis to the end of 2017. During this period, CPIT inflation was 5.6 percent on average, median inflation was 5.7 percent and the standard deviation was 1.1 percent (Figure 4.4), the lowest of all three subsamples.

Figure 4.4 Targeted consumer inflation according to subsamples



The BER Survey data are published quarterly and record the annual CPIT inflation expectations for the current calendar year and the next two years by three different economic groups in the economy.[24] The individual short-term (current year) and longer-term (two-years-ahead) South African inflation expectations from the BER Survey data were also separated into these three periods. To compare the longer-term inflation expectations during the disinflation period (2000q2 to 2003q4), the acceleration period (2004q1 to 2008q4) and the period from the financial crisis and thereafter (2009q1 to 2017q4), the individual responses of all three groups in the BER Survey were analysed over the short term or current year and the longer-term, or two- and five-years-ahead expectation horizons (see Table 4.2).

[24] The nature of the questions posed in the BER Survey entails respondents being surveyed on their inflation expectations for a particular calendar year. Therefore, the BER Survey expectations reflect a fixed-event expectation, unlike the fixed-horizon reflected in the RIE Survey. This implies that as the year progresses, additional observed inflation information becomes available which could impact on the expectation formation process of the BER respondents for the current calendar year's inflation expectation.

Table 4.2: BER inflation expectations sub-sample diagnostics for short- and longer-term horizons

	Horizon	Obser-vations	Mean	Median	Std dev.
Disinflation (2000q2-2003q4)	**Financial analysts:**				
	Current year	249	7.55	7.50	1.07
	Two years ahead	249	5.71	5.60	0.94
	*Equality test prob***		*0.00*	*0.00*	*0.04*
	Business representatives:				
	Current year	5895	8.11	8.00	1.43
	Two years ahead	5895	7.78	7.50	1.86
	*Equality test prob***		*0.00*	*0.00*	*0.00*
	Trade Union officials:				
	Current year	176	7.96	7.70	1.47
	Two years ahead	176	7.69	7.50	2.00
	*Equality test prob***		*0.16*	*0.02*	*0.00*
Accelerating inflation (2004q1-2008q4)	**Financial analysts:**				
	Current year	312	6.12	5.30	2.35
	Two years ahead	312	5.18	5.20	0.72
	*Equality test prob***		*0.00*	*0.05*	*0.00*
	Business representatives:				
	Current year	6558	6.03	5.50	1.89
	Two years ahead	6558	6.18	6.00	1.64
	*Equality test prob***		*0.00*	*0.00*	*0.00*
	Trade Union officials:				
	Current year	331	6.15	5.50	2.05
	Two years ahead	331	6.06	5.90	1.67
	*Equality test prob***		*0.52*	*0.44*	*0.00*
Financial crisis and beyond (2009q1-2017q4)	**Financial analysts:**				
	Current year	524	5.73	5.80	0.82
	Two years ahead	524	5.54	5.50	0.58
	*Equality test prob***		*0.00*	*0.00*	*0.00*
	Five years ahead*	344	5.53	5.60	0.58
	*Equality test prob***		*0.00*	*0.00*	*0.00*
	Business representatives:				
	Current year	9729	6.50	6.10	1.51
	Two years ahead	9729	6.74	6.50	1.59
	*Equality test prob***		*0.00*	*0.00*	*0.00*
	Five years ahead*	6086	6.45	6.00	1.25
	*Equality test prob***		*0.02*	*0.04*	*0.00*
	Trade Union officials:				
	Current year	402	6.33	6.00	1.37

	Two years ahead	402	6.48	6.00	1.50
	*Equality test prob***		*0.14*	*0.04*	*0.06*
	Five years ahead*	279	6.08	6.00	1.19
	*Equality test prob***		*0.01*	*0.12*	*0.01*

* The five-years-ahead observations start only from 2011q2.

** The equality test probability shows the probability of accepting the null hypothesis of equal mean, median or standard deviation. It compares the short-term (current-year's expectation) statistic with its longer-term (two-years- or five-years-ahead expectation) counterpart. The mean equality test was the Welch-test result, the median equality test was the Wilcoxon/Mann-Whitney test and the standard deviation equality test was the Bartlett test.

Following the introduction of inflation targeting and the achievement of disinflation to rates within the announced target range, the longer-term means and medians for all three groups were lower from the first sub-period to the second. But they were higher in the last sub-period, albeit still lower than the first sub-period (see Table 4.2). The standard deviations of the longer-term survey data for all three groups shown in Table 4.2 were successively lower from the first sub-period to the last. This evidence suggests less uncertainty about the longer-term outlook for inflation from the first sub-period to the following two sub-periods.

During the first sub-period, the financial analysts and business representatives groups had lower average longer-term inflation expectations than they did for their short-term expectations (only the financial analysts' longer-term expectations were below the upper end of the inflation target band of 6%). The average longer-term expectation for the trade union officials was also lower than its short-term expectation counterpart, but this difference was not statistically significant based on the reported equality test. This statistically significant (see Table 4.2 for the rejection of equal means by the equality tests) slowdown, from the short-term average expectation to that of the longer-term, points to a downward slope in the inflation expectations term structure for the first sub-sample. The financial analysts were less uncertain about the longer-term outlook for inflation than they were for the short-term, based on the evidence from the standard deviations reported in Table 4.2. This is in contrast with the expectations for the business representatives and trade union officials, who appear to have been more uncertain with their longer-term inflation expectations outlook for the first sub-sample period.

During the accelerating inflation period, where consumer inflation initially fell within the target range but rose thereafter, inflation expectations recorded by the BER Survey were lower compared with those for the disinflation period, especially over the short-term horizons. The width of the distributions also appears narrower compared with those of the disinflation period (note the narrower distributions in Figures 4.5 to 4.10). This behaviour is consistent with the experience of inflation targeting, which guides inflation expectations closer to the inflation target range.

Even though the uncertainty based on the standard deviations of the groups' longer-term inflation expectations was lower than for the first sub-period, the business representatives and trade union officials groups were almost twice as uncertain as the financial analysts group, a similar result as for the first sub-period. The only instance where the financial analysts groups appear to have been more uncertain than the other two surveyed groups was the current-year horizon for the accelerating inflation sub-sample. The unexpected shocks to consumer inflation, explained previously, during this sub-sample appear to have affected the financial analysts' short-term inflation outlook more than those of the other two groups. This is also observed by the large number of outliers in Figure 4.5, in the second panel. This short-term shock behaviour is an observation also shown in the preceding chapter, where the financial analysts tended to have reacted more to shorter-term shocks than did the other two groups.

In the second sub-sample, the lower longer-term means, when compared with the short-term means, is consistent with a downward slope in the term structure of the financial analysts' inflation expectations, confirmed by the equality test in Table 4.2. The results for the business analysts indicate a slight downward sloping term structure, and the trade union officials' term structure appears flat, based on the non-rejection of the null hypothesis of mean equality.

It is not clear whether it was the aftermath of the global financial crisis or the uncertainty of respondents about how the South African Reserve Bank (SARB) would act that caused the longer-term means and medians of the third sub-period to rise for all three groups, albeit still lower than for the disinflation period. The change in inflation expectations is evident in the increase of the two-years-ahead or longer-term expectation means, which ranged from 5.2, 6.2 and 6.1 percent in the accelerating inflation period to an average range from 5.5, 6.7 and 6.5 percent in the period beyond the financial crisis, yet it was still lower than those recorded in the disinflation period. Furthermore, only the financial analysts reported with more certainty (lower standard deviation) than before that inflation would remain within the target range.

The degree of uncertainty for the business representatives and the trade union officials was higher since the global financial crisis compared with that for the disinflation period, as measured by the reported standard deviations. In this sub-sample, the financial analysts again showed a downward-sloping term structure of mean inflation expectations as the horizon of expectations stretches. The results for the business representatives showed an upward-sloping term structure for the two-years-ahead mean inflation expectation, but a slightly downward-sloping term structure for the five-years-ahead horizon (see Table 4.2 for the equality tests, which show the statistical significance of these comparisons).

The trade union officials' means show a statistically significant downward-sloping term structure from the short-term to the five-years-ahead horizon, but the equality tests show no statistically significant difference between the current-year and the two-years-ahead horizons, indicating a flat term structure of inflation expectations.

Interestingly, the business representatives appear to have been the most pessimistic about longer-term inflation and had the highest average longer-term inflation expectation of the three groups for all three sub-periods. The most optimistic group about longer-term inflation expectations was the financial analysts (see Table 4.2). Also, the financial analysts group expected longer-term inflation to be mainly inside the inflation target range, while the other two groups did not. The business representatives and trade union officials groups were also much more uncertain about the longer-term inflation outlook than the financial analysts for the two-years-ahead horizon. [25]

It was observed that the average and modal intervals for all the groups considered declined from the disinflation period to the accelerating inflation period (see Figures 4.5 to 4.10). However, these increased following the global financial crisis, to be close to the upper level of the inflation targeting range. The results are consistent with a hypothesis that the respondents realised that the central bank will not necessarily act when inflation rises within the target band to the upper end. Rather, the central bank is more likely to act when inflation breaches the upper or lower target levels. Over time, it may be that the respondents have learnt that the monetary authority would only act or raise concern if inflation had breached the (mainly upper) target band (hard edge) and consequently anchored their inflation expectations to the upper end of the target band, instead of to the midpoint.

According to Andolfatto et al. (2002), such perceived policy flexibility induced by the wide inflation target band in South Africa can undermine efforts to anchor longer-term inflation expectations, and this may have complicated decision makers' expectations about the monetary policy stance. South Africa's inflation target band is among the highest for inflation targeting countries (see Du Plessis and Reid, 2015) and the commensurate higher nominal interest rate

[25] Uncertainty was proxied by the standard deviation metric.

increases the scope for carry trade. This can add to exchange rate volatility (see Hassan, 2016) and thereby distort attempts to stabilise inflation and inflation expectations at an appropriate rate. Lower exchange rate pass through since 2009, has however muted its impact on actual inflation, complimented by enhanced communication from the central bank about inflation and the inflation target, also played a role to dampen the impact of such surprises on actual inflation (Kabundi and Mlachila, 2019).

Research on inflation targeting countries, which include South Africa, shows that there is a positive correlation between the upper level of the inflation targeting band and exchange rate volatility over the long run (see Du Plessis and Reid, 2015). This finding is supported by Amod and Hassan (2014), who show that South African exchange rate volatility has increased post the implementation of inflation targeting, which also coincided with the adoption of a flexible exchange rate regime. Such volatility can increase uncertainty in the price- and expectations-formation behaviour of decision makers.

Figure 4.5: Histograms of BER financial analysts current-year inflation expectations, sub-samples

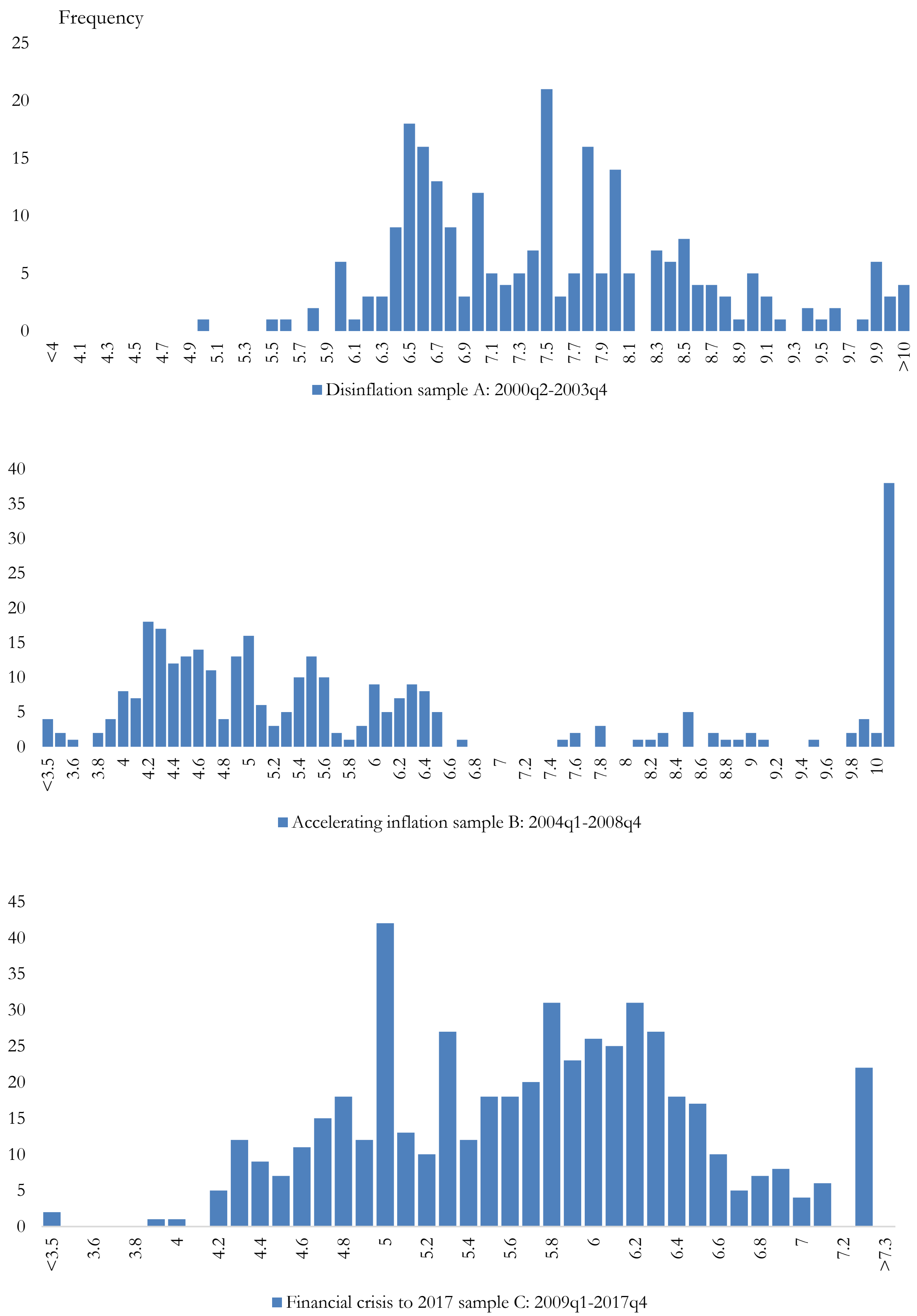


Figure 4.6: Histograms of BER financial analysts two-years-ahead inflation expectations, sub-samples

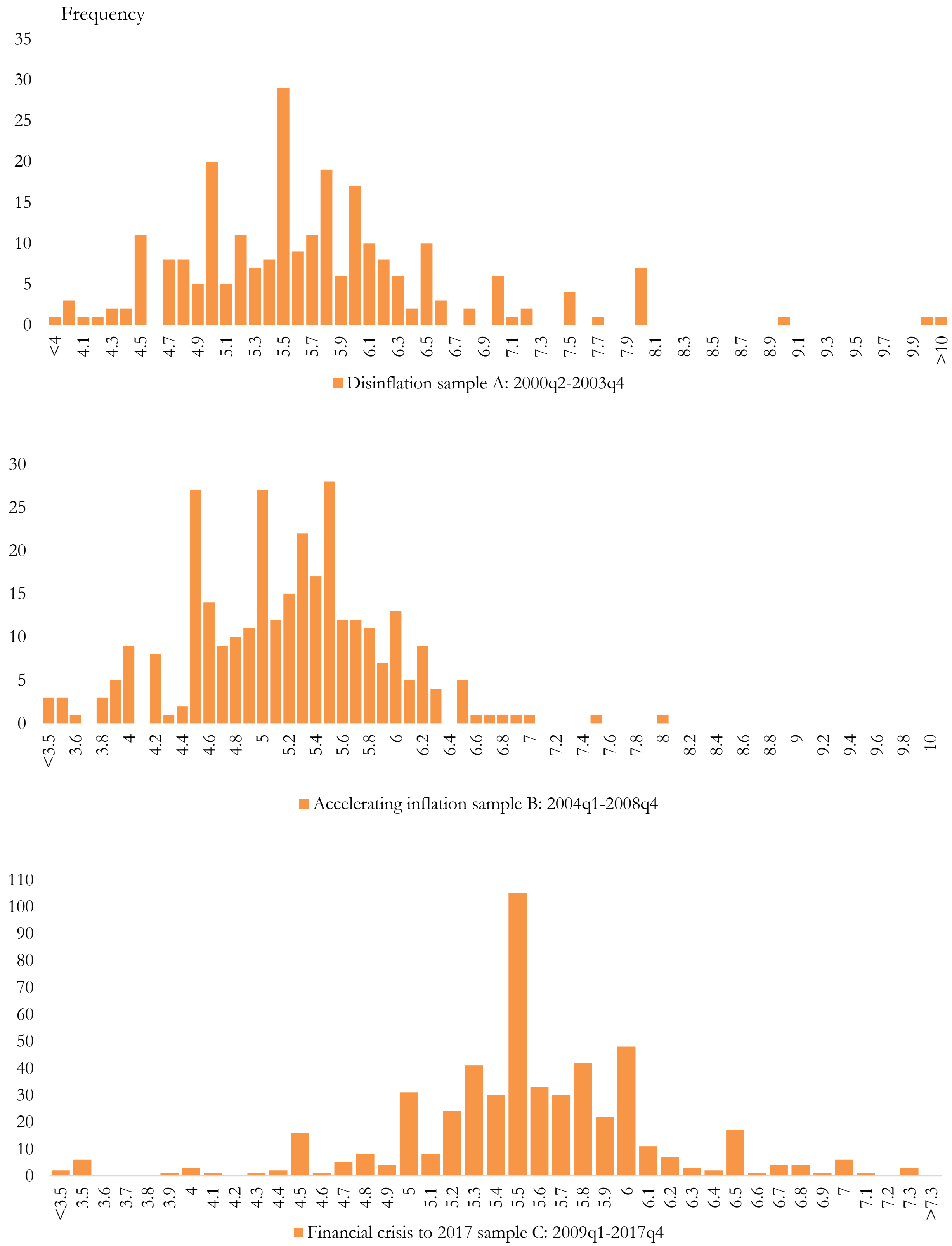


Figure 4.7: Histograms of BER business representatives current-year inflation expectations, sub-samples

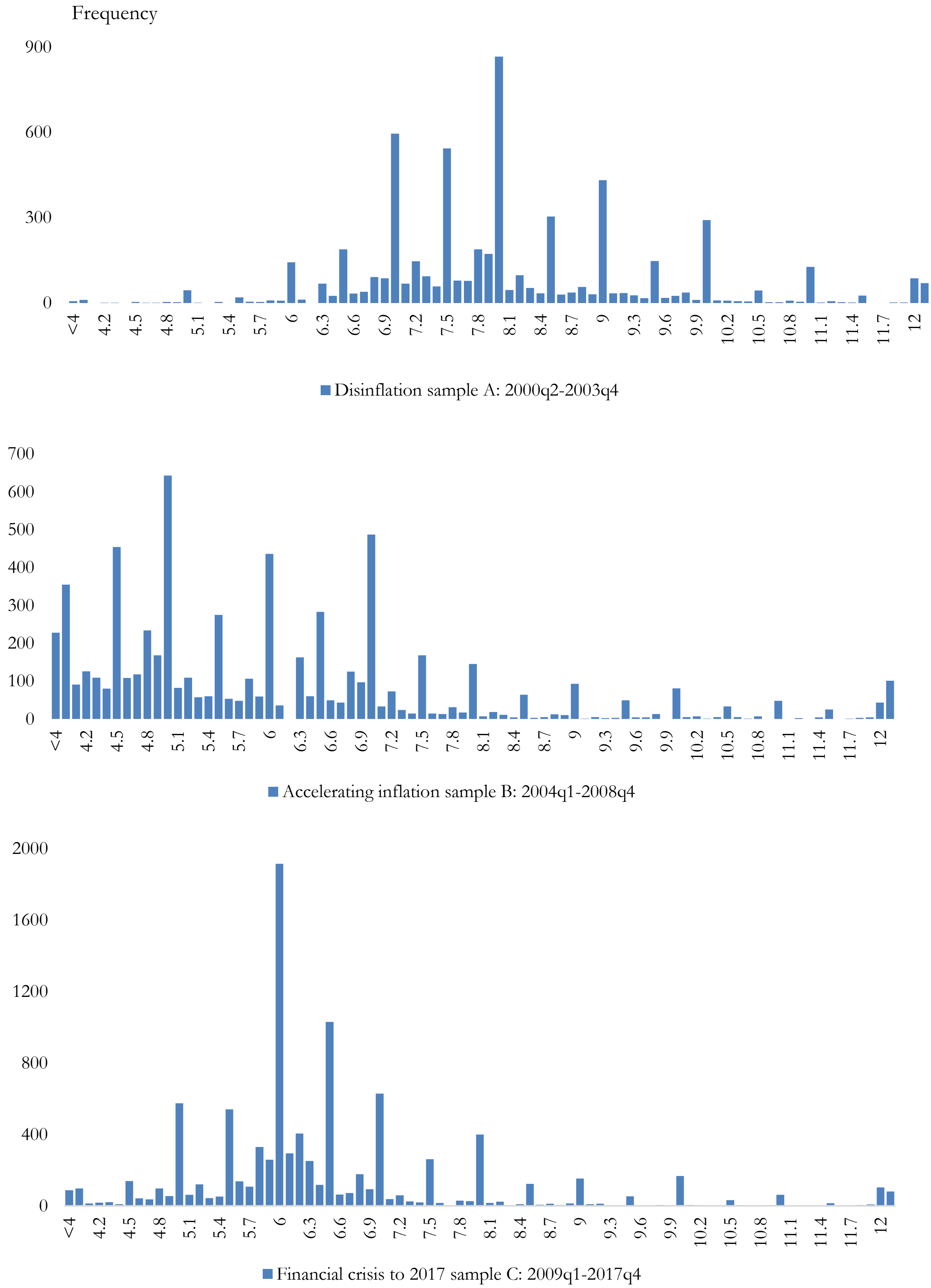


Figure 4.8: Histograms of BER business representatives two-years inflation expectations, sub-samples

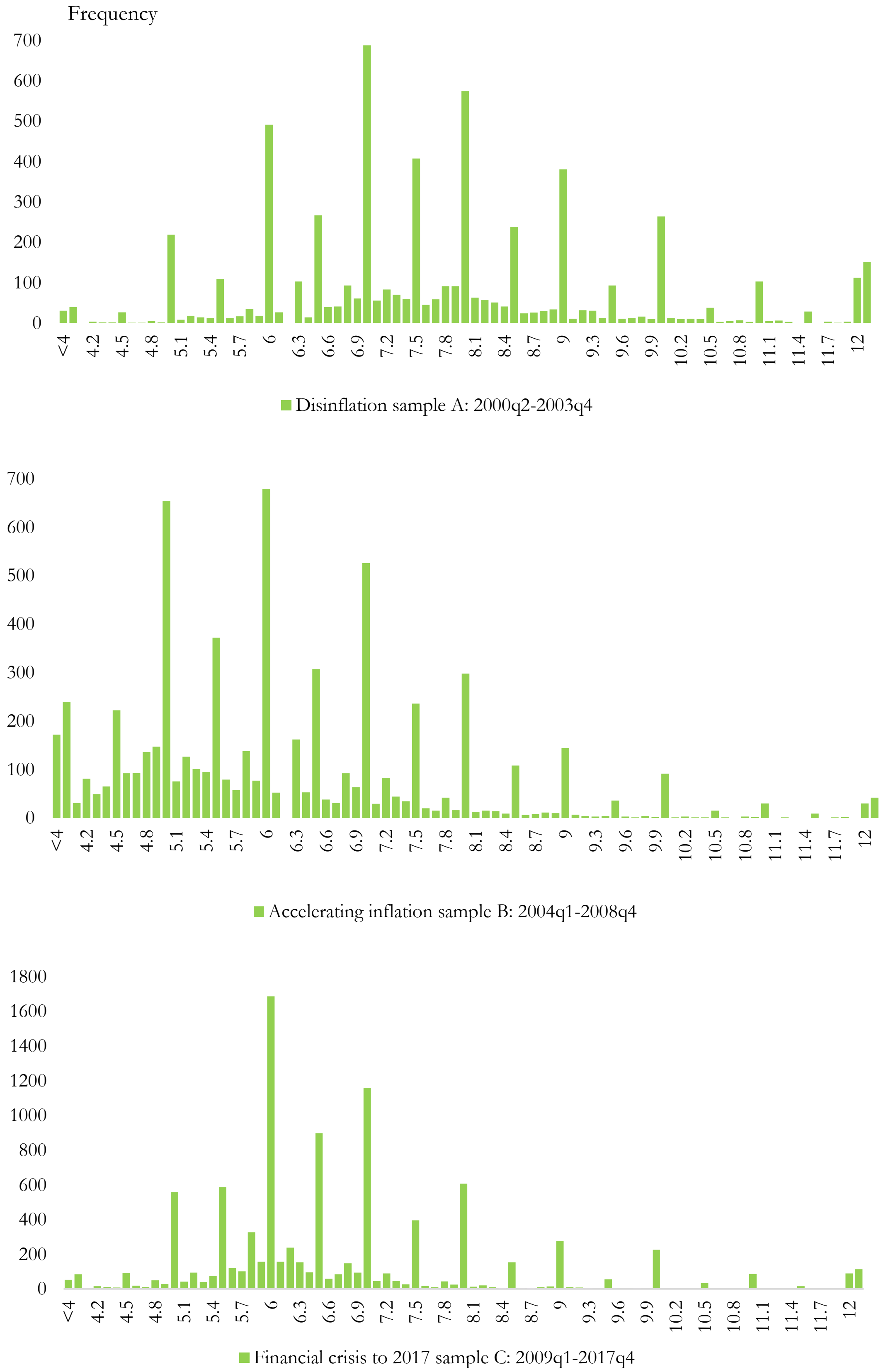


Figure 4.9: Histograms of BER trade union officials current-year inflation expectations, sub-samples

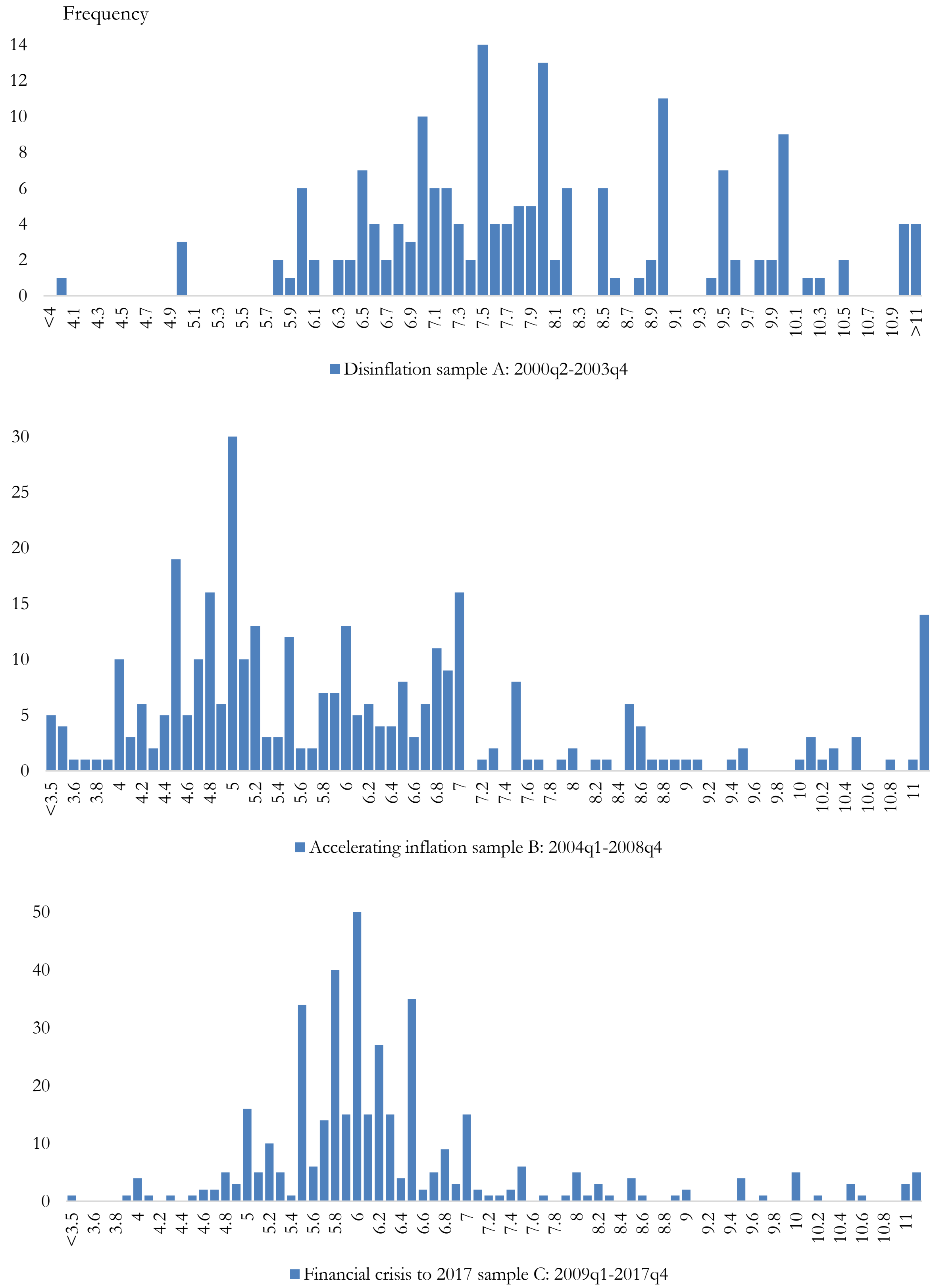
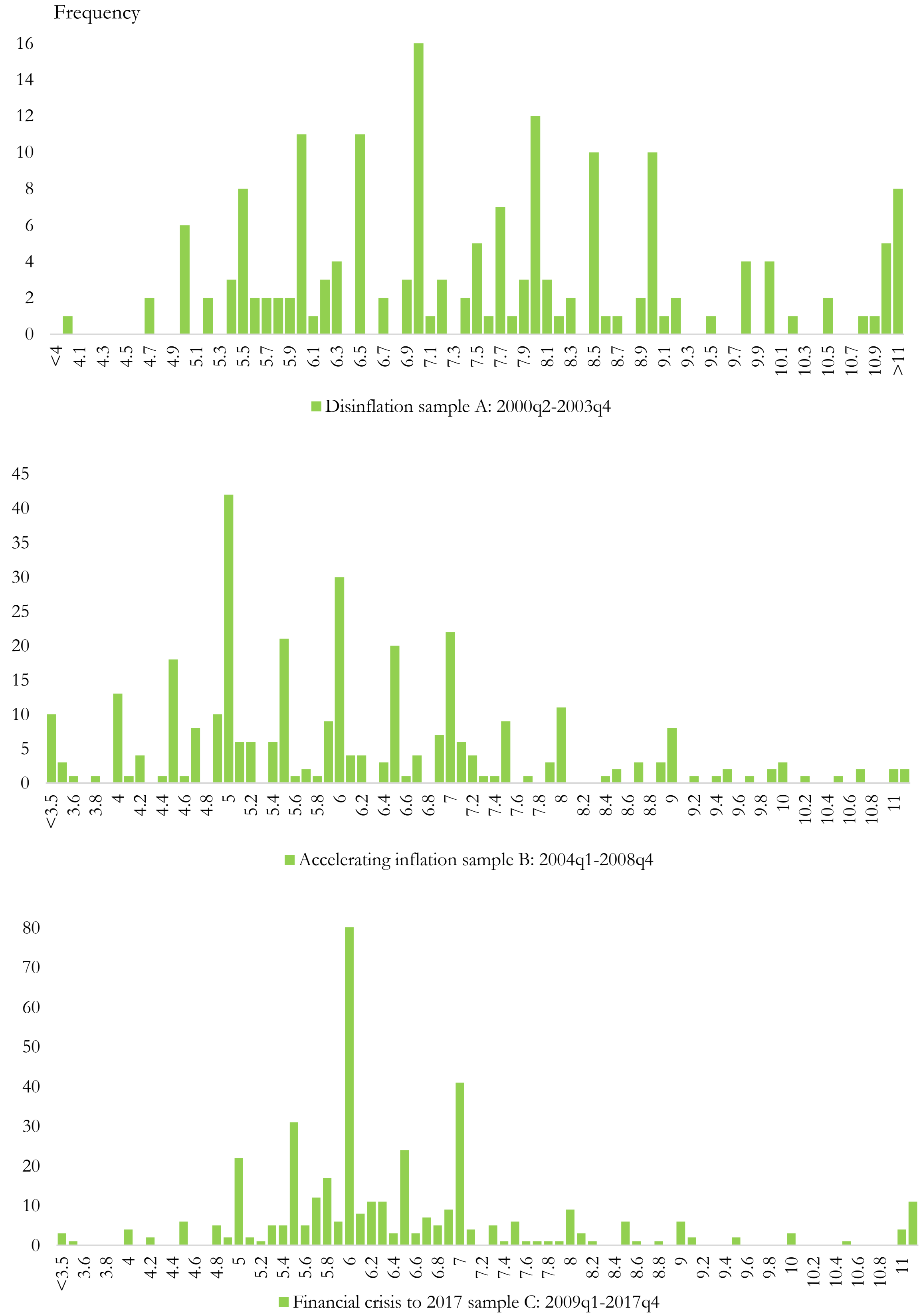


Figure 4.10: Histograms of BER trade union officials two-years-ahead average inflation expectations



4.3 Digit preference

The multiple peaks in the density functions of the individual survey responses shown in the previous section have important implications for the choices of analytic approaches and techniques to be used for inference. This phenomenon is often observed in open-ended numeric questionnaires and is not limited only to the field of economics (Baker, 1992; Edouard and Senthilselvan, 1997). The tendency of respondents to provide rounded responses or favour certain digits by restricting their choices to integers or half percentages is called *digit preference* (Fry and Harris, 2002; Curtin, 2006; Pfajfar and Santoro, 2010; Dräger and Lamla, 2014; Pfajfar and Zakelj, 2015). Digit preference is observed as multiple peaks in the histogram of survey responses (Fry and Harris, 2002) and is recognised in survey data when a multi-modal distribution is observed. This is consistent with the theories of heterogeneous expectations formation (Fry and Harris, 2002; Branch, 2007).

However, in the context of inflation expectation surveys, Curtin (2006) explains that the appearance of the same responses should not necessarily be interpreted as indicating that respondents were unresponsive to changes in the inflation environment or the policies pursued (see also Bryan and Palmqvist, 2005). Consequently, he cautions against potential misinterpretations.

Digit preference, or rounding behaviour, may be ascribed to uncertainty (Branch, 2007) or may relate to the cost of providing or forecasting more accurately. According to Pfajfar and Zakelj (2015), inattentiveness may be a source of rounding behaviour, particularly when inflation is low and stable and therefore forecast accuracy is considered less important.

In Figures 4.5 to 4.10, evidence of digit preference is observed where the more frequently reported inflation forecasts from the individual respondents are separated by 0.5 percentage points from each other. These multi-modal distributions do change over the three periods under consideration, which is similar to the inflation expectations data reported by Branch (2007) for the United States. Curtin (2006) considers this rounding behaviour as survey measurement errors, which result in less precise responses. Such observed survey responses may be considered to be discrete choices, rather than choices from a continuous set of numbers.

The existence of digit preference or rounded digits in survey responses may cause the median to be stable over relatively long periods, punctuated by discrete jumps to new rounded numbers. This characteristic is noticeable in Table 4.1, in the following section, where the median appears stable over some expectation horizons, lowering its information value, and hence the means are likely to yield more information for analysis (Biau et al., 2010).

The shape of the observed density functions and multiple modal points is not static between sub-samples, as respondents adapted or learnt more about their economic environment in general and also about the inflation targeting regime. The multiple focal points in the density functions provide evidence consistent with heterogeneity and concur with the evidence in the previous chapter. When heterogeneity and digit preference are present in the data, traditional methods of estimating a singular perceived inflation anchor can be misleading, which is exacerbated by the presence of multiple and time-varying focal points. Alternative approaches that can be used in such circumstances to estimate inflation expectations anchors are discussed in the following section.

4.4 Inflation expectations curves estimated within term-structure frameworks

Multiple focal points and associated heterogeneity in survey data can complicate traditional estimation approaches, since conventional regression analyses aggregate information from the distribution to provide singular parameter estimates. To determine whether longer-term inflation expectations are anchored, and if so, at what level, alternative estimation approaches are required. Useful alternative approaches include time-varying approaches or term-structure estimations, which can generate a term-structure curve that matches both the time-series and cross-section variations of inflation expectations.

4.4.1 Similarities between yield curves and inflation expectations term structures

Inflation expectations survey data and financial market data such as bond yields data share similarities, where both have time-series (observed at certain points in time) and cross-sectional (variation across maturities or expectation horizons) dimensions that can be explored. One of the main similarities is that both can be viewed in terms of a maturity or an expectation trajectory, which can be decomposed analytically. Other similarities that are shared by yield-curve and inflation expectations term-structure properties include the smoothness of, and persistence in the curve (Diebold and Li, 2006; Aruoba, 2016). Average yield curves are normally upward sloping, concave and assume a variety of shapes over time. Longer-term rates (end of the yield curve) are less volatile and more persistent than short-term rates (start of the yield curve).

Average inflation expectation curves are not necessarily linear: they can be concave or convex. Longer-term inflation expectations are less volatile and more persistent than short-term expectations (Miyajima and Yetman, 2018). Different dynamics exist in the short-term compared with the long-term, which can generate the intertemporal heterogeneity shown in the previous chapter. Correlations between short- and longer-term horizons exist, though not to the same extent. Due to these similarities, some of the techniques such as yield curve modelling techniques developed for bond market data can be extended to analyse inflation expectations data.

From a modelling point of view, these parallels endorse the use of term-structure analyses for inflation expectations data. Other central banks such as the Reserve Bank of New Zealand, the Federal Reserve Bank of Philadelphia and the Bank of Japan have recently applied this technique to inflation expectations survey data (Lewis and McDermott, 2016; Lewis, 2016; Aruoba, 2016; Maruyama and Suganuma, 2019) to analyse these factors and to estimate the longer-term perceived inflation target and the time it takes to reach the target. Such a term structure can be generated for any point in time.

This section reports the individual responses comprising the BER Survey inflation expectations data, which were captured in such a way to obtain a term structure of inflation expectations per individual and per survey release. Specifically, for each survey publication round, the current-year, one-year-ahead, two-years-ahead, and later on, also the five-years-ahead expectations form an expectations curve. This is submitted by individual respondents and is conditional on the data available at that point. For each BER Survey group, these constructed trajectories of inflation expectations were used to estimate the three latent factors of the Nelson and Siegel (1987) term-structure approach which, in turn, can be used to approximate inflation expectations curves. Of particular interest is the estimation of the longer-term level to analyse the rate at which surveyed inflation expectations are anchored, or the perceived longer-term target rate of respondents who have been shown to be heterogeneous.

4.4.2 Factor analyses: principal components

The popular Nelson and Siegel (1987) (NS) yield-curve estimation approach mathematically distils three informative concepts from yield curve observations, namely the longer-term level (L_t), the slope (S_t) and the curvature (C_t), phrased as the three latent factors of the bond yield curve. The role of the three factors underlies one of the most flexible and parsimonious yield-curve modelling frameworks (Litterman and Scheinkman, 1991; Rummel, 2013). These curves were estimated using information from survey data, although macroeconomic information can also be included (Diebold et al., 2006).[26]

In the literature the NS specification has been extended to four- and five-factor models (Björk and Christensen, 1999), with insignificant improvement in the fit of the model. Another approximation of a four-factor model is provided by Svensson (1994), where the fourth term provides additional information about the curvature factor. Even more complex functional forms of the NS specification did not provide significant improvements (Dahlquist and Svensson, 1996).

4.4.2.1 Principal component analyses

To formulate a specification for a term structure, the number of factors that can sufficiently explain the variation of the variable, needs to be determined (Bai and Ng, 2008). For yield curve data, Litterman and Scheinkman (1991) and Steeley (1991) find that three factors can explain almost all of the variation in the zero-coupon yield-curve for the United States and the United Kingdom respectively. There is a quest for a rich, yet parsimonious representation by the number of factors in the term structure, yet there is a risk of over-parameterising the specification.

Factor analyses can be used to determine the number of factors that can parsimoniously summarise the changes in the underlying determinants of the inflation expectations term structure (Bliss, 1997). This is done by condensing the information from observed variables to a smaller number of unobserved variables (or factors), by utilising the covariance structures between these.

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[26] Some authors then generate a term structure of real interest rates from the difference between the nominal yield for a particular horizon and its representative estimated inflation expectation, where an inflation risk premium will remain within the real interest rates estimates.

Principal component analyses provide an indication of the number of unobserved factors that can be used to describe most of the data variability.

According to the principal component eigenvalue results in Table 4.3, single-factor models are insufficient to explain the variation in the inflation expectations data for all three groups. For the financial analysts, three factors explain 93 percent of the variation in their inflation expectations data, with one factor explaining 53 percent of it. The expectations of the business representatives and the trade union officials appear to be dominated by one factor, which explains 77 percent and 74 percent of the variation in the data. The combination of two factors explains 93 percent and 95 percent of the variation, and that of three factors, 99 percent and 98 percent.

According to the principal components results, the combination of two factors may be sufficient to explain 93 percent and 95 percent of the variation in the inflation expectations data for the business representatives and the trade union officials, but only 78 percent for the financial analysts groups. The combination of three factors appear to sufficiently represent most of the variation for the term structures of the three groups and therefore the specification of the terms structures for the three groups will use three factors and is discussed in detail in the following section. The principal components analyses are only used to inform on the number of factors that should be used in the following term structure specifications.

Table 4.3: Principal components of BER inflation expectations survey data: eigenvalues

Number	Eigenvalue	Proportion of variance explained	Cumulative proportion of variance explained
Financial analysts			
1	2.13	0.53	0.53
2	1.00	0.25	0.78
3	0.60	0.15	0.93
4	0.27	0.07	1
Business representatives			
1	3.09	0.77	0.77
2	0.65	0.16	0.93
3	0.22	0.05	0.99
4	0.05	0.01	1
Trade union officials			
1	2.94	0.74	0.74
2	0.84	0.21	0.95
3	0.15	0.04	0.98
4	0.07	0.02	1

The elements of the eigenvectors measure the influence of the factor over a particular inflation expectation horizon. Each principal component is a linear combination of the eigenvectors in Table 4.3, with the associated same horizon individual inflation expectations for each BER Survey group.

Table 4.4: Principal components of BER inflation expectations survey data: eigenvectors

	Principal component 1	**Principal component 2**	**Principal component 3**	**Principal component 4**
Financial analysts				
Current year	0.41	0.68	0.58	-0.17
One year ahead	0.55	0.30	-0.60	0.49
Two years ahead	0.56	-0.32	-0.24	-0.73
Five years ahead	0.47	-0.58	0.49	0.45
Business representatives				
Current year	0.49	-0.51	0.58	0.40
One year ahead	0.55	-0.21	-0.10	-0.80
Two years ahead	0.53	0.04	-0.72	0.45
Five years ahead	0.41	0.83	0.37	0.02
Trade union officials				
Current year	0.50	-0.49	0.62	0.35
One year ahead	0.56	-0.17	-0.13	-0.80
Two years ahead	0.56	0.07	-0.67	0.49
Five years ahead	0.36	0.85	0.39	0.01

The relatively constant elements of Principle component 1 in Table 4.4 suggest that each expectation horizon affected the principal component with a similar positive magnitude; hence a level effect was relevant to explain variations in the data and could be associated with a constant term. This observation held for all three BER Survey groups. The first two shorter-term elements or weights with which individual expectations loaded onto the second principal component had opposite signs to the longer-term elements of the component, which was consistent with the notion that a slope factor was relevant to explain variations in the inflation expectations.

There are many different approaches in the literature for estimating the factors of the NS curve, and in the study discussed here. The one methodology is non-parametric and use statistical or accounting formulas to calculate approximations for the three factors. The other two methodologies are parametric and based on estimated equations and a third based on a state-space Kalman filter approach.

4.4.3 Nelson-Siegel term-structure estimation using the Diebold and Li (2006) approach

There are several reasons why the NS (1987) curve is a popular term-structure approximation (De Pooter, 2007; Coroneo et al., 2011) such as parsimony, a small set of parameters to be estimated, and that it can be used interpolate missing observations in a dataset. It also tends to represent yields data well (De Pooter, 2007; Coroneo et al., 2011) and performs well in forecasting exercises, as shown by Diebold and Li (2006), who demonstrate that this approach produces more accurate one-year-ahead forecasts than other standard benchmark models. Aruoba (2016) lists the flexibility of the curve in fitting many possible shapes smoothly as an additional motivation for its use. From only four numbers, a term structure can be estimated for any horizon at any time. Often the Nelson-Siegel model needs an arbitrage-free adjustment when applied to bond data; however, this is not required when applied to inflation expectations survey data, since these relate directly to expectations, and no adjustment for the market price of risk is required (Lewis, 2016).

According to the NS framework, the forward rate curve for bond yields (Equation 4.1) consists of three factors and three-factor loadings. The three factor loadings provide a clear intuitive interpretation where it fits a curve at any given date with approximating functions that consist of a longer-term level, a polynomial and an exponential decay term.

$$f_t(\tau) = \beta_1(1) + \beta_2 \exp\left(-\frac{\tau}{\lambda}\right) + \beta_3\left(\frac{\tau}{\lambda}\right)\exp\left(-\frac{\tau}{\lambda}\right) \tag{4.1}$$

Where β_1, β_2, β_3 and λ are estimable parameters. The parameter λ is the exponential decay rate and determines the maturity at which the loading on β_3, the curvature component, reaches its maximum and τ represents the time to maturity. The factor loading $\exp\left(-\frac{\tau}{\lambda}\right)$ is an exponential decay function, reflecting a downward slope when $\beta_2 < 0$ and an upward slope when $\beta_2 > 0$. The factor loading $\left(\frac{\tau}{\lambda}\right)\exp\left(-\frac{\tau}{\lambda}\right)$ is a Laguerre function that generates the curvature.

The spot yield rate function is the average of the forward rate curve up to time to maturity:

$$y_t(\tau) = \beta_1 + (\beta_2 + \beta_3)\ \left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) - \beta_3 e^{-\lambda\tau} \tag{4.2}$$

Or

$$y_t(\tau) \; = \; \beta_1 + \beta_2 \left(\frac{1-e^{-\lambda\, \tau}}{\lambda\, \tau}\right) + \beta_3 \left(\frac{1-e^{-\lambda\, \tau}}{\lambda\, \tau} - \; e^{\lambda \tau}\right) \tag{4.3}$$

Where $y_t(\tau)$ is the continuously-compounded zero-coupon nominal yield at time t of a bond with residual maturity τ . β_1, β_2, β_3 and λ are estimable parameters with loadings.

The factor loading for β_1 is a constant (value of one) that represents the long-term level, the factor loading for β_2 is an exponential decay function $\left(\frac{1-e^{-\lambda\, \tau}}{\lambda\, \tau}\right)$ reflecting a downward ($\beta_2 > 0$) or upward slope ($\beta_2 < 0$) and the factor loading for β_3 is a Laguerre function $\left(\frac{1-e^{-\lambda\, \tau}}{\lambda\, \tau} - \; e^{\lambda \tau}\right)$, which generates the curvature. The factor loading on β_2, or slope, is viewed as a short-term factor, since it starts at 1 and decays to 0, influenced by the chosen value for lambda. When the yield curve slope is defined as long-term yields minus short-term yields, it is considered to be equal to -β_2 (see Frankel and Lown, 1994 and Diebold and Li, 2006).

The factor loading on β_3 or the curvature, starts at 0 reaches an optimal point (determined by the choice of lambda) and decays back to 0 as it progress with τ, the time to maturity. The curvature can be approximated by doubling the mid-term yield and subtracting the sum of the short- and long-term yields; hence the curvature will have a small impact over very short or very long horizons (Diebold and Li, 2006).

4.4.4 Inflation expectations curves

The term structure of inflation expectations is a smooth, continuous curve that represents different inflation expectations made at time t for different horizons in the future, analogous to the well-known yield curve concept. Inflation expectations survey data can be quite sparse and often cover non-standard horizons. Combining such survey data to estimate a continuous inflation expectations term structure can be very useful for producing inflation expectations curves over any arbitrary horizon, especially in the presence of heterogeneity and digit preference behaviour among the respondents. The shape of an expectations curve can be modelled with a set of unobserved or latent factors that attempt to distil the whole information set of the curve at each point in time into three factors corresponding to level, slope and curvature (Rummel, 2013).

The economic interpretation of the level provides information about the longer-term perceived anchor for inflation expectations. The slope and curvature factors provide information about the expected speed of convergence of inflation expectations to reach the perceived focus (Lewis, 2016). The estimated level factor can be used for interpretations about perceived longer-term inflation expectations and to monitor its evolution over time, which can be useful information for policy makers.

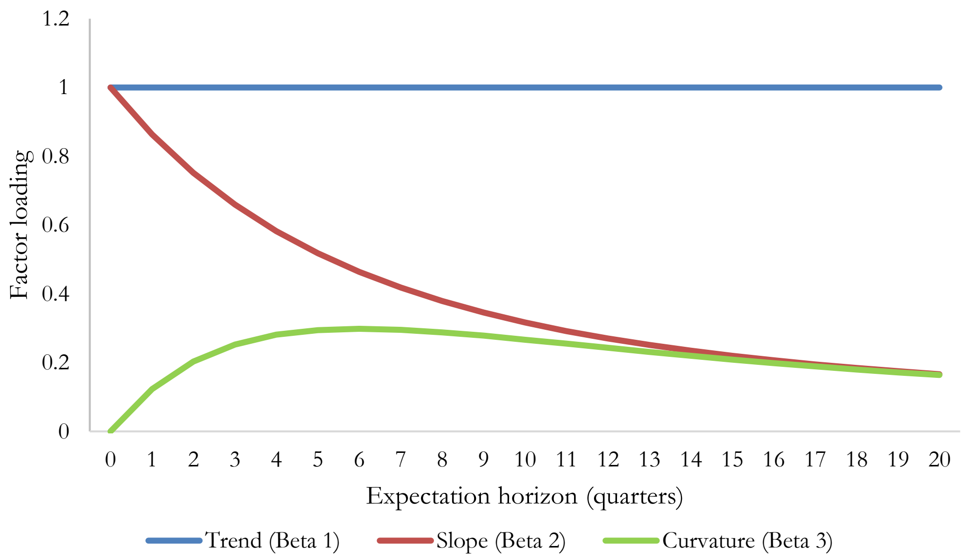
The BER surveys and publish South African annual inflation expectations for discrete horizons, namely the current-year, one-year-, two-years- and five-years-ahead horizons on a quarterly basis. These annual inflation expectations that are surveyed per respondent on a quarterly basis for different horizons, are particularly useful for term structure modelling of these inflation expectations. The term structure estimation approach is parsimonious, not shape restrictive and can flexibly handle missing data from infrequent observations or limited data availability. It can flexibly estimate and forecast inflation expectations at any horizon, even those that are not observed. The main benefit of term structure models is their ability to distinguish between and represent short-term, medium-term and long-term processes, a property that enables the monitoring of inflation expectations and how these change during the year.

The term structure of inflation expectations was modelled based on the Diebold and Li (2006) and later the Diebold et al. (2006) versions of the NS curve, since they facilitate parsimony and convenient solution properties. The factors can be time-varying in the latter case, using the Diebold et al. (2006) approach. To estimate the three-factor NS model via the Diebold and Li (2006) approach, β_1, β_2 and β_3 were estimated for each BER Survey group, using three approaches. The factors were estimated using Equation 4.4, using one non-parametric and two parametric approaches, which will be discussed later on.

$$\pi_t^e(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right) + C_t\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{\lambda\tau}\right) \qquad (4.4)$$

In the above equation, π_t^e represents expected inflation for horizon τ; the three factors to be estimated are L_t S_t and C_t, each associated with factor loadings 1, $\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau}\right)$ and $\left(\frac{1-e^{-\lambda\tau}}{\lambda\tau} - e^{\lambda\tau}\right)$. The specification of Equation 4.4 differs in notation for the loadings from Equation 4.3, where β_1 is replaced by L_t, β_2 is replaced by S_t and β_3 is replaced by C_t. Note that λ controls the shape of the slope and curvature loadings; it also determines the point at which the loading of the curvature factor is maximised. The λ chosen for this aspect of the study was calibrated at 0.3, and the resulting factor loadings are shown in Figure 4.11.[27] This assumption was relaxed, and λ was estimated and is covered in subsequent sections. The choice of lambda at 0.3 ensured that the curvature loadings were maximised at around six quarters, which corresponds to the timing of the conventional policy transmission mechanism for South Africa (Smal and De Jager, 2001). In a similar approach, Aruoba (2016) estimated lambda to be 0,12 for monthly USA survey inflation expectations data, which implies that the curvature was maximised at around 15 months or five quarters, the point where the inflation expectations curve reached its peak before declining to the longer-term perceived anchor. This estimate for lambda is lower than the range suggested by Christensen et al. (2009) of between 0.5 and 1 for US Treasury yield data.

Figure 4.11: Factor loadings based on lambda of 0.3



[27] To view the sensitivity of alternative lambda (λ) specifications on the factor loadings, refer to Appendix C.1.

4.4.4.1 Estimation of the three-factor model using approximating accounting formulas

Following Equation 4.4, an inflation expectations terms structure can be expressed as a linear combination a longer-term level (L_t), slope (S_t) and curvature (C_t), each with its associated factor loadings. To approximate the three factors to be used in Equation 4.4, an accounting approach was followed to determine the factors L_t S_t and C_t. The non-parametric formula used provides a reasonable representation for the level, slope and curvature of the expectations curves and the descriptions are explained in more detail later on.

The means and medians of the inflation expectations distributions for the different expectation horizons is presented in Table 4.1 and was used to estimate L_t (proxied by the mean longer-term inflation rate), S_t (the longer-term inflation mean minus the short-term inflation expectations mean) and C_t, (the one-year-ahead inflation expectations mean minus the average of the short and longer-term inflation expectations average). These were substituted into Equation 4.4 and together with the factor loadings, provide the accounting-based NS expectations curves, denoted as dotted lines in Figure 4.12. These approximations can be made using either the mean or median values to determine the factors L_t S_t and C_t, and both resulting inflation expectations term structure curves are shown in Figure 4.12.

Table 4.5: Descriptive statistics and curve-factor estimates of the BER respondents' individual CPIT inflation expectations: Sample 2000q2-2017q4.

	Observations	Mean	Median	Std dev.
Financial analysts:				
Current	1085	6.26	6.00	1.64
One year ahead	1085	5.74	5.70	0.89
Two years ahead (Level2)	1085	5.47	5.50	0.75
Five years ahead (Level5)	344	5.53	5.60	0.58
Slope2	1085	-0.79	-0.50	1.58
Slope5	344	-0.19	-0.20	0.79
Curvature2	1085	-0.26	-0.10	1.37
Curvature5	344	-0.32	-0.40	0.91
Business representatives:				
Current	22182	6.79	6.50	1.81
One year ahead	22182	6.84	6.50	1.70
Two years ahead (Level2)	22182	6.85	6.50	1.79
Five years ahead (Level5)	6086	6.45	6.00	1.25
Slope2	22182	0.06	0.10	1.36
Slope5	6086	0.34	0.10	1.18
Curvature2	22182	0.05	0.00	0.93
Curvature5	6086	0.27	0.10	1.47
Trade union officials:				
Current	909	6.58	6.20	1.80
One year ahead	909	6.60	6.20	1.72
Two years ahead (Level2)	909	6.56	6.10	1.77
Five years ahead (Level5)	279	6.08	6.00	1.19
Slope2	909	-0.02	0.00	1.30
Slope5	279	0.17	0.00	1.22
Curvature2	909	0.05	0.00	1.12
Curvature5	279	0.19	0.10	1.30

For the term structure components, Level2 is the two-years-ahead expectation, Level5 is the five-years-ahead expectation, Slope2 is the slope calculated as the difference between the two-years-ahead and the current-year expectation, Slope5 is the slope calculated as the difference between the five-years-ahead and the current-year expectation; also note that the slope is equal to $-\beta 2$ when the slope was proxied by the difference between long and short yields. Curvature2 was calculated as twice the one-year-ahead expectation minus the sum of the current-year and two-years-ahead expectations; Curvature5 was calculated as twice the two-years-ahead expectation minus the sum of the current-year and five-years-ahead expectations or 2 (two-years-ahead expectation) – (current-year expectation + five-years-ahead expectation).

It is noticeable from Table 4.5 that the impact of digit preference caused the medians to be almost static over the expectations curve, or horizons, with very little variation and less information content than the mean, which shows more variability. The medians of the business representatives for the first three horizons show no change, where their means show a slight increasing curve.

The financial analysts appear to have a downward sloping expectations curve and have the lowest longer-term inflation perception of 5.5 percent, which is consistent with a perception that perceived longer-term inflation would be lower than the perceived current-horizon inflation. They also showed less uncertainty over longer horizons. Short-term shocks were not considered to be persistent, shown by the narrowing of the distribution over longer horizons.

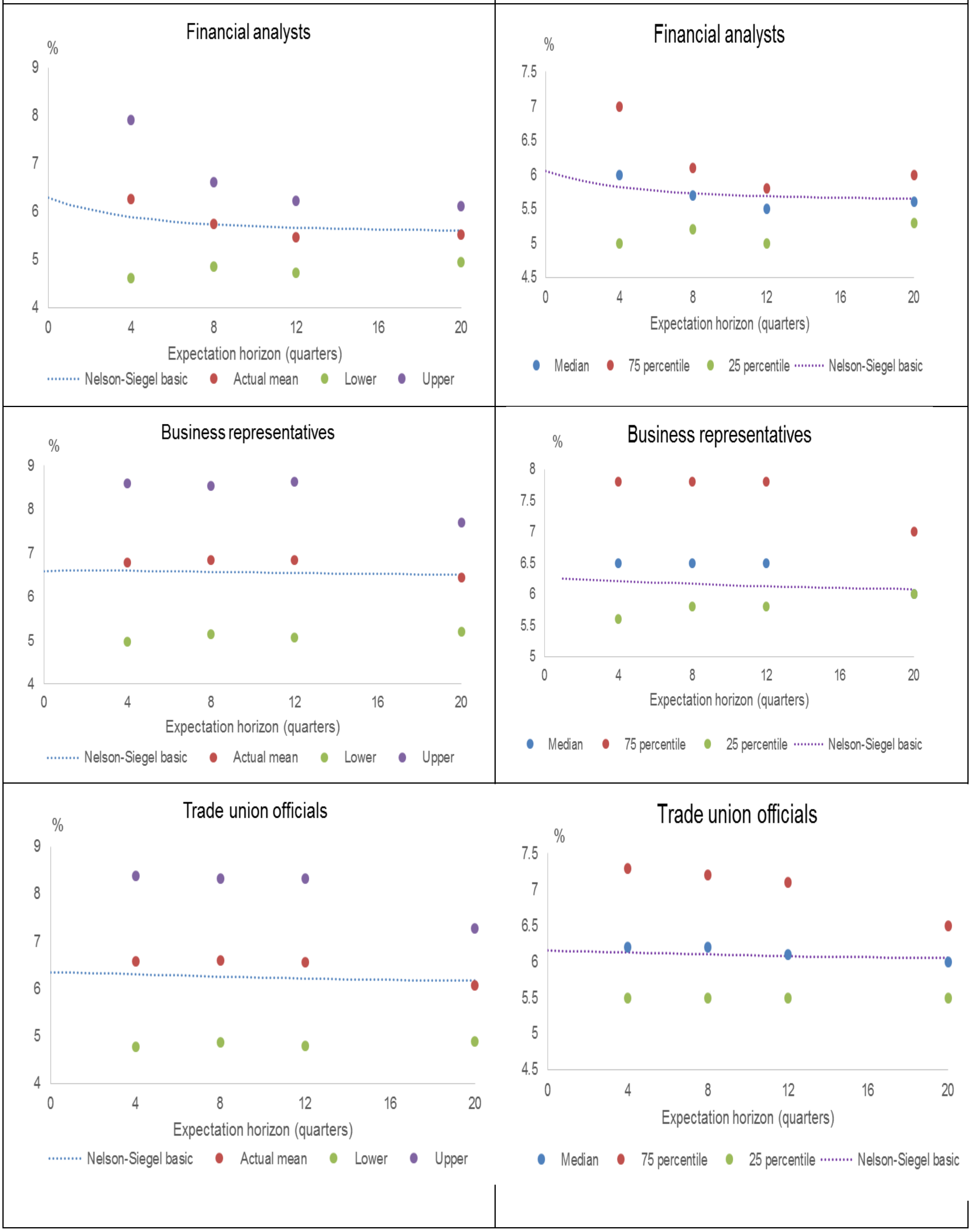
The business representatives and trade union officials appear to have flatter curves, and the trade union officials expected longer-term inflation to be 6.1 percent. The business representatives appear to have been the most pessimistic about longer-term inflation at 6.5 percent, one percentage point higher than the expectations of the financial analysts. The distribution of the business representatives and trade union officials does not narrow notably over longer horizons, suggesting that they expected a relatively high degree of persistence of shocks and were less anchored to a longer-term focal point than were the financial analysts.

All three inflation term-structure curves have a longer-term level or anchor after 20 quarters that is just below the upper target band for the financial analysts and just above the upper target band for the other two groups (Figure 4.12).

To consider the robustness of the results and to attempt to improve on the fit of the formula-based inflation expectations curves in Figure 4.12, a model-based estimation procedure is presented in the following section.

Figure 4.12: Formula-based Nelson-Siegel term-structure curve estimates

Based on means	Based on medians



Note: Upper refers to the mean of inflation expectations plus twice the standard deviation, and lower refers to the mean minus twice the standard deviation.

4.4.4.2 Model-based estimated factors

Even though the accounting-based approach to estimating the three factors of the term structure of inflation expectations is useful and intuitive, a model-based NS approach was used to compare and potentially improve the fit of the estimated curves to the observed data shown in Figure 4.12. This second parametric approach to estimating the inflation expectations curve factors uses factor loadings calculated with lambda assumed at 0.3. These factor loadings were then used as the three regressors in an ordinary-least-squares estimation of Equation 4.4 to estimate the values of L_t S_t and C_t. The results are shown in Table 4.6.

Similar to the accounting-formula-based estimates, the business representatives have the highest inflation expectations curve and the financial analysts the lowest from four quarters onwards, and the same applied to their respective perceived longer-term inflation targets (Figure 4.13). The financial analysts had a longer-term inflation perception within the target band of 5.48 percent, and that of the trade union officials was estimated to be 5.5 percent. The business representatives had perceived longer-term expectations at the upper end of the target band at 6.0 percent.

The financial analysts' inflation expectations curve exhibits a downward slope, which implies that they did not expect short-term disturbances to persist. The business representatives and trade union officials also appear to have expected a deceleration in their inflation expectations trajectories, as shown by their negative slope factor, following the peak of the curve. However, the business representative's slope is much smaller in magnitude compared with that of the financial analysts, and the trade union officials' slope is not statistically significant. The curvature factors of all three groups are statistically significant.

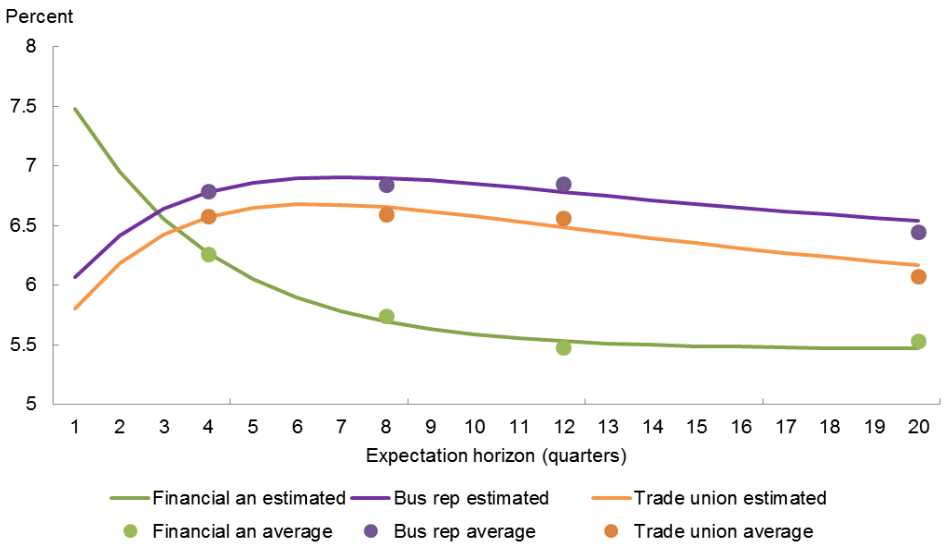
Table 4.6: Model-based loading factor estimates

	Financial analysts	**Business representatives**	**Trade union officials**
Lambda	0.3	0.3	0.3
Level (L)	**5.48**	**6.02**	**5.50**
std err	0.18	0.09	0.34
(prob)	(0.00)	(0.00)	(0.00)
Slope (S)	**-2.71**	**-0.46**	-0.27
std err	0.65	0.21	0.74
(prob)	(0.00)	(0.03)	(0.72)
Curvature (C)	**-2.81**	**3.67**	**4.37**
std err	1.41	0.59	2.13
(prob)	(0.05)	(0.00)	(0.04)
S.E. of regression	1.119	1.729	1.718
Observations	3599	72632	3006

Note: Boldface numbers indicate statistical significance at 5 percent probability. Newey-West standard errors were used.

The estimated inflation expectations curves in Figure 4.13 were plotted with the corresponding observed average inflation expectations per horizon. The versatility of the three-factor model allowed the estimated model to represent the observed averages fairly well, and it appears to have been an improvement on the accounting-based estimates, since the model-based inflation expectations curves appear to better fit the inflation expectations distribution averages.

Figure 4.13: Average and model-based expectation curves



4.4.4.3 State-space estimation of factors of inflation expectations curves

In the previous section, inflation expectations term-structure curves were estimated conditional on a constant lambda (the parameter that determines the point where the curvature is maximised) calibrated at 0.3, which considers the length of the SA transmission mechanism. Also, no explicit allowance was made to specify the correlation between the term-structure factors.

Inflation expectation curves can be reasonably represented by static versions of the NS specification; however, dynamic versions where the parameter estimates of lambda and the factors are allowed to vary can provide enhanced descriptions of the evolution of the term structures. Diebold et al. (2006) introduced a dynamic element to the NS curve by adding time-varying elements to represent the evolution of bond yields over time, using equation 4.5 as the measurement equation for the state-space system that contains the unobservable latent factors. State-space estimation provides an appropriate methodology for estimating such time-varying elements.

Due to the unobservability of the latent factors and the complexity of the estimation, the Kalman filter technique, which is based on maximum likelihood procedures, was used to estimate the parameters.[28] Other benefits of this estimation approach are that the factor loadings and the time-varying values for lambda are estimated (lambda is assumed in the previous two approaches), and the Kalman filter technique can handle missing data (the five-years-ahead expectations were surveyed only from 2011q2).

$$\pi_t^e(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau}\right) + C_t\left(\frac{1-e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{\lambda_t\tau}\right) \qquad (4.5)$$

Where L_t, S_t, C_t and λ_t are time-varying factors followed by their factor loadings. The coefficients L_t and λ_t have loadings equal to one.

Based on the dynamic Diebold et al. (2006) model (Equation 4.5), the following state-space equations were specified:

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[28] Durbin and Koopman (2012) provides an elaborate explanation of the Kalman filter approach for estimating state-space systems. For more detail see Hamilton (1994) and Harvey (1990).

$(f_t - \mu) = A\,(f_{t-1} - \mu) + \eta_t$ (4.6)

$x_t = Z\, f_t + \varepsilon_t$ (4.7)

The vector f_t contains the unobservable time-varying factors L_t, S_t and C_t, assumed to follow a VAR(1) process, μ is the mean state vector (3x1) of coefficients and A is the transition matrix (3x3). The following is the transition equation of the state space system in matrix VAR(1) form.

$$\begin{pmatrix} L_t - \mu_L \\ S_t - \mu_S \\ C_t - \mu_C \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mu_L \\ S_{t-1} - \mu_S \\ C_{t-1} - \mu_C \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix} \quad (4.8)$$

The mean state vector μ has three parameters and is given by:

$\mu = [\mu_L \quad \mu_S \quad \mu_C\,]'$

The vector x_t contains the four horizons of observed data representing the current, one-year-ahead, two-years-ahead and five-years-ahead inflation expectations. The measurement matrix Z contains the factor loadings for each of the four expectation horizons and is given by:

$$Z = \begin{pmatrix} b_L^1 & b_S^1 & b_C^1 \\ b_L^2 & b_S^2 & b_C^2 \\ b_L^3 & b_S^3 & b_C^3 \\ b_L^4 & b_S^4 & b_C^4 \end{pmatrix}$$

The transition error vector $\eta_t \sim N(0,Q)$ was assumed to be white noise and was unrestricted. The Q matrix, the variance of the transition vector, was assumed to be non-diagonal and allowed the shocks to the term-structure factors to be correlated.

The measurement error vector $\varepsilon_t \sim N(0,H)$ was assumed to be white noise and diagonal, to ensure that the deviations from the expectations curve of different horizons (the measurement error terms) were uncorrelated.

$H = \text{diag}\,(\sigma_1^2, \sigma_2^2, \sigma_3^2, \sigma_4^2)$

The parameters of the Kalman filter were estimated with a maximum likelihood approach, by iterating the Marquart and Brendt-Hall-Hall-Hausman algorithms using a convergence criteria of 10^{-5}. [29] The factors L, S and C and their respective variances were initialised using the information obtained in the previous numerical and model-based estimations from Table 4.5 and Table 4.6.

The state-space estimation for the financial analysts converged after 900 iterations using 1114 observations. The longer-term level of inflation expectations for the financial analysts was estimated to be 5.1 percent (see Table 4.7), which is lower than the 5.48 percent estimate of the model-based procedure, which assumed a lambda of 0.3. The slope estimate was negative, although this and the curvature estimate were not statistically significant. The parameter that controls the shape of the slope and curvature loadings, or Lambda (λ), also determines the point at which the loading on the curvature factor is maximised. The lambda chosen for the part of the study covered in the preceding section of the dissertation was calibrated at 0.3. According to the results in Table 4.6, lambda is estimated higher, at 0.97, which implies the turning point of the curve where the curvature is maximised, at two quarters, much faster than the assumed 0.3, which implies maximisation at six quarters.

The business representatives had the highest estimated longer-term level at 6.7 percent (see Table 4.8), which is higher than the model-based estimates in Table 4.5 of 6 percent. The results show strong persistence in the longer-term level process of 0.92. The estimated value for lambda in this instance is 0.24, not much different from the 0.3 assumed in the previous approaches, which implies a turning point of the curve, or maximisation of the curvature, at seven quarters. The state-space system for the business representatives converged after 494 iterations based on 22182 observations. Note that to aid the estimation and convergence processes, the error variance for the current-year horizon for business representatives was assumed to be 0.61, which was informed by the results from the model-based estimation presented previously.

The trade union officials have an estimated longer-term level of 6.1 percent (see Table 4.9), which is higher than the model-based estimate of 5.5 percent, indicating that their longer-term perception of inflation was just above the upper end of the target band. They also demonstrated relatively high persistence of 0.68 on their level factor. The trade union officials had the lowest estimated lambda, of 0.17, which implies a turning point of their expectations curve or the maximisation of the curvature at 11 quarters, the slowest of all three groups. The state-space system for the trade union officials converged after 900 iterations based on 1114 observations.

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[29] For more detail see Diebold et al. (2006).

Table 4.7: Kalman filter results: financial analysts (converged 852 iterations, obs = 1114)

Transition equations with substituted estimated coefficients (see Equation 4.8).

$$\begin{pmatrix} L_t - \mathbf{5.07} \\ S_t - (-0.75) \\ C_t - 5.81 \end{pmatrix} = \begin{pmatrix} \mathbf{-0.14} & \mathbf{-0.07} & \mathbf{-0.07} \\ 0.40 & \mathbf{1.18} & 0.20 \\ 3.81 & 0.04 & \mathbf{1.03} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{5.07} \\ S_{t-1} - (-0.75) \\ C_{t-1} - 5.81 \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability.

The measurement equations relates the inflation expectations to the three unobservable factors L_t, S_t and C_t, for each expectation horizon as per Equation 4.5 (see Diebold et al. (2006) p. 312 Equation 3).

$$\pi_t^{e,0}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 4}}{\lambda_t 4}\right) + C_t\left(\frac{1-e^{-\lambda_t 4}}{\lambda_t 4} - e^{\lambda_t 4}\right)$$

$$\pi_t^{e,1}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 8}}{\lambda_t 8}\right) + C_t\left(\frac{1-e^{-\lambda_t 8}}{\lambda_t 8} - e^{\lambda_t 8}\right)$$

$$\pi_t^{e,2}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 12}}{\lambda_t 12}\right) + C_t\left(\frac{1-e^{-\lambda_t 12}}{\lambda_t 12} - e^{\lambda_t 12}\right)$$

$$\pi_t^{e,5}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 20}}{\lambda_t 20}\right) + C_t\left(\frac{1-e^{-\lambda_t 20}}{\lambda_t 20} - e^{\lambda_t 20}\right)$$

Figure 4.14: Kalman filter estimates for financial analysts' latent factors

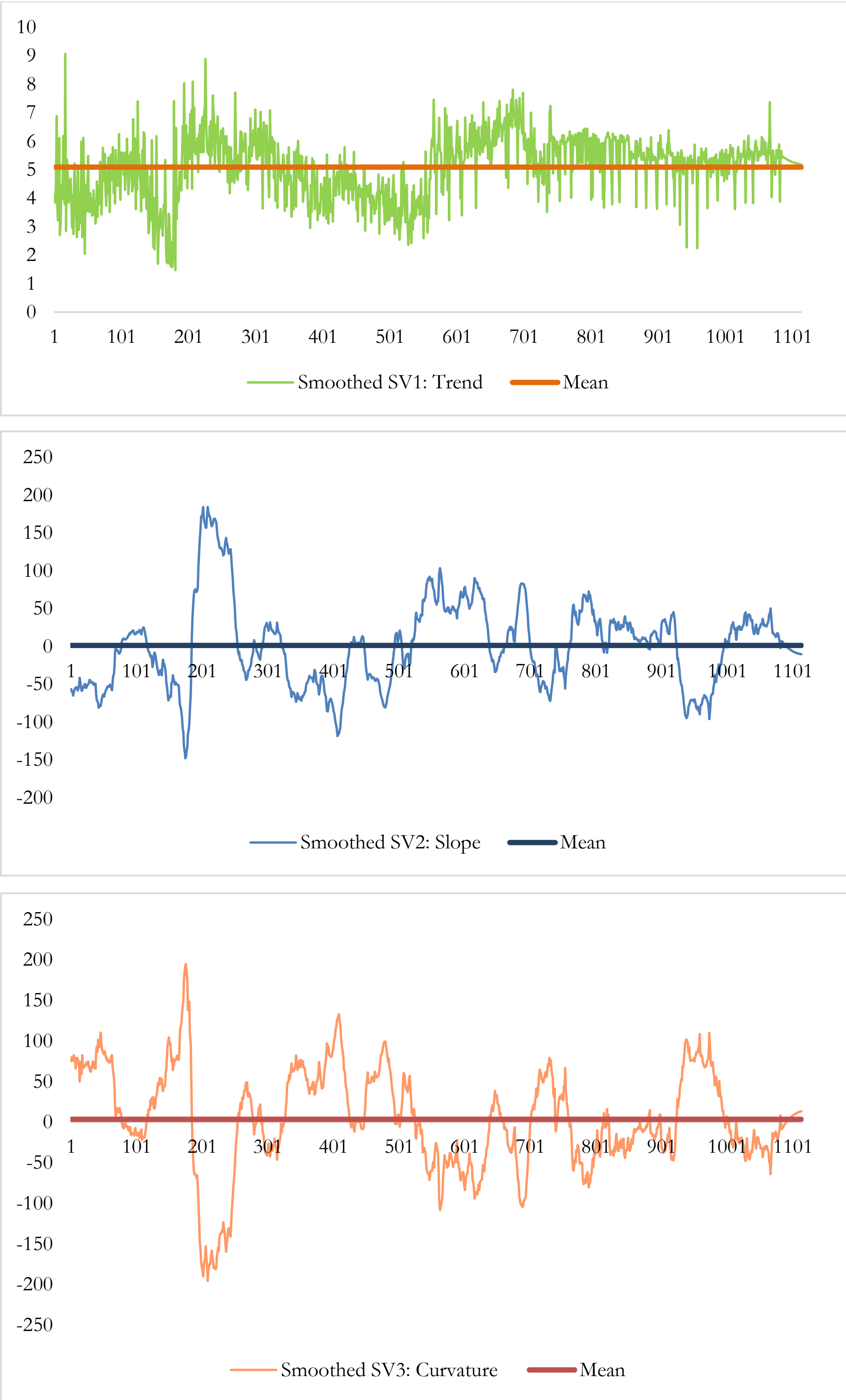


Table 4.8: Kalman filter results: business representatives (converged 494 iterations, obs = 22182)

Transition equations with substituted estimated coefficients (see Equation 4.8).

$$\begin{pmatrix} L_t - \mathbf{6.74} \\ S_t - 0.11 \\ C_t - \mathbf{0.75} \end{pmatrix} = \begin{pmatrix} \mathbf{0.92} & \mathbf{0.02} & \mathbf{-0.09} \\ \mathbf{0.18} & \mathbf{0.95} & \mathbf{0.21} \\ \mathbf{-0.74} & \mathbf{0.20} & \mathbf{0.15} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{6.74} \\ S_{t-1} - 0.11 \\ C_{t-1} - \mathbf{0.75} \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability. Measurement equations specifications for each expectation horizon were the same as for financial analysts.

Table 4.9: Kalman filter results: trade union officials (converged 210 iterations, obs = 909)

Transition equations with substituted estimated coefficients (see Equation 4.8).

$$\begin{pmatrix} L_t - \mathbf{6.10} \\ S_t - 0.27 \\ C_t - 1.00 \end{pmatrix} = \begin{pmatrix} \mathbf{0.68} & \mathbf{0.40} & \mathbf{0.08} \\ \mathbf{0.57} & \mathbf{0.33} & \mathbf{-0.09} \\ -0.63 & -0.36 & \mathbf{-0.11} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{6.10} \\ S_{t-1} - 0.27 \\ C_{t-1} - 1.00 \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability. Measurement equations specifications for each expectation horizon were the same as for financial analysts.

Figure 4.15: Kalman filter estimates for business representatives' latent factors

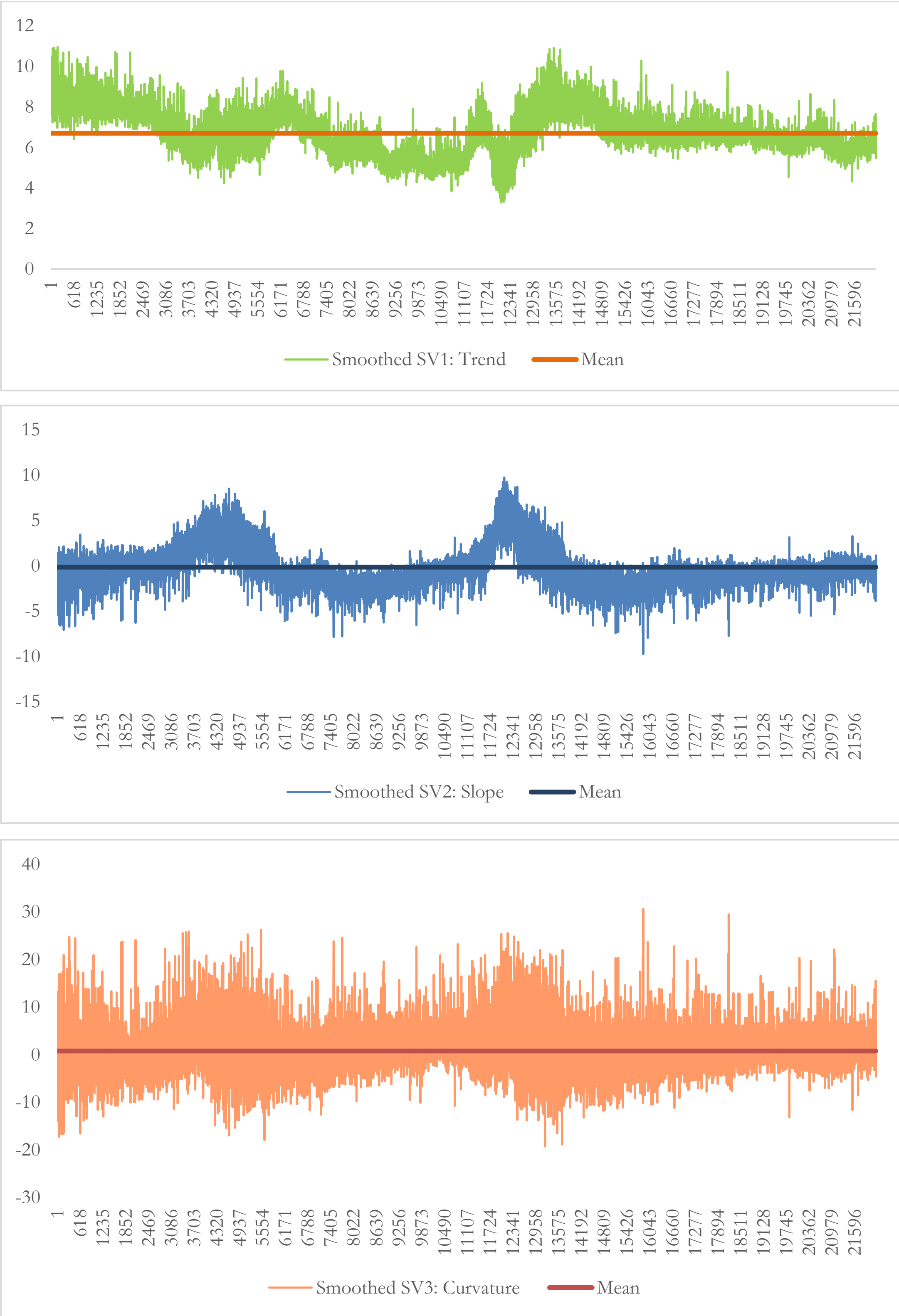


Figure 4.16: Kalman filter estimates for trade union officials' latent factors

4.5 Time-to-maturity BER inflation expectations data

The novel feature of the BER survey data where annual inflation expectations are surveyed on a quarterly basis, allows for an innovation that considers the data in terms of the time at which it matures, or in the case of inflation, will be published. This innovation will provide information gains due to the longer time horizon term structures based on such data will have. In this part of the study an alternative approach was used to analyse the BER inflation expectations data. This approach considers the unique nature of the BER Survey, where four quarterly publications produce surveyed average annual inflation data per year. This feature presents another dimension of the data, which is useful for an alternative approach to estimating inflation expectations curves using term-structure techniques. In the following framework, called the time-to-maturity data set, the data are set up in terms of maturity, or time to the realisation of the expectation, when the inflation number was published.

Table 4.10: Time-to-maturity BER inflation expectations data example for a specific year

	Expectation horizon (residual maturity to publication)			
	Current year	**One year ahead**	**Two years ahead**	**Five years ahead**
March q1 publication	4 q to maturity y(4)	8 q to maturity y(8)	12 q to maturity y(12)	24 q to maturity y(24)
June q2 publication	3 q to maturity y(3)	7 q to maturity y(7)	11 q to maturity y(11)	23 q to maturity y(23)
Sept q3 publication	2 q to maturity y(2)	6 q to maturity y(6)	10 q to maturity y(10)	22 q to maturity y(22)
Dec q4 publication	1 q to maturity y(1)	5 q to maturity y(5)	9 q to maturity y(9)	21 q to maturity y(21)

In this framework the y(1) expectation category represents the shortest time to publication; only one quarter remains unknown before the calendar year is published. Similarly, the y(24) expectation category represents the longest forecast horizon to maturity or to publication of the inflation number. The main difference between the conventional BER Survey data and the time-to-maturity BER Survey data is the available information set when the term structure is surveyed. For the conventional data, each observation on the term structure trajectory is based on the same available information. For the time-to-maturity data this is not the case, yet the commonality is the maturity or the residual quarters remaining until the annual average inflation number is published.

Following the example in Table 4.10, the y(4), y(8), y(12) and y(24) responses were all surveyed for the first publication of the calendar year and were drawn using the same data available at that time. The set of y(1) responses denote those that were drawn for the fourth publication of the calendar year, when there were always three quarters of information available for the year forecasted, though the information is different for each survey year.

A benefit of the time-to-maturity data is that the transposition provides more observation categories along the expectations curve to be estimated, in particular 16 quarterly horizons compared with the 4 annual horizons of the conventional dataset. However, the number of observations for each category is less than for the conventional dataset.

4.5.1 Estimated inflation expectations term structures based on time-to-maturity BER Survey data

The time-to-maturity datasets for the three BER Survey groups are shown in Figure 4.17. It is noticeable that the short-term horizon expectation category y(1) is more volatile than the longer-term horizons (y(12)) and y(24)) categories for the financial analysts. The other two groups show the same feature, but to a much lesser extent than do the financial analysts.

4.5.1.1 Estimation of the three-factor model using approximating accounting formulas: time-to-maturity BER Survey data

Similar to the procedure explained in section 4.4.4.1, this approach assumes that the formulae noted there are reasonable approximations of the level, slope and curvature of the expectations curves. The information presented in Table 4.11 was used to estimate L, S and C, and these were substituted into Equation 4.4 to obtain the accounting-based NS expectations curves, denoted as dotted lines in Figure 4.18. These approximations can be made using either the mean or median values, and both results are shown.

All three BER Survey groups have negative slopes according to the time-to-maturity data, indicating that they expect inflation to decline from the current rates to the longer-term horizon for both the two-years-ahead (y(12)) and the five-years-ahead (y(24)) maturity horizons (see Table 4.11). The financial analysts had the lowest five-years-ahead maturity horizon of 5.6 percent, the trade union officials have an estimate of 5.9 percent and the business representatives had the highest longer-term expectation of 6.4 percent, commensurate with the results reported in the previous section for the conventional BER Survey responses.

Figure 4.17: Time-to-maturity BER average data in terms of residual quarters to maturity

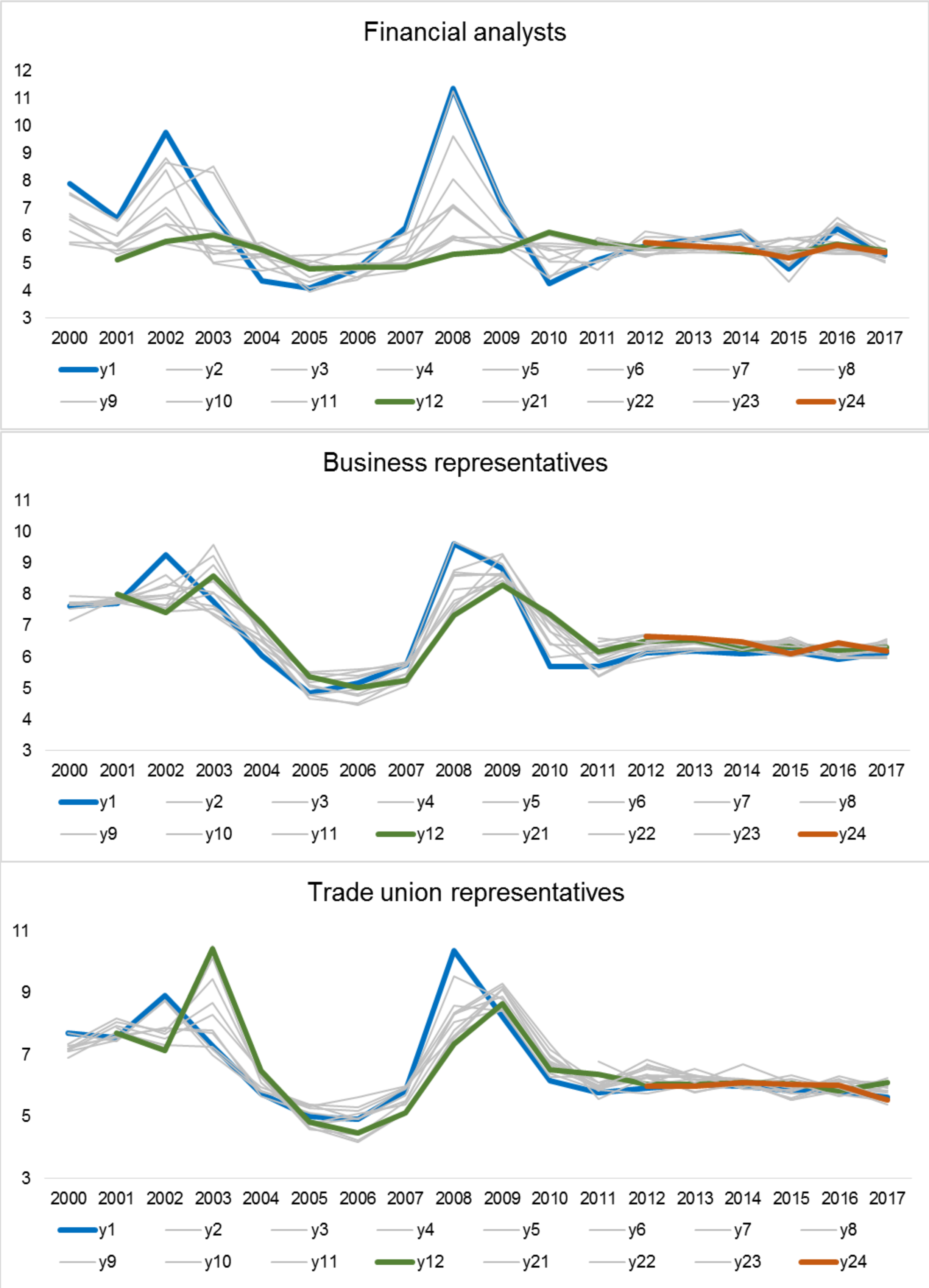
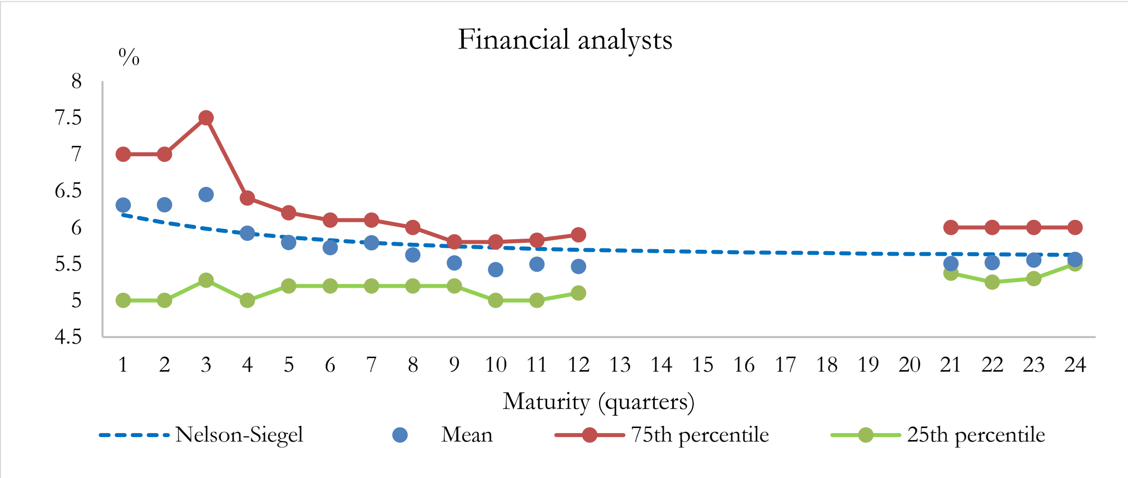
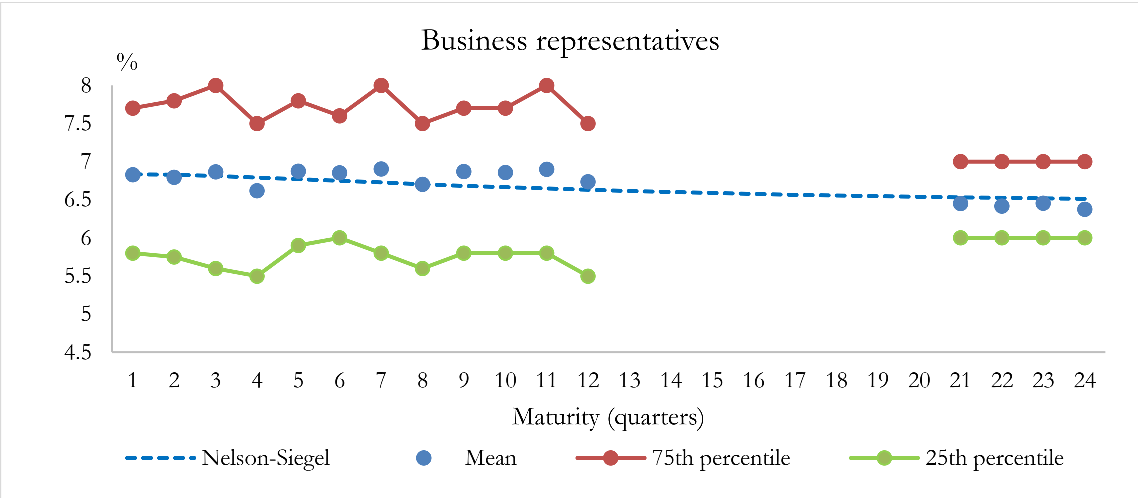


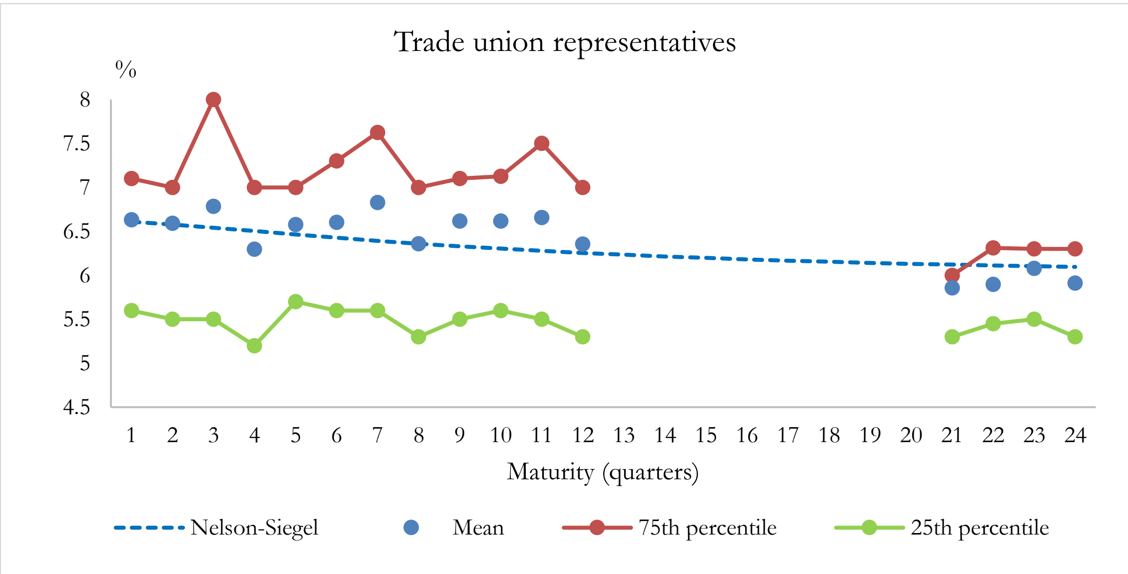
Table 4.11: Descriptive statistics for time-to-maturity BER Survey expectations data

	Financial analysts				**Business representatives**				**Trade union officials**			
	Mean	Median	Std dev	Obs	Mean	Median	Std dev	Obs	Mean	Median	Std dev	Obs
Y(1)	6.305	6	1.86	293	6.828	6.5	1.87	5584	6.632	6.2	1.88	213
Y(2)	6.309	6.1	1.73	279	6.797	6.5	1.74	5863	6.593	6.3	1.75	224
Y(3)	6.450	6.2	1.58	280	6.867	6.5	1.87	5536	6.784	6.15	1.92	244
Y(4)	5.918	5.9	1.23	233	6.618	6.5	1.73	5349	6.298	6	1.60	228
Y(5)	5.792	5.6	1.01	293	6.876	6.5	1.70	5584	6.577	6.1	1.60	213
Y(6)	5.725	5.6	0.78	279	6.853	6.5	1.63	5863	6.603	6.2	1.52	224
Y(7)	5.788	5.7	0.93	280	6.906	6.5	1.77	5536	6.826	6.2	1.93	244
Y(8)	5.622	5.6	0.76	233	6.702	6.5	1.68	5349	6.359	6.05	1.76	228
Y(9)	5.514	5.5	0.73	293	6.873	6.5	1.77	5584	6.615	6.3	1.57	213
Y(10)	5.420	5.5	0.69	279	6.859	6.5	1.74	5863	6.616	6.2	1.64	224
Y(11)	5.497	5.5	0.83	280	6.898	6.5	1.85	5536	6.656	6	1.96	244
Y(12) Level2	5.465	5.5	0.73	233	6.736	6.5	1.78	5349	6.354	6	1.83	228
Y(21)	5.506	5.5	0.55	100	6.451	6	1.22	1615	5.856	6	1.05	39
Y(22)	5.519	5.6	0.68	87	6.419	6	1.31	1719	5.896	6	0.93	48
Y(23)	5.553	5.6	0.53	79	6.455	6	1.24	1370	6.077	6	1.58	42
Y(24) Level5	5.560	5.73	0.56	78	6.374	6	1.22	1522	5.911	5.9	1.25	41
Slope2	-1.01	-0.5	2.08	233	-0.12	0.2	2.43	5349	-0.26	-0.2	2.04	213
Slope5	-1.73	-1.65	1.75	78	-1.58	-1.5	1.89	1522	-1.74	-1.8	1.81	41
Curvature2	-0.22	-0.1	1.77	233	0.20	0	2.61	5349	0.15	0.3	2.26	213
Curvature5	-0.35	-0.6	1.94	78	1.12	1.1	2.39	1522	1.52	1.4	2.70	41

Figure 4.18: Accounting formula-based Nelson-Siegel term-structure estimates with interquartile range







4.5.1.2 Model-based estimated factors

Similar to the approach followed in the part of the study discussed in section 4.4.2, the factor loadings for the inflation expectations curves were estimated with lambda assumed at 0.3. These factor loadings were then used as regressors in an ordinary least squares estimation of Equation 4.3 to estimate L, S and C, the values for the factors of the inflation expectations curves. The results are shown in Table 4.12.

Based on the time-to-maturity dataset, the financial analysts have an inflation expectations longer-term trend level of 5.3 percent, the level for the trade union officials is higher at 5.8 percent and that of the business representatives is the highest at 6.3 percent (Table 4.12). When the standard deviation was considered to be a measure of uncertainty, the trade union officials were the most uncertain about their longer-term inflation expectation.

These results compare favourably with the conventional dataset (Table 4.6), where the financial analysts' level for the model-based estimate of longer-term inflation is 5.48 percent, the trade union officials group is 5.50 percent and the business representatives group is 6.0 percent.

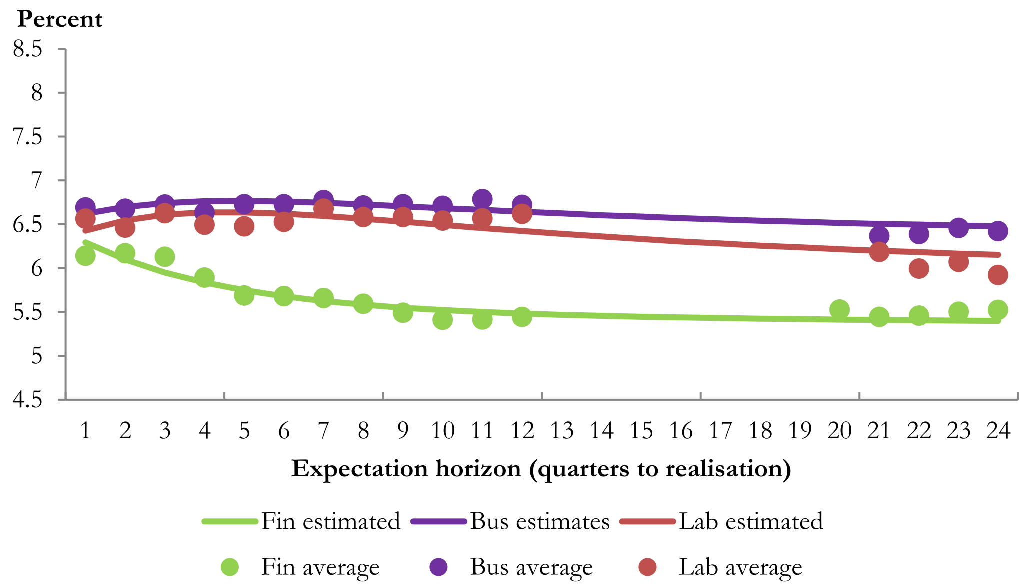
Table 4.12: Model-based loading factor estimates of time-to-maturity BER Survey data

	Financial analysts	**Business representatives**	**Trade union officials**
Lambda	0.3	0.3	0.3
Level (L)	**5.30**	**6.30**	**5.78**
std dev.	0.18	0.11	0.34
(prob)	(0.00)	(0.00)	(0.00)
Slope (S)	**1.48**	**0.32**	0.61
std dev.	0.28	0.12	0.350
(prob)	(0.00)	(0.01)	(0.08)
Curvature (C)	-0.74	**1.39**	1.92
std dev.	0.89	0.41	1.24
(prob)	(0.41)	(0.00)	(0.12)
S.E. of equation	1.121	1.727	1.737

Note: boldface numbers indicate statistical significance at 5 percent probability. Newey-West standard errors used.

The time-to-maturity BER Survey group data are shown in Figure 4.19 in terms of their averages and estimated inflation expectations curves over the quarters remaining until realisation or maturity of the inflation expectation. The statistically significant negative slope for the financial analysts' inflation expectations curve can be observed in Figure 4.19, yet the expectations curves of the other two groups appear to be moving sideways towards the two-years-ahead (y(12)) maturity horizon, though they appear to be slightly less so than for the five-years-ahead (y(24)) maturity horizon.

Figure 4.19: Average and model-based expectation curves, time-to-maturity data



4.5.1.3 State-space estimation of factors of inflation expectations curves

Following the framework explained in section 4.4.3, the state-space framework was used not only to estimate the longer-term trend of the inflation expectations curves, but also the lambda for the time-to-maturity BER Survey data.

Similar to section 4.4.4.3, the parameters of the Kalman filter were estimated with a maximum likelihood approach by iterating the Marquart and Brendt-Hall-Hall-Hausman algorithms using a convergence criteria of 10^{-5}. The parameters were initialised using the information obtained in the previous numerical and model-based estimations.

According to the results, the level of the longer-term inflation expectations of the financial analysts group was 5.2 percent (Table 4.13) and lambda estimated to be 0.58. This longer-term inflation expectation is lower than the 5.3 percent estimate for the model-based procedure, which assumed a lambda of 0.3. The slope estimate was negative, although this was not statistically significant. The higher estimated lambda of 0.58, (Table 4.14) implies that the curvature is maximised at three quarters to maturity, faster than the assumed 0.3, which implies maximisation at six quarters. The state-space system for this estimation did not improve the likelihood after 5 iterations based on 295 observations.

The longer-term level of business representatives was the highest of the three BER Survey groups at 6.5 percent (Table 4.14), which is higher than for the model-based estimate, of 6.3 percent, in Table 4.13. Similar to the results based on the conventional BER data presented in the previous section, the results show strong persistence in the level of the longer-term process of 0.94. The estimated value for lambda in this instance is 0.97, notably different from the 0.3 assumed in the previous approaches, which implies maximisation of the curvature at two quarters. The state-space system for the business representatives converged after 294 iterations based on 5864 observations.

The longer-term level of trade union officials is estimated at 5.9 percent (Table 4.15), which is higher than that of the model-based estimate of 5.8 percent, close to the upper end of the inflation target band. They also showed a relatively high persistence of 1.0 on their level factor. The trade union officials had the lowest estimated lambda of the three BER Survey groups of 0.27, which implies maximisation of the curvature at seven quarters, the slowest of all three groups. The state-space system for the trade union officials converged after 101 iterations based on 245 observations.

Table 4.13: Kalman filter results: financial analysts (failure to improve likelihood after 5 iterations, obs=295)

Transition equations with substituted estimated coefficients (see prior equation, 4.8)

$$\begin{pmatrix} L_t - \mathbf{5.20} \\ S_t - (-1.07) \\ C_t - \mathbf{3.85} \end{pmatrix} = \begin{pmatrix} \mathbf{0.83} & 0.04 & 0.10 \\ -0.55 & \mathbf{1.59} & 0.20 \\ -4.27 & 0.45 & 1.39 \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{5.20} \\ S_{t-1} - (-1.07) \\ C_{t-1} - \mathbf{3.85} \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability.

Measurement equations, one for each expectation horizon (see Diebold (2006) p. 312, Equation 3).

$$\pi_t^{e,1}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 1}}{\lambda_t 1}\right) + C_t\left(\frac{1-e^{-\lambda_t 1}}{\lambda_t 1} - e^{\lambda_t 1}\right) + e\_1$$

$$\pi_t^{e,2}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 2}}{\lambda_t 2}\right) + C_t\left(\frac{1-e^{-\lambda_t 2}}{\lambda_t 2} - e^{\lambda_t 2}\right) + e\_2$$

$$\pi_t^{e,3}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 3}}{\lambda_t 3}\right) + C_t\left(\frac{1-e^{-\lambda_t 3}}{\lambda_t 3} - e^{\lambda_t 3}\right) + e\_3$$

$$\pi_t^{e,4}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 4}}{\lambda_t 4}\right) + C_t\left(\frac{1-e^{-\lambda_t 4}}{\lambda_t 4} - e^{\lambda_t 4}\right) + e\_4$$

$$\pi_t^{e,5}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 5}}{\lambda_t 5}\right) + C_t\left(\frac{1-e^{-\lambda_t 5}}{\lambda_t 5} - e^{\lambda_t 5}\right) + e\_5$$

$$\pi_t^{e,6}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 6}}{\lambda_t 6}\right) + C_t\left(\frac{1-e^{-\lambda_t 6}}{\lambda_t 6} - e^{\lambda_t 6}\right) + e\_6$$

$$\pi_t^{e,7}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 7}}{\lambda_t 7}\right) + C_t\left(\frac{1-e^{-\lambda_t 7}}{\lambda_t 7} - e^{\lambda_t 7}\right) + e\_7$$

$$\pi_t^{e,8}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 8}}{\lambda_t 8}\right) + C_t\left(\frac{1-e^{-\lambda_t 8}}{\lambda_t 8} - e^{\lambda_t 8}\right) + e\_8$$

$$\pi_t^{e,9}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 9}}{\lambda_t 9}\right) + C_t\left(\frac{1-e^{-\lambda_t 9}}{\lambda_t 9} - e^{\lambda_t 9}\right) + e\_9$$

$$\pi_t^{e,10}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 10}}{\lambda_t 10}\right) + C_t\left(\frac{1-e^{-\lambda_t 10}}{\lambda_t 10} - e^{\lambda_t 10}\right) + e\_10$$

$$\pi_t^{e,11}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 11}}{\lambda_t 11}\right) + C_t\left(\frac{1-e^{-\lambda_t 11}}{\lambda_t 11} - e^{\lambda_t 11}\right) + e\_11$$

$$\pi_t^{e,12}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 12}}{\lambda_t 12}\right) + C_t\left(\frac{1-e^{-\lambda_t 12}}{\lambda_t 12} - e^{\lambda_t 12}\right) + e\_12$$

$$\pi_t^{e,21}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 21}}{\lambda_t 21}\right) + C_t\left(\frac{1-e^{-\lambda_t 21}}{\lambda_t 21} - e^{\lambda_t 21}\right) + e\_21$$

$$\pi_t^{e,22}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 22}}{\lambda_t 22}\right) + C_t\left(\frac{1-e^{-\lambda_t 22}}{\lambda_t 22} - e^{\lambda_t 22}\right) + e\_22$$

$$\pi_t^{e,23}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 23}}{\lambda_t 23}\right) + C_t\left(\frac{1-e^{-\lambda_t 23}}{\lambda_t 23} - e^{\lambda_t 23}\right) + e\_23$$

$$\pi_t^{e,24}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 24}}{\lambda_t 24}\right) + C_t\left(\frac{1-e^{-\lambda_t 24}}{\lambda_t 24} - e^{\lambda_t 24}\right) + e\_24$$

$$\pi_t^{e,24}(\tau) = L_t + S_t\left(\frac{1-e^{-\lambda_t 24}}{\lambda_t 24}\right) + C_t\left(\frac{1-e^{-\lambda_t 24}}{\lambda_t 24} - e^{\lambda_t 24}\right) + e\_24$$

Table 4.14: Kalman filter results: business representatives (converged after 294 iterations, obs=5864)

Transition equations with substituted estimated coefficients (see prior equation, 4.8).

$$\begin{pmatrix} L_t - \mathbf{6.54} \\ S_t - 0.06 \\ C_t - 0.78 \end{pmatrix} = \begin{pmatrix} \mathbf{0.94} & \mathbf{0.01} & \mathbf{0.00} \\ \mathbf{0.11} & \mathbf{0.97} & \mathbf{-0.01} \\ \mathbf{0.14} & \mathbf{-0.03} & \mathbf{0.98} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{6.54} \\ S_{t-1} - 0.06 \\ C_{t-1} - 0.78 \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability.

Measurement equations for each expectation horizon were the same as for financial analysts.

Table 4.15: Kalman filter results: trade union officials (converged after 101 iterations, obs=245)

Transition equations with substituted estimated coefficients (see prior equation, 4.8).

$$\begin{pmatrix} L_t - \mathbf{5.88} \\ S_t - 0.23 \\ C_t - 1.31 \end{pmatrix} = \begin{pmatrix} \mathbf{1.06} & 0.05 & 0.02 \\ -0.10 & \mathbf{0.92} & -0.01 \\ -0.41 & 0.02 & \mathbf{0.76} \end{pmatrix} \begin{pmatrix} L_{t-1} - \mathbf{5.88} \\ S_{t-1} - 0.23 \\ C_{t-1} - 1.31 \end{pmatrix} + \begin{pmatrix} \eta_{Lt} \\ \eta_{S_t} \\ \eta_{Ct} \end{pmatrix}$$

Note: Boldface numbers indicate statistical significance at 5 percent probability.

Measurement equations for each expectation horizon were the same as for financial analysts.

Table 4.16: Summary of BER Survey longer-term perceived inflation expectations estimates per methodology, time-to-maturity survey data

Methodology	**Financial analysts**	**Business representatives**	**Trade union officials**
Accounting-based	5.5	6.7	6.4
Model-based	5.3	6.3	5.8
(Lambda)	(0.3)	(0.3)	(0.3)
Kalman filter based	5.1	6.7	6.1
(Lambda)	(0.58)	(0.97)	(0.27)

4.6 Policy considerations

In an inflation targeting regime, it is important for the central bank to ensure that inflation expectations are anchored at an explicit inflation target, to achieve price stability and to lower the cost of responding to adverse price shocks, i.e. to minimise the sacrifice ratio (Bernanke, 2007). When inflation expectations are anchored, it facilitates an environment where the central bank can achieve greater output stability in the short-term and price stability in the long-term (Orphanides and Williams, 2007). Well-anchored longer-term inflation expectations should not be influenced by new economic news or inflation surprises, but should remain relatively stable at their original estimates (Bernanke, 2007; Nautz and Strohsal, 2014).

Often, the credibility of a central bank is measured as the difference between the longer-term implicit inflation expectation or anchor and the announced inflation target (Haldane, 2000). South Africa's current inflation targeting framework differs from most other inflation targeting countries by targeting an inflation range with no official target point. Most other inflation targeting countries target an announced target point within a tolerance band (Hammond, 2012). Of the 27 inflation targeting countries listed by Hammond (2012) only five target a range and do not announce a target point. This approach may be useful for countries that face an initial disinflation challenge in reaching the target band. In such circumstances the optimal inflation rate will likely be more volatile until the target band has been reached through successful disinflation policies.

The inflation targeting countries, i.e. New Zealand, Chile, Israel and to some extent the United Kingdom, introduced their inflation targeting regimes by targeting a range to guide the disinflationary process, changing the range as deemed appropriate until the desired inflation environment was achieved. Eventually, a target point within a tolerance band was announced to emphasise the focus and intention of policy. According to Haldane (2000), the use of an inflation target point within an error-band is a useful approach to focus *ex-ante* policy actions and public inflation expectations, while recognizing the inherent *ex-post* difficulties of inflation control.

Once inflation reaches the target range, it is more appropriate to guide inflation expectations towards an announced target point, which then aids in anchoring longer-term inflation expectations to this focal point. It has been shown in the literature that with inflation targeting regimes, conditional on credible monetary policy, longer-term inflation expectations will be anchored to the intermediate target which is the announced inflation target point (see Pitz and

Sachs, 1984; Conlisk, 1996; Gurkaynak et al., 2007; Gurkaynak et al., 2006; Mishkin and Schmidt-Hebbel, 2006).

In an inflation targeting regime, it may be that the use of a target range without a specific announced target point can create uncertainty among decision makers about the degree of tolerance of the monetary authority and consequently obscure the anchor for inflation expectations. Respondents may initially believe that the midpoint of the range is the desired target rate for inflation. However, over time it may be that the respondents learn that the monetary authority will only act or raise concern if inflation breaches the (mainly upper) target band (hard edge) and consequently anchor their inflation expectations to the upper end of the target band, instead of the midpoint.

It is observed that the average and modal intervals for all the groups considered declined from the disinflation period to the stable inflation period. However, these intervals have increased following the global financial crisis to be close to the upper band of the inflation targeting range. The results indicate that the respondents may have learnt that the central bank will not necessarily act when consumer inflation grows at 4,5 percent, but that it will be more concerned about an outcome of 6 percent or higher.

This specific problem with target-band inflation targeting, as described in Du Plessis (2003), is in part the result of a situation where the edge of the target band becomes the focus of decision makers' and policy makers' deliberations, rather than the midpoint. According to Du Plessis (2003), this hardening of the edge of the inflation targeting range is associated with asymmetrical policy responses, which leads to inconsistent central bank loss-function effects. Communications from the South African Reserve Bank have noted the challenges with inflation expectations at the upper end of the target range (South African Reserve Bank, 2017 October), and subsequent monetary policy statements have included discussions that specifically refer to the midpoint of the inflation target range.

The high degree of flexibility induced by the broad inflation target band in South Africa has undermined efforts to anchor longer-term inflation expectations, according to Klein (2012), who also states that this may have complicated decision makers' expectations about the monetary policy stance. From the study results, it is clear that the implicit longer-term inflation expectations of the three BER Survey groups are not at the midpoint of the target band, but rather are closer to the upper end of the target band.

Research on the South African economy shows that there is a positive correlation between the upper level of the inflation targeting band and exchange rate volatility over the long run (see Du Plessis and Reid, 2015). This finding is supported by Amod and Hassan (2014), which shows that South African exchange rate volatility has increased post the implementation of inflation targeting, which coincided with the adoption of a flexible exchange rate regime. South Africa's inflation target band is among the highest of inflation targeting countries (see Du Plessis and Reid, 2015), and the commensurate higher nominal interest rate increases the scope for carry trade, which can add to exchange rate volatility (see Hassan, 2016).

A further policy challenge is the presence of heterogeneous beliefs. A recent contribution by Agliari et al. (2017) warns that setting the policy interest rate via the Taylor principle in a rational expectations modelling framework, where heterogeneity is present, may not be sufficient to achieve the inflation target and may well lead to instability.

4.7 Conclusion

Anchoring long-term inflation expectations is crucial; this according to Greenspan (1998), when he highlighted the link between short- and longer-term inflation expectations. In his testimony to Congress, he stated that if firms are convinced that longer-term inflation will remain stable, they will reserve increases in their prices as a last resort, fearing a loss of market share. Likewise, if households are convinced of longer-term price stability, they will not consider changes in short-term relative prices as motivations to alter their long-run inflation expectations. Progress toward this objective of longer-term price stability will dampen the impact of future supply shocks and make the economy less vulnerable to those that do occur. Greenspan's argument draws attention to the importance of the term structure of inflation expectations and its role in the price formation process.

A richer and more dynamic representation of the processes involved in forming inflation expectations in South Africa is required to sufficiently represent the data generating processes for short- and longer-term inflation expectations, which allows for the portrayal of observed intertemporal heterogeneity, digit preferencing and multi-modal distributional characteristics shown in this dissertation. The distributions of individual inflation expectations responses show a concentration at increments of 0.5 percentage points, a phenomenon known as digit preference, which is associated with the heterogeneous characteristics of decision makers. Another observation from these inflation expectations distributions is that the midpoint, of 4.5 percent, of the inflation target range does not appear to be a dominant (modal) choice among the respondents; rather 6 percent is a prominent choice among the business representatives and trade union officials for all the surveyed horizons and for the five-years-ahead horizon for financial analysts.

Interestingly the business representatives appear to have been the most pessimistic about longer-term inflation and had the highest average longer-term inflation expectation of the three groups in all three sub-periods. The most optimistic group about longer-term inflation expectations was the financial analysts (see Table 4.16). Also, the financial analysts group expected longer-term inflation to be mainly inside the inflation target range, while the other two groups did not. The business representative and trade union official groups were also much more uncertain about the longer-term inflation outlook than the financial analysts for the two-years-ahead horizon.

Drawing on some of the analogous properties between financial market (yield curves in particular) and inflation expectations data, term-structure modelling techniques were applied to differentiate between and estimate the data generating processes for short- and longer-term inflation expectations. This provides an efficient and parsimonious approach to estimating inflation expectations curves where the focus is on the perceived longer-term level for the purpose of estimating the perceived inflation anchors of the three BER Survey groups.

The term structure of inflation expectations is a conceptually continuous curve that represents different inflation expectations made at time t for different horizons in the future, analogous to the well-known yield-curve concept. This term-structure estimation approach, especially when estimated with a Kalman filter, is parsimonious, not restrictive and can handle missing data due to infrequent observations or limited availability of data. It can flexibly estimate and forecast inflation expectations over any horizon, even those that are not observed, and it is able to provide information on how inflation expectations evolve across forecast horizons and over time. Specifically, the estimation of the term structure of inflation expectations was based on the popular Nelson-Siegel (1987) framework, where three latent factors were estimated to distil the longer-term level or the perceived longer-term inflation focal point, the slope and the curvature of inflation expectations, based on the individual responses comprising the survey data.

The economic interpretation of the longer-term level provides information about the longer-term perceived inflation anchor, which is important for monitoring and for comparison with the announced target in a heterogeneous environment. The slope and curvature factors provide information on the expected speed of convergence of inflation expectations in reaching the announced target (Lewis, 2016). This information can usefully and timeously inform policy makers of an inflation targeting regime for making efficient policy decisions, when the perceived longer-term inflation anchor diverges from the inflation target.

The inflation expectation term structure for the financial analysts is downward sloping, and those of the business representatives and trade union officials are more flat. The financial analysts were less persistent in transmitting shocks to the longer-term expectations horizons, as is shown in the previous chapter, which contributed to their downward sloping inflation expectations curve.

Table 4.16: Summary of BER Survey longer-term perceived inflation expectations estimates [30]

	Financial analysts	Business representatives	Trade union officials
Accounting-based	5.5	6.9	6.6
Model-based	5.5	6.0	5.5
Kalman filter based	5.1	6.7	6.1

None of the approaches used in the study to approximate longer-term inflation expectations provided estimates close to the midpoint of the inflation target range for all three of the BER Survey groups analysed (Table 4.16). Most of the estimates are instead clustered around the upper end of the target range, with none of the estimates being recorded below 5 percent. The business representatives had the highest longer-term inflation expectations, which were above the 6 percent upper end of the inflation target band, regardless of the estimation approach used. The trade union officials had lower longer-term inflation expectations, and the financial analysts, the lowest. These results compare favourably with those of Kabundi et al. (2015) and Miyajima and Yetman (2018), who also found the longer-term inflation expectations anchors for the financial analysts to be the lowest of the three groups, and those of the business representatives and trade union officials to be close to the upper level of the target range. Kabundi et al. (2015) found the longer-term inflation expectations of the financial analysts to be anchored at 5.4 percent, those of the business analysts, at 6.8 percent and those of the trade union officials, at 6.6 percent, all estimated for the sample 2001q1 to 2013q1.

The three methods presented for estimating the term structures of survey-based inflation expectations were based on fairly different approaches. Yet all three provided very similar results, which indicates robustness and validates the suggested insights provided.

[30] Summary of conventional BER Survey data, not the time-to-maturity BER Survey data.

Chapter 5

Summary of findings presented in the thesis

5.1 Introduction

A key factor in the success of any inflation-targeting regime is the psychological process by which decision makers form their expectations of future inflation. In modern monetary theory, the link between monetary policy, prices and wages depends almost entirely on the expectations channel. It is often assumed (though seldom confirmed) in the models used in Monetary Economics that decision makers form their expectations of inflation rationally, that is, without bias or informational inefficiencies. This assumption simplifies model properties and eases solution convergence by reducing the number of potential solutions (Sargent, 1993). When rationality is not confirmed by the data, the conventional linkages in the transmission mechanism may be obscured, and model specifications should be sensitive to this. Knowledge of the methods used by decision makers to estimate future inflation can aid the policy environment and inflation-targeting frameworks in particular, which aim to monitor, influence and anchor the longer-term inflation expectations of decision makers.

The findings expounded in this thesis are that South African inflation expectations survey respondents did not behave consistently with rationality, mainly as a result of the informational inefficiencies and multiple variations of heterogeneity among the different BER groups. In addition there was a distinct difference between the short- and longer-term inflation expectations formation processes, i.e. intertemporal heterogeneity coupled with observed digit preference. Modelling frameworks for South African inflation expectations processes should hence reflect these characteristics to more accurately represent these observed processes. Due to the inherent similarities between yield-curve data and inflation expectations data, term-structure estimation procedures were applied. They are proposed as viable approaches for representing the process of forming inflation expectations that encompass and allow for several of the identified heterogeneities.

Inflation expectations are not directly observed, though, and this complicates analysis of the processes by which they are formed. Empirical proxies such as survey data, financial market expectations or model-based expectations are required for this purpose. In this dissertation, data from both the BER Inflation Expectations Survey and the RIE Survey were evaluated over different expectations horizons to assess the rationality and heterogeneity of expectations formation for different economic groups in South Africa. An important distinction in classification was made between fixed-event expectations and fixed-horizon expectations in analysing surveyed expectations data. In the study presented in this thesis both the unaltered original BER Survey data, which represents the fixed-event expectations, and an approximated version, which attempts to represent the fixed-horizon version, were analysed.

5.2: Inflation expectations behaviour in South Africa: bias and informational inefficiencies

Multiple definitions and interpretations of the rational expectations principle have evolved in the literature, and a clear consensus remains elusive. Often, rationality is informally believed to refer to incredible optimising individuals who form expectations of future events using all the available knowledge and models (see Sent (2006) for an overview). Another approach in the literature focuses more on the information set of the aggregate group, which is assumed to have systematic unbiased forecast errors (Mankiw et al., 2004), as motivated by Muth (1961), who argued that rational expectations should, on average, be an unbiased predictor of the actual outcome. Individuals need not always be correct according to Muth (1961), but their collective forecast error distribution should have a zero mean and minimum variance.

To obtain a perspective on the intended definition of rational expectations, the deliberations of the rational expectations pioneers were consulted. The rational expectations revolution was formalised in the period 1971–1973 (McCallum, 2002) and gained momentum following the Lucas critique (Sargent, 1973) and (Lucas, 1976) as research was guided more towards micro-level analyses, with a particular focus on the behaviour of decision makers. Sargent (2008) classified rational expectations as an encompassing modelling technique used widely throughout economics, rather than a school of economic thought. McCallum (2002) explains that the purpose of these models are to be structural (i.e. policy invariant) and these models are in some instances enhanced with explicit optimisation features where decision makers act in a dynamic and stochastic environment. According to Muth's (1961) principle of rational expectations, individual expectations need not necessarily the correct, but the distribution of their collective expectations are, on average, and should match the predictions of the applicable economic theory. This implies that expectations should be unbiased and their mean equal to the mean of the actual inflation outcome (i.e. the forecast error must be zero).

The premise of rationality tests is based on the requirement that decision makers form expectations to minimise and avoid systematic forecast errors and they involve tests for the unbiasedness, efficiency and orthogonality of the data (weakly rational). Secondly, if the expectations data outperforms the forecasts of naïve models, such as autoregressive moving-average (ARMA) models, then expectations may be classified as sufficiently rational. Thirdly, if the predictive power of the survey data outperforms a combination of various forecasts, then expectations may be classified as strictly rational (Granger and Newbold, 1973). The first chapter of this thesis reports on these tests applied to the South African inflation expectations survey data.

According to the results, the RIE Survey respondents, comprising mostly of financial analysts, formed unbiased expectations of CPIT inflation for the sample 2000q1 to 2016q4. These respondents were surprised by the influences of significant price shocks during 2002 and 2008, which emanated predominantly from adverse exchange rate and oil price movements. Both the duration and magnitude of these shocks were not fully anticipated and resulted in a series of underestimates of inflation which, in turn, hid some of the usual expectations-formation dynamics. When these two events are controlled for, the results of the unbiasedness test across all the forecast horizons still do not detect, on average, a systematic bias for the RIE Survey respondents.

The results for the BER survey respondent groups indicate that the financial analysts tended to form unbiased expectations over all five forecast horizons, even when the oil price and exchange rate shocks of 2002 and 2008 were controlled for, confirming the unbiasedness results from the RIE Survey, where the respondents are also financial market participants. The trade union officials and the business representatives groups appear to have formed unbiased CPIT inflation expectations over all horizons under consideration, except for the current horizon, where the business representatives tended to be biased. However, when the oil price and exchange rate shocks were controlled for, both these groups appear to have been biased towards systematically overestimating CPIT inflation over all five horizons. This result is consistent with the nature of wage negotiations on the part of trade unions, since the inflation outlook is an important point of discussion, and the loss incurred by underestimating inflation, and therefore accepting a lower wage increase for their members, could be problematic. Trade unions are averse to inflation surprises and motivated to increase the real wage premium of their members (Klein, 2003).

The results for the informational efficiency tests of the RIE and BER Survey respondents show that the null hypothesis of informational efficiency was strongly rejected in all cases. This suggests that past forecast errors contained useful information that was not utilised by the respondents, and therefore, these decision makers were inefficient in using the information at their disposal. Heterogeneity among decision makers and their inability to acquire and process relevant information are some of the impediments that prevent the empirical data to conform to the rational expectations theory. Although the RIE Survey respondents and the financial analysts group in the BER Survey appear to have formed unbiased expectations of CPIT inflation, the biasedness of the other two groups and the inefficiency of all the groups in using the available information led to the conclusion that none of the groups surveyed over the period under investigation can be considered to be weakly rational.

To determine the predictive ability of the RIE and BER Survey respondents, the inflation expectations data were compared with the forecasts of a random-walk model and an AR model. The RIE Survey expectations outperformed those of the random-walk model across all forecast horizons and outperformed the AR model's forecasts for the one-quarter- and two-quarters-ahead forecast horizons. The forecast error statistics analysed indicate that, over the shorter term, the expectations of the BER Survey groups outperformed those of the random-walk model, but only the financial analysts' expectations outperformed the AR models' current-year forecasts. As the forecast horizon extends (i.e. one year ahead and two years ahead), the evidence shows that the BER Survey groups' forecasting performance deteriorated somewhat so that it was worse than that of the AR model, but still outperformed the random walk model. This could be related to longer-term uncertainty about inflation and the difficulty associated with distinguishing between transitory and permanent shocks. The ability to correctly anticipate the magnitude and the persistence of these shocks may also complicate forecasting efforts – a situation to which the AR model forecast is largely immune. It appears that these longer-term expectations were not naïvely formed, yet all of the relevant information was not incorporated into the forecasting processes.

The business representatives and trade union officials groups' forecasting performance was notably worse than that of the financial analysts group across all the horizons analysed, demonstrating their inefficient use of available information, which was better utilised by the financial analysts group.

5.2.1 Conclusion

The data from the RIE and BER surveys show that decision makers do not form expectations rationally – the result of inefficient forecasting processes – and in some cases, systematically overestimated inflation on average. In the study presented in this thesis, tests were performed to evaluate these conditions in the RIE and BER Survey data on inflation forecasts. The respondents in the RIE Survey appear to have produced unbiased expectations of CPIT inflation, on average, across all expectation horizons under review. This result is supported by the analyses done on the data for the BER Survey, where the expectations of the financial analysts for CPIT inflation also appear to have been unbiased across short- and longer-term horizons. Heterogeneity in the form of bias to overestimate inflation was evident in the expectations of the business representatives and trade union officials for all three forecasting horizons. This was the case even when the oil price and exchange rate shocks were controlled for.

The fact that the inflation expectations survey data consistently outperformed the forecasting capability of a random walk process, with the exception of the current-quarter forecasts of the RIE Survey data, provides evidence that the formation of inflation expectations in South Africa cannot be classified as naïve. Notwithstanding this, there is much improvement that can be made by the respondents in order to efficiently analyse all available information, for it to perform better than the forecasts of the AR model.

In general, the evidence from both the RIE and BER Surveys suggests that South African decision makers probably do not form their inflation expectations rationally. The results reported here do not support the hypothesis of exclusively rational expectations in South Africa, mainly owing to the inefficient use of available information by the respondents. It does not seem appropriate to proxy inflation expectation processes for South Africa with the rational expectations principle, since it does not adequately represent the data generating processes observed for survey data. It is suggested that a richer representation of the inflation expectation formation process is required in a model context to enhance the approximated properties of the economic transmission mechanism and hence improve forecast capabilities.

5.3 South African inflation expectations: non-rational heterogeneity

In this study the factors or influences that likely underlie the actual decision rules whereby decision makers form inflation expectations were investigated. Consideration was given to extrapolative and adaptive behaviour (pre and post the financial crisis of 2008), information diffusion from a potential leader to followers, the perceived influence of external shocks and micro-level learning behaviour.

A common observation is that inflation expectations are not formed uniformly or homogenously. Departures from homogeneity require monetary authorities to understand the nature of expectation formation so that the appropriate policy can be prescribed at the appropriate time. Heterogeneity was observed across different surveyed groups, the information used, and the methodologies applied. Intertemporal heterogeneity — the differences in the processes that appear to govern expectation formation over shorter-term horizons compared with longer-term horizons — stands out. The distinction of intertemporal heterogeneity, i.e. different expectations formation behaviour in the short versus the longer term has, as far as could be determined, not been specifically addressed in recent papers.

The study presented in this thesis indicate that decision makers do not act in terms of a single approach when forming their expectations of consumer inflation. They do, however, appear to differentiate in terms of short-and longer-term approaches.

5.3.1 Influences on and determinants of inflation expectations rules

This study evaluated alternative approaches or influences that can affect expectations behaviour. Decision makers' expectations formation behaviour, or rules, can take on different forms, guided by adaptive behaviour, by adjustments made due to recent expectation errors, by the extrapolation of recent trends or by information diffusion (Curtin, 2006). Their approach may be influenced by the associated costs involved in the collecting and processing of information, and the benefits realised from producing an accurate inflation forecast.

Conventional tests indicated that the South African RIE and BER Survey respondents did not behave consistently with the rational expectations framework when they formed their inflation expectations, mainly due to their inefficient use of available information. Furthermore, their shorter-term expectations were formed differently from their longer-term ones; where the longer-term expectations were likely not focussed on the inflation target.[31] There are several approaches in the literature that attempt to define and test for anchored inflation expectations (see Dräger and Lamla (2014) for an overview of these). In this study expectations formation behaviour was considered anchored if changes in the information set had a negligible impact on expectations formation behaviour.

The pioneering specifications of rational expectations were tested to determine whether survey respondents behave accordingly or whether they behave heterogeneously. The influence of perceived financial experts, or information diffusion, on the formation of inflation expectations also received attention, and the impact of information surprises emanating from sudden exogenous shock events, proxied by exchange rate movements, was tested.

5.3.1.1 Extrapolative and adaptive inflation expectations behaviour

Many factors can influence the formation of inflation expectations, and according to the Hicks (1946) rule, adjustments to inflation expectations are proportionally related to an adjustment for the change in inflation, or inflation momentum. This formulation is known as the extrapolative expectations hypothesis, which states that inflation expectations are formed as the distributed lag functions of realised inflation. A limitation of the class of extrapolative expectations rules is that these are naïve and do not make allowance for decision makers to include their own expectations or to learn from forecast mistakes, since they are formulated as lagged representations of past inflation outcomes.

An alternative decision rule, the adaptive expectations rule, formalised by Cagan (1956) and Nerlove (1958), states that inflation expectations are revised proportionally to the last forecast error, and they labelled this as the adaptive expectations formulation. Support for adaptive behaviour is found if current and past information impacts significantly on expected inflation

[31] Kabundi et al., 2015 analysed BER survey data and confirm that South African two-year ahead inflation expectations are not anchored within the target range of 3 to 6 per cent.

The extrapolative expectations rule based on Hicks (1946) and the adaptive rule of Cagan (1956) and Nerlove (1958) were tested on the RIE and the BER Survey data. The conventional test of extrapolative and adaptive behaviour was applied across all surveyed horizons to distinguish between short- and longer-term behaviour and to assess the presence of heterogeneity between the groups, as well as intertemporal behaviour.

The RIE respondents projected almost half of the change in actual inflation into their current-quarter and one-quarter-ahead expectations. Over the longer-term horizons, this effect appears to have been muted. Observed inflation momentum appears to have impacted short-term expectations, but did not affect the longer-term expectations, which is indicative of intertemporal heterogeneity.

The results for the BER Survey respondents showed that the financial analysts appear to have been cognisant of inflation momentum, but mainly in the short-term, similar to the results for the RIE respondents, who are mainly financial market participants. The business representatives and trade union officials tended to extrapolate current inflation momentum into their longer-term expectations, albeit to a somewhat lesser degree over the longer term. It appears that these two groups showed more inflation expectations persistence than the financial analysts did in their behaviour. This may indicate that the longer-term outlook of the financial analysts is less sensitive to inflation momentum surprises, compared with that of the other two groups. The decay in the extrapolative behaviour of all three groups from the short-term to the longer-term horizons following an inflation surprise suggests that intertemporal heterogeneity was present and other factors were likely guiding their longer-term views. If a particular homogeneous group's longer-term adaptive coefficients are statistically significant and not notably smaller than the short-term adaptive coefficients, it might indicate respondents' uncertainty and unanchored longer-term inflation outlook as they incorporated persistence.

The Cagan-Nerlove adaptive expectations rule tests the sensitivity of respondents to the forecast error they had made in the previous period and was estimated over all reported forecast horizons for the RIE and BER Survey data. For every percentage point error made in their previous quarter's expectation, the RIE Survey respondents adjusted their inflation expectations for the current quarter and for the one-quarter-ahead by -0.9 and -0.5 percentage points on average, respectively. The negative sign shows that the respondents adjusted their expectation trajectory in the opposite direction to the forecast error. The adaptive coefficients for the two-quarters-ahead to five-quarters-ahead expectations decline over the longer-term horizons, and the six-quarters-ahead adaptive expectation coefficient is not statistically significant.

Based on the BER Survey data, for every one percentage-point expectation error that the financial analysts made, they adjusted their expectations for the current year, one year ahead, two years ahead, the current rolling horizon and the one-year-ahead rolling horizon by -0.39, -0.07, 0.08 (not statistically significant), -0.18 and -0.04 percentage points, respectively. This indicates their sensitivity to incorporating inflation surprises over the short-term horizon, yet the results show limited persistence over the longer-term horizons.

The decay of the coefficients associated with adaptive behaviour for both the RIE and BER Survey data, from the short- to the longer-term horizons, indicates that respondents did not think that the short-term inflation surprises will persist over the longer-term horizons, indicating intertemporal heterogeneity. It appears that their longer-term views were not necessarily affected by forecast mistakes, but rather by other factors in their information set.

Expectations formation processes are not static and may change following a major unanticipated event such as the global financial crisis. Therefore, the data was divided into two sub-samples, i.e. pre and post 2009q1 to contrast the resulting adaptive coefficients. To evaluate whether South African respondents' sensitivity towards inflation surprises were altered after the global financial crisis, the adaptive behaviour prior to the global financial crisis (2000-2008q4) and afterwards (2009-2016q4) was compared. The adaptive behaviour of the RIE respondents appear to have been somewhat more sensitive post the global financial crisis, although the decay in persistence over time remains present in both sub-samples. In particular, the average adaptive coefficient for the first four expectations horizons (i.e. the first four quarters) is -0.40 prior to, and -0.48 post the crisis. The respondent disagreement, proxied by the average standard error, increased only marginally from 0.09 in the pre-crisis period to 0.13 in the post-crisis period. Therefore, it appears that the adaptive behaviour of the RIE respondents was marginally more responsive (more negative) to inflation surprises and slightly more uncertain post the global financial crisis.

The adaptive behaviour results for the BER Survey correspond to those of the RIE Survey. The financial analysts and business representatives showed notable declines in their adaptive behaviour from the short-term to the longer-term horizons, which indicates that they did not adjust their longer-term expectations as much as they did their short-term expectations following inflation surprises. Therefore, their expectations appear to have been more anchored over the longer forecast horizons. This behaviour was not as pronounced for the trade union official group, who appear to have been less anchored, particularly following a major shock such as the global financial crisis. The trade union officials group showed increased longer-term persistence by almost double the pre-crisis magnitude, indicating their increased perpetuation of realised expectation errors.

According to the BER Survey results following the global financial crisis, the adaptive behaviour of the financial analysts group appeared to have been much more sensitive to inflation surprises over the short-term horizon, but remained largely unchanged over the longer-term horizons. They made notable changes by increasing their short-term adaptive behaviour, where the other two groups decreased their short-term adaptive behaviour slightly.

The respondents were not passive or inattentive when forming their short-term inflation expectations, since they incorporated information from their forecast mistakes and, to a lesser extent, momentum in observed inflation. Over the longer-term horizons, these impacts were not persistent and other factors in their information set were likely guiding their longer-term behaviour. When both the extrapolative and adaptive effects were accounted for in an estimated equation, it appears that the adaptive rule was more prominent than the extrapolative rule when both these effects were estimated simultaneously. In most cases the extrapolative effect was not statistically significant, where the adaptive effect was. This result is similar to that for the RIE Survey data, where respondents appear to have been more sensitive to forecast mistakes than to inflation momentum when formulating their expectations, notably over the short-term horizon. This result corresponds with that of Madeira and Zafar (2015) who found that US survey respondents did not believe that short-term surprises were persistent over longer periods.

5.3.1.2 Heterogeneous information diffusion

Decision makers, when forming their inflation expectations, may choose to draw on available information and forecasts from perceived financially knowledgeable leaders, which is often referred to as herd behaviour. Such a leader should be observed and regarded by the followers to have superior financial literacy and forecasting performance, hence the behaviour. The diffusion concept engineered by Carroll (2003), where agents adopt experts' forecasts with a certain probability, rather than their own, was applied to test whether diffusion of information from one group that was considered to be more financially literate than other groups did occur.

The degree of financial literacy is an important source of heterogeneity in inflation expectations according to Gnan et al. (2011). In an environment with varying degrees of financial literacy, the question is to what extent one group could be considered as a leader, or anchor, and the remaining groups as followers. Of additional interest is whether the followers incorporate information from a perceived leader heterogeneously.

The BER Survey reports on three groups with likely differentiated levels of financial literacy, where the presence of heterogeneous information diffusion was tested. The respondents in the financial analysts group of the BER inflation expectations survey are the most likely candidate group to have superior financial literacy compared with the business representatives and trade union officials groups.

The effects of expert input and own input were tested between the two groups and also over time. The results indicate that the business representatives and trade union officials groups tended to rely more on their own previous period's inflation expectation, i.e. possibly a naïve and inexpensive method of expectation formation, than on those of the assumed expert group. This finding is in accordance with Lombardelli and Saleheen (2003), Malmendier and Nagel (2009) and Ehrmann et al. (2015), that an important determinant of inflation expectations is the individual's own inflation experience over their lifetime.

Over longer expectation horizons, the expert group's influence on the other two groups appeared to have decreased, more so for the business representatives than for the trade union officials. Over longer horizons when faced with more uncertainty, the two groups appear to have preferred to draw on their own previous inflation expectation. This behaviour is in contrast to Carroll (2003) and Ehrmann et al. (2015) who found that respondents in the United States tended to converge towards professional forecasts over time. Heterogeneity was noted where the trade union officials group appears to have been far more influenced by the expert group than by the business representatives group over the longer horizon.

The evidence reported indicates that the business representatives and trade union officials groups were not motivated to believe or convinced that expert forecasts (assumed to have been by the financial analysts group) may enhance their information sets and ultimately their forecast accuracy. Over the short-term forecast horizons, respondents appear to have relied far more on their own past inflation experience, rather than hedging towards the forecasts of a more financially literate group. Even though this information diffusion effect was not dominant, the respondents relied even less on the financial literate group over longer forecast horizons. The lack of convergence of inflation expectations on one particular expert group also contributed to the heterogeneity between these groups.

5.3.1.3 Heterogeneous impact of open economy effects on inflation expectations

It has been established that the RIE and BER Survey respondents do not use available information efficiently when formulating their inflation expectations. Another source of information that may influence inflation expectations formation is the release of inflation-relevant economic information such as the exchange rate. One of the most prominent influences on an open economy's inflation is the exchange rate, since it impacts directly on the price of imports, transport costs and indirectly on various price categories. Indifference by decision makers to the exchange rate effect when formulating their inflation expectations could support the information inefficiency finding and provide insights into potential divergence or heterogeneity between different demographic groups on their use and interpretation of economic information (Mankiw et al., 2004).

When confronted with exchange rate shocks, the three BER Survey groups behaved heterogeneously. The financial analysts group adjusted their inflation expectation for the current year's expectation horizon more than did the other two groups, yet they discounted these shocks more in the one-year- and two-years-ahead horizons than did the other two groups. It is interesting that the trade union official group appears to have handled exchange shocks quite differently, by adjusting their one-year-ahead inflation expectation by more than the current year, and only slightly lowering their two-years-ahead inflation expectation, demonstrating more persistence than did the other groups.

It seems reasonable to conclude that the financial analysts group considered exchange rate shocks to have a more prominent, yet less persistent effect on inflation than did the other two groups. The trade union officials and business representatives behaved similarly in the current year's expectation horizon, but the former group tended to compensate more by increasing their perceived exchange rate impact for the one-year-ahead horizon, where the business representatives decreased theirs.

The notable decay of the exchange rate impact for the financial analysts and business representatives groups from the short-term to the longer-term horizons, suggests that intertemporal heterogeneity was present i.e. they followed different expectations formation processes for different expectation horizons. In addition, it appears that following an exchange rate shock, the financial analysts and business representatives groups were more anchored over the longer-term horizons than were the trade union representatives group, another source of heterogeneity.

Considering the size of the impact of the exchange rate on inflation expectations, it appears that the respondents favoured their own lagged inflation expectations and did not incorporate exchange rate news considerably in their annual inflation outlook. This supports the information inefficiency finding, and therefore the rational expectations assumption is not likely relevant to South African decision makers.

5.3.1.4 Adaptive learning

The process of inflation expectations formation involves estimating an initial expectation, but it also involves opportunities to revise these for any appropriate reason. It is shown by Anderson et al. (2010) that expectations formation by United States (US) agents are effected by engaging learning processes heterogeneously. The authors indicate that individual forecast accuracy is less diverse at the re-interview than at the initial interview, implying that the process of learning may reduce the initial heterogeneity.

To investigate whether the BER Survey respondents followed a process of learning, the approach by Anderson et al. (2010) was adopted. During the course of a calendar year, the respondents are approached four times, once per quarter, to submit forecasts for the current, the one-year-ahead and the two-years-ahead annual average consumer inflation number. Subsequent to the initial interview conducted during the first quarter of the year, the following three quarterly interviews provide respondents with the opportunity to revise their previously reported expectations, especially since new information is available for them to include into their information sets. As a result, these four instances ask respondents for overlapping forecasts, but on each subsequent occasion, more information is available, which the respondents may use to improve their forecast errors. These subsequent interviews were considered to be re-interviews.

An observed forecast change by the individual respondent upon subsequent re-interview alone does not imply learning. Respondents should incorporate the additional information such that their realised forecast error was smaller compared with the previous interview, to indicate successful learning. These re-interviews provide opportunities to examine whether individual respondents update and reconsider their information sets and hence meaningfully update their forecasts such that their absolute forecast errors are smaller from the first to the fourth interview for the year. Hence, the test aims to observe if learning behaviour improved their forecast accuracy.

The mean absolute errors of the respondents declined from the first to the fourth interview of the year. According to maximum likelihood estimations, only the current year's forecast horizons have a statistically significant decay for all the three groups considered. The financial analysts tended to have the best improvement in their forecast errors, by them declining by 0.31% from the first to the fourth quarter on average. The trade union officials improved their absolute forecast errors by 0.26%, and the business representatives improved theirs by 0.17% on average per consecutive quarter. The one-year- and two-years-ahead horizons did show slightly lower absolute errors over the four interviews, but these were not statistically significantly different from each other.

The short-term expectations formation processes of the individual BER Survey respondents indicate that they did learn and improve their forecast errors when re-interviewed for the same forecast event. However, this was not the case with the longer forecast horizons. Therefore, intertemporal heterogeneity was present with regard to how these individual respondents learnt. The respondents analysed here, appear to have followed a process of adaptive learning only in the short-term and seem to have been anchored to their own past inflation experiences in the longer-term.

5.3.2 Conclusion

Different types of heterogeneity were observed between the groups surveyed by the BER Survey. The financial analysts and the business representatives showed notable declines in their adaptive behaviour from the short-term to the longer-term horizons, indicating that they did not adjust their longer-term expectations by as much as they did their short-term expectations following inflation surprises. Therefore, they appear to have been more anchored over the longer forecast horizons. This behaviour was not as pronounced for the trade union officials group, who appear to have been less anchored, particularly following the global financial crisis.

In the short-term, respondents were motivated to change their expectations when they realised their forecast errors. They also considered inflation momentum, exchange rate effects, and they learnt from their forecast mistakes. Information diffusion from the financial analysts to the other two groups was also observed. However, over the longer-term horizons, it appears that mainly their own expectations mattered when forming their expectations. Economic news, forecast mistakes and information diffusion had almost no longer-term influence, but own perceived inflation did play a prominent role.

In the study presented in this thesis, several elements of the inflation expectations processes of decision makers, were investigated. Heterogeneity was observed across different groups, their perceptions of the persistence of inflationary shocks, their information diffusion from a more financial literate group and the degree of their learning. A common observation found in all the areas considered was the difference in the short- and longer-term processes of agents' expectation formation processes, i.e. intertemporal heterogeneity. The respondents were certainly not naïve when forming their expectations, but their intertemporal heterogeneity could pose a challenge for policy formulation, especially when central banks focus on influencing longer-term expectations.

5.4 The term structure of inflation expectations

Short- and longer-term inflation expectations follow different, yet linked processes. In this study, the individual inflation expectations of the BER Survey for the financial analysts, business representatives and trade union officials groups across both short and longer horizons were examined. Using distributional analyses, multiple focal points (digit preferencing) were observed for each BER survey group, and the associated heterogeneity complicates traditional estimation approaches. This occurs when conventional regression analyses aggregate information from the underlying distribution to provide singular parameter estimates. Under these circumstances, alternative estimation approaches are suggested to establish if longer-term inflation expectations are anchored and if so, at what level.

A richer and more dynamic representation of South African inflation expectations formation processes is required to separately represent the short- and longer-term data generating processes, based on the observed intertemporal heterogeneity and multi-modal distributional characteristics. Drawing on some of the analogous properties between financial market (yield curves in particular) and inflation expectations data, term-structure modelling techniques were applied to dynamically differentiate and estimate short- and longer-term expectations data generating processes, with a particular focus on the estimated longer-term level or perceived anchor of inflation expectations.

5.4.1 Inflation expectations curves estimated within term-structure frameworks

The term structure of inflation expectations is a continuous curve that represents different inflation expectations made at time t for different horizons in the future, analogous to the well-known yield-curve concept. This term-structure estimation approach is parsimonious, not shape restrictive and can handle missing data from infrequent observations and limited data availability. It can flexibly estimate and forecast inflation expectations over any horizon, even those that are not observed. These statistical models are able to indicate how inflation expectations evolve across horizons and over time and make a distinction between longer-term, medium-term and short-term processes.

In this study presented in this thesis, estimating the term structure of inflation expectations was based on the popular Nelson-Siegel (1987) approach, where three latent factors were estimated to distil the longer-term level or the perceived longer-term inflation focal point, the slope and the curvature of inflation expectations, based on the individual responses in the survey data. The economic interpretation of the level provides information about the longer-term perceived inflation anchor, which is useful for monitoring and comparing it with the announced inflation target. The slope and curvature factors provide information on the expected speed of convergence of inflation expectations in reaching the announced target (Lewis and McDermott, 2016). There are many different methods in the literature for estimating the factors of the Nelson-Siegel (NS) curve, and in the study presented in this thesis, three were used, one based on accounting formulas, another on a model and a third on a state-space Kalman filter approach.

5.4.2 Inflation expectations curves

Inflation expectations survey data can be quite sparse and often cover non-standard horizons. Combining such survey data to estimate a continuous inflation expectations term structure can be very useful in producing inflation expectations curves over any chosen horizon, especially in the presence of heterogeneity and digit preference behaviour among the respondents. The shape of an expectations curve can be modelled with a set of unobserved or latent factors that attempt to distil the whole information set of the curve at each point in time. In the study presented in this thesis, the set comprised three factors corresponding to level, slope and curvature (Rummel, 2013).

In the study presented in this thesis, the term structure of inflation expectations was modelled based on the Diebold and Li (2006) and later the Diebold et al. (2006) version of the NS curve, since it facilitates parsimony and convenient solution properties. The BER surveys South African inflation expectations data per individual respondent at discrete horizons, namely the current-year, one-year, two-years- and five-years-ahead horizons. These create a term structure of inflation expectations per respondent and per survey.

5.4.2.1 Factor analysis

The Nelson-Siegel (1987) framework usually involves estimating three latent factors to describe a term structure. However, the number of factors that best encapsulate a particular term structure may be different from three, and this assumption was validated with factor analysis. Factor analysis can be used to determine the number of factors that can parsimoniously summarise the changes in the underlying determinants of the inflation-expectations term structure (Bliss, 1997). This was done by condensing the information from observed variables to a smaller number of unobserved variables (or factors), by utilising the covariance structures between these. Such principal component analyses provide an indication of the number of unobserved factors that can be used to describe most of the data variability (Litterman and Scheinkman, 1991).

According to the principal component eigenvalue results, single-factor models are insufficient to explain the variation in the inflation expectations data of all three BER Survey groups. For the financial analysts, three factors explain 93 percent of the variation in their inflation expectations data, where one factor explains 53 percent. The expectations of the business representatives and the trade union officials appear to be dominated by one factor, which explains 77 percent and 74 percent of the variation in the data. The combination of two factors explain 93 percent and 95 percent of the variation, and three factors, 99 percent and 98 percent.

Based on the principal component analyses, at least two factors may be adequate to explain most of the variation in the inflation expectations data for the business representatives and the trade union officials. However, three factors appear to sufficiently represent most of the variation in the term structures of the three groups and were estimated as such.

5.4.2.2 Estimation of the three-factor model using approximating accounting formulas

The approximation to estimate the latent factors of the term structure was based on an accounting approach, in contrast to a stochastic approach, and provided a reasonable representation for the level, slope and curvature of the expectations curves. In terms of this approach, the financial analysts appear to have had a downward sloping expectations curve and have had the lowest longer-term inflation perception of 5.5 percent, which is consistent with the perception that perceived longer-term inflation would be lower than perceived inflation for the current-horizon. They also showed less uncertainty over the longer horizons. Short-term shocks were not considered to be persistent, as is shown by the narrowing of the distribution over the longer horizons.

The business representatives and the trade union officials appear to have flatter inflation expectations curves, and the trade union officials expected longer-term inflation at 6.1 percent. The business representatives appear to have been the most pessimistic about longer-term inflation at 6.5 percent, one percentage point higher than the expectations of the financial analysts. The distributions of the business representatives' and trade union officials' expectations do not narrow notably over the longer horizons, suggesting that they expected a relatively high degree of persistence of shocks and were less anchored to a longer-term focal point than the financial analysts.

All three inflation-term structure curves reached a longer-term level or anchor after 20 quarters, which was just below the upper target band for the financial analysts and just above the upper target band for the other two groups.

5.4.2.3 Model-based estimated factors

Even though the accounting-based approach to estimating the three factors of the term structure of inflation expectations is useful and intuitive, a model-based NS approach was used to potentially improve the fit of the estimated curves to the observed data and to evaluate the robustness of the results. This stochastic approach to estimating the inflation expectations curve factors used factor loadings calculated with lambda assumed at 0.3, which is consistent with the SARB estimate of the length of the SA transmission mechanism. These factor loadings were then used as three regressors in an ordinary-least-squares estimation of the coefficients of the level, slope and curvature of the term structure.

The business representatives have the highest inflation expectations curve – similar to the accounting-formula-based estimates for them – and the financial analysts, the lowest from four quarters onwards, and the same applies to their respective perceived longer-term inflation targets. The financial analysts have a longer-term inflation perception within the target band of 5.48 percent and that of the trade union officials was estimated to be 5.5 percent. The business representatives have perceived longer-term expectations at the upper end of the target band, at 6.0 percent.

The financial analysts' inflation expectations curve exhibits a downward slope, which implies that they did not expect short-term disturbances to persist. The business representatives and trade union officials also appear to have expected a deceleration in their inflation expectations trajectories, as shown by their negative slope factor, following the peak of the curve. However, the slope of the business representative's curve is much smaller in magnitude compared with that of the financial analysts, and the trade union officials' slope is not statistically significant. The curvature factors of all three groups are statistically significant.

5.4.2.4 State-space estimation of factors of inflation expectations curves

Inflation expectation curves can be reasonably represented by static versions of the NS specification; however, dynamic versions where the parameter estimates of lambda and the latent factors are allowed to vary can provide enhanced descriptions of the evolution of the term structures. State-space estimation provides an appropriate methodology for estimating such time-varying elements.

Due to the unobservability of the latent factors and the complexity of the estimation, the Kalman filter technique was used to estimate the time-varying parameters and lambda (lambda was assumed previously). Also, no explicit allowance was made to specify the correlation between the term structure factors.

The inflation expectations term structure for the financial analysts appears to be downward sloping – similar to the previous approaches for them – and those of the business representatives and trade union officials appear to be more flat. The financial analysts were less persistent in transmitting shocks to the longer-term expectations horizons, as shown in the previous chapter, which contributed to their downward-sloping inflation expectations curve.

None of the approaches used in the study presented in this thesis to approximate longer-term inflation expectations provides estimates close to the midpoint of the inflation target range for all three BER Survey groups analysed. Most of these estimates are instead clustered around the upper end of the target range, with none of the estimates recorded below 5 percent. The business representatives had the highest longer-term inflation expectations perception, which was above the 6 percent upper end of the inflation target band, regardless of the estimation approach used. The trade union officials had lower longer-term perceived inflation expectations, and the financial analysts, the lowest. These results compare favourably with those of Kabundi et al. (2015) and Miyajima and Yetman (2018) who also found the longer-term inflation expectations anchors for the financial analysts to be the lowest of the three groups, and those of the business representatives and trade union officials to be close to the upper level of the target range.

Even though the three methods presented for estimating the term structures of survey-based inflation expectations are based on fairly different approaches, all provided very similar results, which indicates robustness and validates the suggested insights provided.

5.5 Concluding summary

Inflation expectations by surveyed South African decision makers are not formed rationally, yet the survey respondents are not passive or inattentive, since they do observe and respond to certain influences, though heterogeneously and mainly in the short-term. Interestingly, they appear to prefer their own perceived judgement of longer-term inflation expectations - borne out by the influences tested and presented in this thesis, which did not significantly affect longer-term expectations behaviour. A dynamic representation of South African inflation expectations formation processes is required to represent sufficiently and separately the short- and longer-term data generating processes involved for inflation expectations, based on the observed non-rationality, multiple forms of heterogeneity and multi-modal distributional characteristics shown in the study presented in this thesis. Term structure analyses provide a robust, flexible and encompassing framework for facilitating a parsimonious representation of both short- and longer-term inflation expectations in South Africa and are suggested for empirical inflation expectations modelling frameworks. They also facilitate estimation of the longer-term level, or perceived anchor, of inflation expectations. The results obtained in using these analyses were very similar when using different methods and also when using the time-to-maturity version of the BER Survey data.

Appendices

Expectation horizon notation legend for Appendices:

x: current calendar year expectation; x + 1: one calendar year ahead expectation; x + 2: two calendar years ahead expectation; rx: current year rolling fixed-horizon expectation; rx1: one year ahead rolling fixed-horizon expectation.

Appendix A.1: Unbiased test based on Holden and Peel (1990)[32]

Estimate equation and perform t-test on *a*: $\pi^e_{t-k|t} - \pi_t = \alpha + v_t$

Table A.1.1 RIE Survey data: unbiased test results

	No adjustment for oil price and exchange rate shocks: n: 2000q1 – 2016q4	Adjustment for oil price and exchange rate shocks: n: 2000q1 – 2016q4	
Expectation	**T-test (prob)**	**T-test (prob)**	**Control** [33]
$\pi^e_{t\|t}$	0.550* (0.584)	1.426* (0.159)	02q1-q4, 03q2-04q1, 07q4-08q3
$\pi^e_{t-1\|t}$	-0.319* (0.750)	0.884* (0.380)	02q1-q4, 03q2-04q1, 08q1-08q3
$\pi^e_{t-2\|t}$	-0.751* (0.455)	0.989* (0.327)	02q2-03q1, 03q2-04q1, 07q4-08q4
$\pi^e_{t-3\|t}$	-0.981* (0.330)	0.837* (0.406)	02q2-03q1, 03q3-04q1, 07q4-08q4
$\pi^e_{t-4\|t}$	-1.141* (0.258)	0.484* (0.630)	02q2-03q1, 03q4-04q1, 07q4-08q4
$\pi^e_{t-5\|t}$	-1.192* (0.238)	0.338* (0.736)	02q2-03q1, 03q4-04q1, 07q4-08q4
$\pi^e_{t-6\|t}$	-1.174* (0.245)	0.395* (0.694)	02q2-03q1, 03q4-04q1, 07q4-08q4

Note: * = unbiased.

[32] In accordance with Brown and Maital (1981) and Mills and Pepper (1999), the covariance matrices were estimated by applying the procedure suggested by Newey and West (1987) in order to yield consistent standard errors.

[33] All dummy variables have p-values of 0.000, indicating statistical significance.

Table A.1.2 BER Survey: unbiased test results for business representatives, financial analysts and trade union officials [34] [35]

Business representatives	No control for exchange rate shocks		Control for exchange rate shocks		
Expectation	**T-test (prob)**	**JB test LM test**	**T-test (prob)**	**JB test LM test**	**Control (prob)**
Current (x) (n1)	2.001 (0.049)	0.228 0.000	3.819 (0.000)	0.569 0.000	Dum02, Dum08 (0.000), (0.000)
x+1 (n2)	1.315* (0.193)	0.002 0.000	3.683 (0.001)	0.190 0.000	Dum02, Dum08 (0.000), (0.000)
x+2 (n3)	1.411* (0.164)	0.002 0.000	3.539 (0.001)	0.392 0.000	Dum02, Dum08 (0.000), (0.000)
Rolling current year (rx) (n1)	2.023 (0.047)	0.119 0.000	4.253 (0.000)	0.806 0.000	Dum02, Dum08 (0.000), (0.000)
Rolling one-year-ahead (rx1) (n2)	1.322* (0.191)	0.001 0.000	3.787 (0.000)	0.149 0.000	Dum02, Dum08 (0.000), (0.000)
Financial analysts	**No control for exchange rate shocks**		**Control for exchange rate shocks**		
Expectation	**T-test (prob)**	**JB test LM test**	**T-test (prob)**	**JB test LM test**	**Control (prob)**
Current (x) (n1)	-0.077* (0.939)	0.000 0.000	1.379* (0.173)	0.000 0.000	Dum02q1, Dum08q1 (0.000), (0.000)
x+1 (n2)	-0.956* (0.343)	0.000 0.000	1.370* (0.176)	0.765 0.000	Dum02q1, Dum08q1 (0.000), (0.000)
x+2 (n3)	-0.996* (0.323)	0.000 0.000	0.316* (0.753)	0.463 0.000	Dum02, Dum08 (0.000), (0.000)
Rolling current year (rx) (n1)	-0.998* (0.322)	0.011 0.000	0.823* (0.414)	0.575 0.001	Dum02, Dum08 (0.000), (0.000)
Rolling one-year-ahead (rx1) (n2)	-1.147* (0.256)	0.000 0.000	0.850* (0.399)	0.723 0.000	Dum02, Dum08 (0.000), (0.000)
Trade union officials	**No control for exchange rate shocks**		**Control for exchange rate shocks**		
Expectation	**T-test (prob)**	**JB test LM test**	**T-test (prob)**	**JB test LM test**	**Control (prob)**
Current (x) (n1)	1.562 (0.123)	0.089 0.000	3.494 (0.001)	0.340 0.000	Dum02q1, Dum08q1 (0.000), (0.000)
x+1 (n2)	0.991* (0.326)	0.071 0.000	2.925 (0.005)	0.000 0.000	Dum02q1, Dum08q1 (0.000), (0.000)
x+2 (n3)	1.146* (0.257)	0.030 0.000	2.955 (0.005)	0.572 0.000	Dum02, Dum08 (0.000), (0.000)
Rolling current year (rx) (n1)	1.486* (0.142)	0.076 0.000	3.818 (0.000)	0.552 0.000	Dum02, Dum08 (0.000), (0.000)
Rolling one-year-ahead (rx1) (n2)	1.019* (0.312)	0.067 0.000	3.010 (0.004)	0.000 0.000	Dum02, Dum08 (0.000), (0.000)

[34] * = unbiased, JB = p-value Jarque Bera test for normality, LM = p-value Lagrange multiplier test for serial correlation (lag=4), Dum02 = 1 for 2002, Dum08 = 1 for 2008.

[35] Sample sizes: n1 = 2000q3-2016q4, n2 = 2001q3-2016q4, n3 = 2002q3-2016q4

Appendix A.2: Tests for informational efficiency[36]

Estimate the following equation, and test the null hypothesis for informational efficiency: H_0: $\alpha = \beta_j = 0$

$$\pi^e_{t-k|t} - \pi_t = \alpha + \sum_{j=1}^{n} \beta_j \left(\pi^e_{t-k|t,t-j} - \pi_{t-j}\right) + v_t$$

Table A.2.1 RIE Survey informational efficiency test results

Expectation	Lag (j)	Wald test	Null hypothesis
Current quarter (x)	1	p = 0.0003 (X^2)	Reject
x+1	1	p = 0.0000 (X^2)	Reject
x+2	2	p = 0.0000 (X^2)	Reject
x+3	2	p = 0.0000 (X^2)	Reject
x+4	2	p = 0.0000 (X^2)	Reject
x+5	2	p = 0.0000 (X^2)	Reject
x+6	2	p = 0.0000 (X^2)	Reject

Table A.2.2: BER Survey informational efficiency test results[37]

Respondent group	Expectation	Wald test	Null Hypothesis
Business representatives	Current year (x)	p = 0.0000	Reject
	x+1	p = 0.0000	Reject
	x+2	p = 0.0000	Reject
	rx	p = 0.0000	Reject
	rx1	p = 0.0000	Reject
Financial analysts	Current year (x)	p = 0.0000	Reject
	x+1	p = 0.0000	Reject
	x+2	p = 0.0000	Reject
	rx	p = 0.0000	Reject
	rx1	p = 0.0000	Reject

36 The covariance matrices were estimated by applying the procedure suggested by Newey and West (1987) to yield consistent standard errors. Sample: 2000q1-2016q4.

37 The lag in equation specification was specified as 1, due to degrees of freedom constraints.

Trade union officials	Current (x)	p = 0.0000	Reject
	x+1	p = 0.0000	Reject
	x+2	p = 0.0000	Reject
	rx	p = 0.0000	Reject
	rx1	p = 0.0000	Reject

Appendix A.3: Description of forecast-error test statistics

In an attempt to replicate the expectations-formation processes and real-time information sets used at the time of the published RIE expectations, the random-walk and AR models were simulated on a rolling monthly basis. The random-walk model was without drift. The AR model for the RIE data contained a constant, AR(1), AR(2) and AR(12) terms. The AR models for the BER data contained a constant, AR(1) and AR(2) terms. These forecasts were then aggregated into quarterly frequencies by averaging the monthly estimates.

Suppose the forecast sample is $j = T + 1, T + 2, \ldots, T + h$ and denotes the actual and forecast value in periods as y_t and $\hat{y}_t$, respectively. The reported forecast error statistics were computed as follows:

Root-mean-squared error (RMSE): $\sqrt{\sum_{t=T+1}^{T+h} (\hat{y}_t - y_t)^2 / h}$

Theil inequality coefficient:

$$\frac{\sqrt{\sum_{t=T+1}^{T+h} (\hat{y}_t - y_t)^2 / h}}{\sqrt{\sum_{t=T+1}^{T+h} (\hat{y}_t)^2 / h} + \sqrt{\sum_{t=T+1}^{T+h} (y_t)^2 / h}}$$

Table A.3.1: RIE Survey forecast error test statistics (Sample: 2000q1-2016q4)

	Random-walk model		AR model		Reuters consensus	
	RMSE	**Theil**	**RMSE**	**Theil**	**RMSE**	**Theil**
Current	0.402	0.030	0.322	0.024	0.571	0.043
x+1	1.371	0.103	1.190	0.090	1.113	0.086
x+2	2.123	0.160	1.752	0.134	1.766	0.139
x+3	2.683	0.203	2.077	0.159	2.075	0.168
x+4	3.067	0.232	2.244	0.173	2.336	0.192
x+5	3.278	0.248	2.265	0.175	2.465	0.205
x+6	3.423	0.258	2.279	0.176	2.574	0.215

Table A.3.2: BER Survey forecast error test statistics (Sample: 2000q1-2016q4)

		AR model	**Random-walk model**	**Financial analysts**	**Business representatives**	**Trade union officials**
Current year (fixed event)	RMSE Theil	1.375 0.106	1.501 0.114	0.802 0.062	1.507 0.112	1.463 0.110
1 year ahead (fixed event)	RMSE Theil	2.013 0.156	2.913 0.222	2.049 0.168	2.511 0.188	2.570 0.194
2 years ahead (fixed event)	RMSE Theil	2.069 0.161	3.558 0.269	2.245 0.191	2.784 0.211	2.905 0.221
Current year rx (fixed horizon)	RMSE Theil	1.648 0.127	1.501 0.114	1.251 0.100	1.899 0.143	1.843 0.140
1 year ahead rx1 (fixed horizon)	RMSE Theil	2.023 0.157	2.913 0.222	2.082 0.175	2.618 0.199	2.710 0.208

Appendix B.1: Estimated coefficients of extrapolative and adaptive expectations tests[38]

Rule: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-k}^{e,h} - \pi_{t-k}^{h}) + v_t$

Let *h* = current for the current year, x+1 for one-quarter-ahead, x+2 for two-quarters-ahead, x+3 for three-quarters-ahead, x+4 for four-quarters-ahead, x+5 for five-quarters-ahead and x+6 for six-quarters-ahead horizons. Let *k* = the quarterly time operator

Table B.1.1: RIE Survey adaptive expectations coefficients (sample 2000q2-2016q4)

	Current	x+1	x+2	x+3	x+4	x+5	x+6
β	**-0.890**	**-0.527**	**-0.285**	**-0.102**	**-0.039**	**-0.022**	**-0.012**
T-stat	-3.46	-8.90	-9.24	-4.46	-4.47	-2.85	-1.30
Std error	0.257	0.059	0.031	0.023	0.009	0.008	0.009
JB	0.117	0.938	0.708	0.126	0.012	0.58	0.549
LM	0.017	0.565	0.010	0.032	0.047	0.953	0.354
Control dummy	03q2, 09q1,	03, 09q1q2	03, 09q2q3	02q403q1, 03q4, 09q3	03q1q2n, 09q2,09q4	09q3, 10q1q2	09q4

Note: JB refers to the Jarque-Bera test for the null hypothesis of normal distributed error terms. LM refers to the Breusch-Godfrey Lagrange-Multiplier test for the null hypothesis of non-serially correlated error terms.

Table B.1.2: RIE Survey adaptive expectations coefficients: pre-financial crisis (**s**ample 2000q2-2008q4)

	Current	x+1	x+2	x+3	x+4	x+5	x+6
β	**-0.724**	**-0.530**	**-0.281**	**-0.069**	**-0.043**	**-0.031**	**-0.009**
T-stat	-2.72	-7.06	-7.71	-4.92	-3.78	-3.19	-1.07
Std error	0.266	0.075	0.036	0.014	0.011	0.010	0.008
JB	0.675	0.839	0.743	0.252	0.077	0.342	0.881
LM	0.132	0.817	0.231	0.039	0.114	0.551	0.087
Control dummy	03	03	03	02q403q1, 03q4	03q1q2	03	03

Table B.1.3: RIE Survey adaptive expectations coefficients: post-financial crisis (sample 2009q1-2016q4)

	Current	x+1	x+2	x+3	x+4	x+5	x+6
β	**-0.833**	**-0.493**	**-0.348**	**-0.262**	**-0.038**	**-0.006**	**-0.033**
T-stat	-3.27	-3.09	-5.87	-5.36	-2.93	-0.93	-2.01
Std error	0.255	0.160	0.059	0.049	0.013	0.006	0.016
JB	0.697	0.915	0.869	0.668	0.505	0.610	0.368
LM	0.020	0.686	0.022	0.116	0.098	0.328	0.751
Control dummy	09q1, 09q3	09q1q2	09q2q3	09q3	09q2,09q4	09q3, 10q1q2	09q4

[38] Note: Newey-West standard errors.

Table B.1.4: RIE Survey extrapolative expectations coefficients

Rule: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \gamma(\pi_{t-1}^{h} - \pi_{t-2}^{h}) + v_t$

Estimated sample 2000q2-2016q4

	Current	x+1	x+2	x+3	x+4	x+5	x+6
ɣ	**0.471**	**0.520**	**0.182**	**0.063**	**0.028**	**0.000**	**-0.019**
T-stat	5.130	6.772	2.313	1.697	1.843	0.006	-1.301
Std error	0.092	0.077	0.079	0.037	0.015	0.019	0.015
JB	0.36	0.903	0.485	0.283	0.691	0.155	0.651
LM	0.166	0.015	0.011	0.011	0.037	0.832	0.611
Control dummy	03q2, 08q3q4, 09q1	09q1q2	03q4, 08q4, 09q2q3	03q4, 02q403q1, 09q1, 09q3,	03q1q2n, 04q1, 05q1, 09q2,09q4,	09q3, 10q1q2,	09q4

Table B.1.5: RIE Survey extrapolative and adaptive expectations coefficients

Rule: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-k}^{e,h} - \pi_{t-k}) + \gamma(\pi_{t-1} - \pi_{t-2}) + v_t$

Estimated sample 2000q2-2016q4

	Current	x+1	x+2	x+3	x+4	x+5	x+6
β	**-0.524**	**-0.479**	**-0.330**	**-0.114**	**-0.033**	**-0.024**	**-0.016**
T-stat	-2.010	-5.789	-7.263	-4.063	-4.507	-3.578	-1.726
Std error	0.261	0.083	0.045	0.028	0.007	0.007	0.009
ɣ	**0.288**	**0.070**	**-0.109**	**-0.053**	**0.031**	**-0.014**	**-0.028**
T-stat	3.192	0.829	-1.707	-1.002	1.149	-0.776	-2.313
Std error	0.090	0.085	0.064	0.053	0.027	0.018	0.012
JB	0.141	0.885	0.618	0.447	0.170	0.608	0.520
LM	0.010	0.421	0.027	0.120	0.010	0.948	0.407
Control dummy	03q2, 09q1	03, 09q1q2	03, 09q2q3	02q403q1, 03q4, 09q3	03q1q2n, 09q2,09q4,	09q3, 10q1q2,	09q4

Table B.1.6: BER Survey own-horizon forecast error impact

Rule: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-k}^{e,h} - \pi_{t-k}) + v_t$

Fe (t-k), where h = horizon category, k = 1 (current year); 5 (one year ahead); 9 (two years ahead)

Estimated sample 2000q4-2016q4.

Horizon		Financial	Business rep	Trade unions
	Financial			
x	β; k=1	-0.386	-0.175	-0.263
	T-stat	-9.320	-5.187	-7.654
	α	0.113	0.111	0.152
	T-stat	4.165	3.211	2.800
	JB	0.257	0.038	0.046
	LM	0.147	0.025	0.236
x+1	β; k=5	-0.063	-0.052	-0.075
	T-stat	-2.481	-2.357	-6.047
	α	0.034	0.033	0.079
	T-stat	0.800	0.731	1.693
	JB	0.982	0.180	0.028
	LM	0.150	0.443	0.900
x+2	β; k=9	-0.031	-0.037	-0.074
	T-stat	-3.274	-3.749	-4.017
	α	0.025	0.003	0.092
	T-stat	1.430	0.082	1.261
	JB	0.665	0.738	0.242
	LM	0.069	0.890	0.452
rx	β; k=1	-0.324	-0.095	-0.199
	T-stat	-4.427	-2.063	-6.752
	α	0.016	-0.016	0.079
	T-stat	0.286	0.044	2.021
	JB	0.183	0.718	0.031
	LM	0.029	0.290	0.030
rx1	β; k=5	-0.024	-0.046	-0.054
	T-stat	-1.725	-2.785	-2.684
	α	0.013	0.002	-0.039
	T-stat	0.564	0.044	-0.863
	JB	0.530	0.718	0.101
	LM	0.010	0.290	0.389

Table B.1.7: BER Survey short-term forecast error impact

Model: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-1}^{e,1} - \pi_{t-1}) + v_t$

Current forecast error, how current horizon error affects longer-term expectations

Estimated sample 2000q4-2016q4.

Horizon		Fin analysts	Business rep	Trade unions
x	β	-0.386	-0.175	-0.263
	T-stat	-9.320	-5.187	-7.654
	α	0.113	0.111	0.152
	T-stat	4.165	3.211	2.800
	JB	0.257	0.038	0.046
	LM	0.147	0.025	0.236
x+1	β	-0.072	-0.073	-0.115
	T-stat	-1.602	-2.500	-1.595
	α	0.049	-0.001	0.007
	T-stat	1.251	-0.052	0.098
	JB	0.884	0.981	0.010
	LM	0.019	0.260	0.035
x+2	β	0.080	-0.014	-0.029
	T-stat	3.718	-0.675	-0.466
	α	0.037	-0.048	-0.056
	T-stat	1.447	-1.174	-0.664
	JB	0.730	0.887	0.186
	LM	0.673	0.744	0.050
rx	β	-0.179	-0.083	-0.199
	T-stat	-3.547	-1.949	-6.752
	α	0.003	-0.015	0.079
	T-stat	0.033	-0.223	2.021
	JB	0.706	0.736	0.031
	LM	0.064	0.567	0.030
rx1	β	-0.038	-0.057	-0.145
	T-stat	-1.622	-1.579	-2.269
	α	0.010	-0.008	-0.014
	T-stat	0.427	-0.223	-0.189
	JB	0.531	0.736	0.513
	LM	0.025	0.567	0.221

Table B.1.8: BER Survey extrapolative impacts

Model: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \gamma(\pi_{t-k}^{h} - \pi_{t-k-1}^{h}) + v_t$

Used quarterly y/y consumer inflation, not annual average.

Estimated sample 2000q4-2016q4.

Horizon		Fin analysts	Business rep	Trade unions
x	γ; k=1	0.209	0.172	0.357
	T-stat	2.120	3.544	5.999
	α	0.147	-0.026	0.069
	T-stat	1.635	-0.704	1.356
	JB	0.019	0.041	0.061
	LM	0.224	0.444	0.044
x+1	γ; k=5	0.048	0.112	0.208
	T-stat	0.910	2.637	4.798
	α	0.080	-0.015	0.042
	T-stat	1.812	-0.472	1.132
	JB	0.310	0.165	0.016
	LM	0.093	0.773	0.466
x+2	γ; k=9	0.044	0.085	0.118
	T-stat	1.776	1.824	1.639
	α	0.019	-0.008	-0.045
	T-stat	0.690	-0.212	-0.728
	JB	0.377	0.715	0.226
	LM	0.093	0.313	0.275
rx	γ; k=1	0.169	0.184	0.221
	T-stat	2.072	3.145	2.975
	α	0.051	0.005	0.007
	T-stat	0.807	0.207	0.148
	JB	0.051	0.363	0.106
	LM	0.342	0.042	0.232
rx1	γ; k=5	-0.008	0.101	0.185
	T-stat	-0.220	1.853	2.863
	α	0.037	0.007	0.018
	T-stat	1.126	0.207	0.311
	JB	0.215	0.363	0.080
	LM	0.527	0.042	0.254

Table B.1.9: BER Survey own horizon forecast error and extrapolative impacts

Model: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-k}^{e,h} - \pi_{t-k}) + \gamma(\pi_{t-k} - \pi_{t-k-2}) + v_t$

D(CPI(t-1)), Fe (t-k), where h = horizon category, k = 1 (current year); 5 (one year ahead); 9 (two years ahead)

Used quarterly y/y consumer inflation, not annual average.

Estimated sample 2000q4-2016q4.

Horizon		Fin analysts	Business rep	Trade unions
x	β; k=1	-0.419	-0.101	-0.225
	T-stat	-6.146	-3.477	-5.203
	γ	0.091	0.118	0.038
	T-stat	1.133	3.144	0.596
	JB	0.000	0.054	0.841
	LM	0.030	0.253	0.013
x+1	β; k=5	-0.119	-0.050	-0.084
	T-stat	-4.483	-2.263	-4.792
	γ	0.026	-0.023	-0.046
	T-stat	0.586	-0.546	-1.158
	JB	0.725	0.662	0.049
	LM	0.017	0.815	0.215
x+2	β; k=9	-0.045	-0.054	-0.082
	T-stat	-4.104	-2.942	-3.823
	γ	0.047	0.079	0.104
	T-stat	2.392	1.968	1.747
	JB	0.413	0.852	0.459
	LM	0.344	0.685	0.076
rx	β; k=1	-0.146	-0.122	-0.140
	T-stat	-3.368	-5.267	-4.132
	γ	0.137	0.106	0.120
	T-stat	1.757	1.864	1.361
	JB	0.023	0.072	0.810
	LM	0.453	0.051	0.040
rx1	β; k=5	-0.046	-0.085	-0.057
	T-stat	-2.917	-5.068	-2.535
	γ	-0.002	-0.018	-0.064
	T-stat	-0.059	-0.351	-1.579
	JB	0.848	0.129	0.040
	LM	0.194	0.324	0.319

Table B.1.10: BER Survey short-term adaptive expectations coefficients: Sub-samples

Model: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-1}^{e,1} - \pi_{t-1}) + v_t$

	Horizon		Business rep	Fin analysts	Trade unions
Pre-financial crisis Sample: 2000q2-2008q4	Current year (fixed event)	β (T-stat) JB LM	-0.213 (-5.95) 0.393 0.038	-0.440 (-7.39) 0.056 0.017	-0.288 (-7.70) 0.926 0.047
	1 year ahead (fixed event)	β (T-stat) JB LM	-0.053 (-2.74) 0.077 0.713	-0.061 (-4.23) 0.225 0.545	-0.116 (-2.78) 0.831 0.097
	2 years ahead (fixed event)	β (T-stat) JB LM	-0.026 (-1.46) 0.200 0.683	-0.013 (-0.66) 0.317 0.409	-0.126 (-2.91) 0.976 0.839
	Current year rx (fixed horizon)	β (T-stat) JB LM	-0.193 (-4.31) 0.217 0.292	-0.193 (-6.41) 0.797 0.146	-0.207 (-10.80) 0.805 0.175
	1 year ahead rx1 (fixed horizon)	β (T-stat) JB LM	-0.051 (-2.61) 0.462 0.229	-0.042 (-2.66) 0.574 0.294	-0.123 (-3.09) 0.578 0.238
Post-financial crisis Sample: 2009q1-2016q4	Current year (fixed event)	β (T-stat) JB LM	-0.101 (-1.63) 0.160 0.228	-0.632 (-8.39) 0.211 0.179	-0.102 (-1.61) 0.112 0.056
	1 year ahead (fixed event)	β (T-stat) JB LM	-0.044 (-1.83) 0.846 0.333	-0.014 (-0.51) 0.464 0.362	-0.205 (-5.45) 0.323 0.014
	2 years ahead (fixed event)	β (T-stat) JB LM	-0.007 (-0.22) 0.825 0.360	-0.022 (-1.50) 0.886 0.323	-0.105 (-1.60) 0.390 0.488
	Current year rx (fixed horizon)	β (T-stat) JB LM	-0.101 (-2.312) 0.812 0.283	0.171 (0.971) 0.628 0.081	-0.101 (-2.34) 0.466 0.526
	1 year ahead rx1 (fixed horizon)	β (T-stat) JB LM	-0.046 (-2.02) 0.201 0.175	-0.068 (-2.52) 0.861 0.063	-0.208 (-5.62) 0.656 0.066

Table B.1.11: BER Survey own horizon adaptive expectations coefficients: Sub-samples

Model: $\pi_t^{e,h} - \pi_{t-1}^{e,h} = \alpha + \beta(\pi_{t-k}^{e,h} - \pi_{t-k}) + v_t$

where h = horizon category, k = 1 (current year); 5 (one year ahead); 9 (two years ahead)

	Horizon		Business rep	Fin analysts	Trade unions
Pre-financial crisis Sample: 2000q2-2008q4	Current year (fixed event)	β (T-stat)	-0.213 (-5.95)	-0.440 (-7.39)	-0.288 (-7.70)
		JB	0.393	0.056	0.926
		LM	0.038	0.017	0.047
	1 year ahead (fixed event)	β (T-stat)	-0.106 (-3.68)	-0.099 (-3.01)	-0.116 (-2.78)
		JB	0.685	0.664	0.831
		LM	0.429	0.010	0.097
	2 years ahead (fixed event)	β (T-stat)	-0.109 (-2.84)	0.006 (0.22)	-0.126 (-2.91)
		JB	0.439	0.364	0.976
		LM	0.577	0.161	0.839
	Current year rx (fixed horizon)	β (T-stat)	-0.193 (-4.31)	-0.193 (-6.41)	-0.207 (-10.80)
		JB	0.217	0.797	0.805
		LM	0.292	0.146	0.175
	1 year ahead rx1 (fixed horizon)	β (T-stat)	-0.103 (-2.85)	-0.042 (-2.66)	-0.123 (-3.09)
		JB	0.349	0.574	0.578
		LM	0.208	0.294	0.238
Post-financial crisis Sample: 2009q1-2016q4	Current year (fixed event)	β (T-stat)	-0.101 (-1.63)	-0.632 (-8.39)	-0.102 (-1.61)
		JB	0.160	0.211	0.112
		LM	0.228	0.179	0.056
	1 year ahead (fixed event)	β (T-stat)	-0.044 (-1.83)	-0.014 (-0.51)	-0.258 (-10.53)
		JB	0.846	0.464	0.123
		LM	0.333	0.362	0.428
	2 years ahead (fixed event)	β (T-stat)	-0.004 (-0.14)	-0.022 (-1.50)	-0.105 (-1.60)
		JB	0.850	0.886	0.390
		LM	0.146	0.323	0.488
	Current year rx (fixed horizon)	β (T-stat)	-0.101 (-2.31)	-0.010 (-0.081)	-0.101 (-2.34)
		JB	0.812	0.371	0.466
		LM	0.283	0.213	0.526
	1 year ahead rx1 (fixed horizon)	β (T-stat)	-0.150 (-1.95)	-0.068 (-2.52)	-0.208 (-5.62)
		JB	0.214	0.861	0.655
		LM	0.102	0.063	0.066

Appendix B.2: Information diffusion from experts to business analysts and trade union officials[39]

Table B.2.1: Comparison of coefficients between groups and over time, coefficients restricted

Model: $\pi_{j,t}^{e,h} = \alpha_0 + \alpha_1 \, \pi_{fin,t}^{e,h} + (1-\alpha_1)\pi_{j,t-1}^{e,h} + \epsilon_t$

Estimated sample 2000q4-2016q4

	α_0	Expert (α_1)	Own lag ($1-\alpha_1$)	Sample
Business representatives (j=1): Current year	0.169 (3.782)	0.322 (5.820)	0.678	2000q4-2016q4
One year ahead	0.117 (2.680)	0.136 (3.345)	0.864	2001q4-2017q4
Two years ahead	0.076 (1.112)	0.067 (1.182)	0.933	2002q4-2018q4
Trade union officials (j=2): Current year	0.156 (3.723)	0.379 (10.523)	0.621	2000q4-2016q4
One year ahead	0.202 (3.504)	0.308 (6.840)	0.692	2001q4-2017q4
Two years ahead	0.290 (2.891)	0.330 (4.079)	0.670	2002q4-2018q4

Table B.2.2: Comparison of coefficients between groups and over time, coefficients not restricted

Model: $\pi_{j,t}^{e,h} = \alpha_0 + \alpha_1 \, \pi_{fin,t}^{e,h} + \alpha_2\pi_{j,t-1}^{e,h} + \epsilon_t$

	α_0	Expert (α_1)	Own lag (α_2)	Sample
Business representatives (j=1): Current year	0.088 (0.517)	0.326 (5.911)	0.686 (11.355)	2000q4-2016q4
One year ahead	-0.915 (-3.952)	0.296 (5.174)	0.882 (25.390)	2001q4-2017q4
Two years ahead	-1.213 (-1.569)	0.382 (1.753)	0.868 (10.562)	2002q4-2018q4
Trade union officials (j=2): Current year	-0.030 (-0.153)	0.390 (11.645)	0.639 (13.667)	2000q4-2016q4
One year ahead	-0.937 (-2.465)	0.483 (8.462)	0.713 (15.990)	2001q4-2017q4
Two years ahead	-1.665 (-1.486)	0.754 (2.722)	0.620 (6.690)	2002q4-2018q4

[39] Note: t-statistics in parenthesis (Newey-West standard errors).

Appendix B.3: Open-economy impacts[40]

Table B.3.1: Comparison of coefficients between groups and over time, coefficients not restricted

Model: $\pi_{x,t}^{e,h} = \alpha_0 + \alpha_1 exd_t + \alpha_2 \pi_{x,t-1}^{e,h} + \epsilon_t$

Estimated sample 2000q4-2016q4

	α_0 : Constant	α_1: Exchange rate	α_2: Own lag
Financial analysts:			
Current year	0.083 (0.322)	0.019 (5.031)	0.988 (19.329)
One year ahead	1.239 (3.955)	0.007 (3.020)	0.780 (13.688)
Two years ahead	0.661 (1.920)	0.003 (1.669)	0.878 (14.005)
Business representatives:			
Current year	0.409 (2.552)	0.006 (3.296)	0.925 (37.976)
One year ahead	0.346 (2.186)	0.004 (2.509)	0.937 (37.791)
Two years ahead	0.282 (1.174)	0.002 (0.727)	0.952 (24.863)
Trade union officials:			
Current year	0.818 (3.077)	0.008 (2.817)	0.847 (18.929)
One year ahead	0.553 (1.227)	0.014 (3.599)	0.897 (12.566)
Two years ahead	1.348 (3.997)	0.009 (2.931)	0.768 (14.436)

[40] Note: t-statistics in parenthesis (Newey-West standard errors)

Table B.3.2: Comparison of coefficients between groups and over time, coefficients restricted

Model: $\pi_{x,t}^{e,h} = \alpha_0 + \alpha_1 exd_t + (1 - \alpha_1)\,\pi_{x,t-1}^{e,h} + \epsilon_t$

Estimated sample 2000q4-2016q4

	α_0 : **Constant**	α_1: **Exchange rate**	**(1-α_1): Own lag**
Financial analysts:			
Current year	0.125 (1.438)	0.019 (5.088)	0.981
One year ahead	0.064 (1.471)	0.003 (1.234)	0.997
Two years ahead	0.012 (0.484)	0.003 (1.800)	0.997
Business representatives:			
Current year	-0.032 (-0.908)	0.005 (2.629)	0.995
One year ahead	-0.035 (-1.012)	0.004 (1.705)	0.996
Two years ahead	-0.031 (-0.924)	0.002 (0.830)	0.998
Trade union officials:			
Current year	-0.101 (-1.496)	0.009 (2.510)	0.991
One year ahead	-0.052 (-0.819)	0.016 (3.625)	0.984
Two years ahead	-0.067 (-1.399)	0.007 (1.811)	0.993

Appendix B.4: Adaptive learning: BER Survey respondents

Table B.4.1: Average absolute errors: financial analysts

Interview number	Current year	One year ahead	Two years ahead
1	1.13	1.94	1.47
2	0.76	1.79	1.46
3	0.35	1.59	1.28
4	0.22	1.62	1.38
F-test	4.86	0.38	0.55
n (set of four obs)	104	95	75

Table B.4.2: Average absolute errors: trade union officials

Interview number	Current year	One year ahead	Two years ahead
1	1.97	2.65	2.55
2	1.84	2.78	2.63
3	1.38	2.50	2.56
4	1.27	2.35	2.15
F-test	4.86	0.38	0.55
n (set of four obs)	67	55	54

Table B.4.3: Average absolute errors: business representatives

Interview number	Current year	One year ahead	Two years ahead
1	1.83	2.26	2.54
2	1.61	2.27	2.54
3	1.43	2.15	2.44
4	1.33	2.12	2.40
F-test	68.09	2.6	2.14
n (set of four obs)	2242	1805	1621

The following equation was estimated:

$$\left|\pi_{i,t|t+k}^{e,h,q} - \pi_{t+k}\right| = \alpha_0 + \alpha_1\ Interview^q + \varepsilon_t$$

Where q = interview number (1,2,3,4), h = forecast horizon classifier (current year, one year ahead, two years ahead), k = the quarter for which the forecast was made, i = respondent 1,…,N and t = time. The parameter α_0 denotes the intercept, α_1 the average individual-specific adaptive learning parameter and ε_t the stochastic error term. In this equation individual respondents were tested to establish whether they do exhibit learning characteristics where the absolute forecast error per consecutive quarterly interview per individual decreases from their first to their fourth interviews.

Table B.4.4: Adaptive learning coefficients: financial analysts

Interview number	Current year	One year ahead	Two years ahead
α_1 p-value	-0.314 0.000	-0.119 0.067	-0.045 0.262
F-test p-value	122.77 0.000	2.2 0.139	0.41 0.524
n (set of four obs)	104	95	75

Table B.4.5: Adaptive learning coefficients: trade union officials

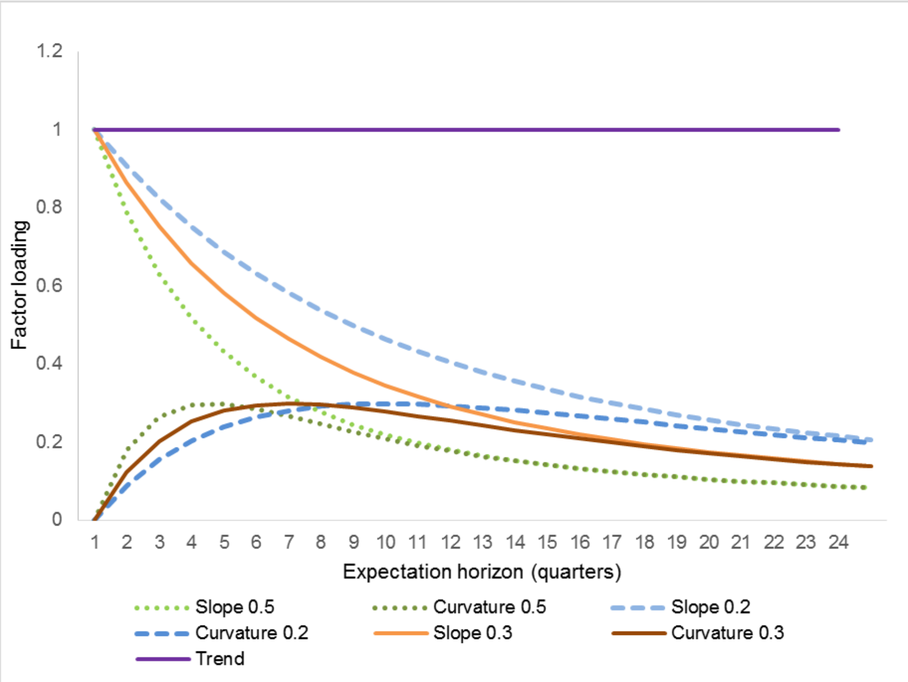
Interview number	Current year	One year ahead	Two years ahead
α_1 p-value	-0.256 0.000	-0.118 0.190	-0.124 0.170
F-test p-value	13.65 0.000	0.77 0.380	0.92 0.338
n (set of four obs)	67	55	54

Table B.4.6: Adaptive learning coefficients: business representatives

Interview number	Current year	One year ahead	Two years ahead
α_1 p-value	-0.170 0.000	-0.052 0.005	-0.053 0.009
F-test p-value	199.03 0.000	6.54 0.011	5.69 0.017
n (set of four obs)	2242	1805	1621

Appendix C.1: Sensitivity of different lambda choices on the three latent factors

Figure C.1: Latent factors of the NS model using different values for lambda



Lambda (λ) is the parameter that controls the shape of the slope and curvature loadings; it also determines the point at which the loading on the curvature factor is maximised. The lambda chosen for the formula-based and model-based estimations of the inflation expectations curves in this study was calibrated at 0.3. It is shown in Figure C.1 that an increase in lambda shortens the point in time when the curvature is maximised, i.e. a higher lambda produces a faster decay in the curve.

Appendix C.2: Kalman filter results

Table C.2.1: Kalman filter results: financial analysts (converged 852 iterations, obs = 1114)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	-0.14	-0.07	-0.07	5.07
Std err	0.07	0.01	0.01	0.17
Prob	0.04	0.00	0.00	0.00
$Slope_t$	0.40	1.18	0.20	-0.75
Std err	3.79	0.25	0.26	17.29
Prob	0.92	0.00	0.43	0.97
$Curvature_t$	3.81	0.04	1.03	5.81
Std err	4.30	0.28	0.29	17.37
Prob	0.37	0.89	0.00	0.74
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.97	0.03	0.00	
var e_x0	0.11	0.05	0.00	
var e_x1	0.16	0.06	0.00	
var e_x2	0.14	0.08	0.00	
var e_x5	0.06	0.25	0.00	
	Diagnostics			
	Akaike	5.53		
	Schwarz	5.64		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	5.17	1.22	4.23	0.00
SV2	-10.51	55.20	-0.19	0.85
SV3	13.65	63.76	0.21	0.83

Table C.2.2: Kalman filter results: business representatives (converged 494 iterations, obs = 22182)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	0.92	0.02	-0.09	6.74
Std err	0.01	0.00	0.00	0.38
Prob	0.00	0.00	0.00	0.00
$Slope_t$	0.18	0.95	0.21	0.11
Std err	0.02	0.01	0.01	0.75
Prob	0.00	0.00	0.00	0.89
$Curvature_t$	-0.74	0.20	0.15	0.75
Std err	0.10	0.04	0.01	0.34
Prob	0.00	0.00	0.00	0.03
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.24	0.00	0.00	
var e_x0	0.61			
var e_x1	0.00	288333.20	1.00	
var e_x2	0.55	0.01	0.00	
var e_x5	1.03	0.01	0.00	
	Diagnostics			
	Akaike	8.52		
	Schwarz	8.52		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	6.08	0.54	11.18	0.00
SV2	-0.28	1.14	-0.25	0.80
SV3	1.08	4.41	0.25	0.81

Table C.2.3: Kalman filter results: trade union officials (converged 210 iterations, obs = 909)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	0.68	0.40	0.08	6.10
Std err	0.17	0.10	0.02	0.55
Prob	0.00	0.00	0.00	0.00
$Slope_t$	0.57	0.33	-0.09	0.27
Std err	0.28	0.17	0.03	0.63
Prob	0.04	0.05	0.00	0.66
$Curvature_t$	-0.63	-0.36	-0.11	1.00
Std err	0.47	0.28	0.04	0.75
Prob	0.18	0.20	0.01	0.18
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.17	0.03	0.00	
var e_x0	0.22	0.21	0.00	
var e_x1	0.16	0.15	0.00	
var e_x2	0.29	0.13	0.00	
var e_x5	0.59	0.07	0.00	
	Diagnostics			
	Akaike	8.92		
	Schwarz	9.03		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	5.55	1.80	3.08	0.00
SV2	-0.35	3.21	-0.11	0.91
SV3	1.46	4.48	0.33	0.74

Table C.2.4: Time to maturity BER Survey data Kalman filter results: financial analysts (failure to improve likelihood after 5 iterations, obs=295)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	0.83	0.04	0.10	5.20
Std err	0.33	0.09	0.09	0.27
Prob	0.01	0.69	0.28	0.00
$Slope_t$	-0.55	1.59	0.20	-1.07
Std err	2.60	0.60	0.61	1.52
Prob	0.83	0.01	0.74	0.48
$Curvature_t$	-4.27	0.45	1.39	3.85
Std err	3.51	0.71	0.81	1.91
Prob	0.22	0.53	0.09	0.04
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.58	0.14	0.00	
var e_y1	8.86	0.41	0.00	
var e_y2	5.34	0.11	0.00	
var e_y3	4.67	0.24	0.00	
var e_y4	3.33	0.15	0.00	
var e_y5	0.59	0.11	0.00	
var e_y6	0.46	0.11	0.00	
var e_y7	0.44	0.07	0.00	
var e_y8	0.57	0.08	0.00	
var e_y9	0.54	0.08	0.00	
var e_y10	0.56	0.10	0.00	
var e_y11	0.52	0.07	0.00	
var e_y12	0.57	0.10	0.00	
var e_y21	0.53	0.20	0.00	
var e_y22	0.52	0.16	0.00	
var e_y23	0.42	0.31	0.01	
var e_y24	0.44	0.36	0.02	
	Diagnostics			
	Akaike	36.51		
	Schwarz	36.94		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	5.64	1.76	3.20	0.00
SV2	2.37	17.39	0.14	0.89
SV3	10.07	17.81	0.57	0.57

Table C.2.5: Time to maturity BER Survey data Kalman filter results: business representatives (converged after 294 iterations, obs=5864)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	0.94	0.01	0.00	6.54
Std err	0.01	0.00	0.00	0.15
Prob	0.00	0.00	0.00	0.00
$Slope_t$	0.11	0.97	-0.01	0.06
Std err	0.02	0.01	0.00	2.28
Prob	0.00	0.00	0.00	0.98
$Curvature_t$	0.14	-0.03	0.98	0.78
Std err	0.05	0.01	0.01	4.66
Prob	0.00	0.01	0.00	0.87
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.97	0.02	0.00	
var e_y1	0.04	0.04	0.00	
var e_y2	2.53	0.02	0.00	
var e_y3	0.43	0.01	0.00	
var e_y4	2.70	0.02	0.00	
var e_y5	3.22	0.02	0.00	
var e_y6	2.08	0.02	0.00	
var e_y7	1.34	0.02	0.00	
var e_y8	1.93	0.03	0.00	
var e_y9	3.07	0.02	0.00	
var e_y10	2.66	0.02	0.00	
var e_y11	2.46	0.02	0.00	
var e_y12	2.34	0.02	0.00	
var e_y21	1.10	0.02	0.00	
var e_y22	1.27	0.02	0.00	
var e_y23	1.35	0.02	0.00	
var e_y24	0.98	0.02	0.30	
	Diagnostics			
	Akaike	42.11		
	Schwarz	42.14		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	6.96	0.68	10.18	0.00
SV2	-0.80	3.89	-0.21	0.84
SV3	3.07	6.72	0.46	0.65

Table C.2.6: Time to maturity BER Survey data Kalman filter results: trade union officials (converged after 101 iterations, obs=245)

	Transition equation results (matrix A)			
	$Level_{t-1}$	$Slope_{t-1}$	$Curvature_{t-1}$	μ
$Level_t$	1.06	0.05	0.02	5.88
Std err	0.07	0.06	0.04	1.02
Prob	0.00	0.40	0.52	0.00
$Slope_t$	-0.10	0.92	-0.01	0.23
Std err	0.08	0.06	0.03	0.64
Prob	0.19	0.00	0.71	0.71
$Curvature_t$	-0.41	0.02	0.76	1.31
Std err	0.33	0.22	0.15	2.77
Prob	0.21	0.94	0.00	0.64
	Measurement equation results			
	Coef	Std err	Prob	
lambda	0.27	0.05	0.00	
var e_y1	1.36	0.11	0.01	
var e_y2	1.30	0.09	0.00	
var e_y3	3.57	0.13	0.00	
var e_y4	1.02	0.11	0.85	
var e_y5	1.62	0.16	0.00	
var e_y6	1.17	0.14	0.27	
var e_y7	3.36	0.18	0.00	
var e_y8	1.54	0.19	0.03	
var e_y9	1.86	0.13	0.00	
var e_y10	1.48	0.13	0.00	
var e_y11	3.41	0.13	0.00	
var e_y12	2.31	0.18	0.00	
var e_y21	0.35	0.19	0.00	
var e_y22	0.25	0.18	0.00	
var e_y23	1.13	0.08	0.10	
var e_y24	2.04	0.21	0.00	
	Diagnostics			
	Akaike	41.71		
	Schwarz	42.20		
	State estimates			
	Final state	Root MSE	z-Statistic	Prob.
SV1	5.52	1.37	4.02	0.00
SV2	0.52	1.17	0.45	0.66
SV3	2.09	4.95	0.42	0.67

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