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Disagreement about Expected Inflation and the Transmission of Monetary Policy in the Czech Republic

Master's thesis

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Declaration of Authorship

The author hereby declares that she compiled this thesis independently, using only the listed resources and literature, and the thesis has not been used to obtain any other academic title.

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Tereza Vesela

Abstract

This thesis examines the impact of disagreement about expected inflation on the transmission of monetary policy in the Czech Republic. Our contribution includes adapting the high-frequency monetary policy shock identification approach to the Czech context. Utilizing a regime-switching local projections model, we analyze how the effectiveness of monetary policy varies between periods of high and low disagreement, indicated by the cross-sectional standard deviation in inflation expectations. Our findings reveal that during high disagreement periods, the transmission of monetary policy shocks is less effective, with muted or even positive responses of inflation and inflation expectations to contractionary policy. This suggests that central bank signals are overshadowed or misinterpreted during such periods and further highlights the need to account for expectation heterogeneity. These insights emphasize the importance of enhancing central bank communication and transparency to mitigate disagreement and improve policy efficacy. Our results have significant implications for the formulation and implementation of monetary policy in small open economies.

JEL Classification	C32, D84, E31, E52, E58, E37
Keywords	Inflation Expectations, Monetary Policy Transmission, Disagreement, High-Frequency Identification, Regime-Switching Models, Local Projections
Title	Disagreement about Expected Inflation and the Transmission of Monetary Policy in the Czech Republic

Abstrakt

Tato práce zkoumá vliv neshody ohledně očekávané inflace na transmisi měnové politiky v České republice. Mezi naše metodologické přínosy patří přizpůsobení přístupu vysokofrekvenční identifikace měnověpolitických šoků českému kontextu. S využitím modelu lokálních projekcí s rozlišením odlišných režimů analyzujeme, jak se mění účinnost měnové politiky mezi obdobími s vysokou a nízkou mírou neshody, kterou indikuje směrodatná odchylka inflačních očekávání napříč subjekty. Naše zjištění ukazují, že v obdobích vysoké míry neshody je transmise měnověpolitických šoků méně účinná, přičemž reakce inflace a inflačních očekávání na restriktivní politiku jsou utlumené nebo dokonce pozitivní. To naznačuje, že signalizace ze strany centrální banky je v těchto obdobích zastíněna nebo nesprávně interpretována, a zdůrazňuje potřeby zohlednit heterogenitu očekávání. Tyto poznatky zdůrazňují význam posílení komunikace a transparentnosti centrální banky pro zmírnění neshody v inflačních očekáváních a zlepšení účinnosti měnové politiky. Naše výsledky mají významné důsledky pro formulaci a provádění měnové politiky v malých otevřených ekonomikách.

Klasifikace JEL	C32, D84, E31, E52, E58, E37
Klíčová slova	Inflační očekávání, Transmise měnové politiky, Neshoda, Vysokofrekvenční identifikace, Režimy, Lokální projekce
Název práce	Neshoda ohledně očekávané inflace a transmise měnové politiky v ČR

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Acronyms

bps basis points

CNB Czech National Bank

CPI Consumer Price Index

CSU Czech Statistical Office

CZK Czech koruna

EC European Commission

ECB European Central Bank

EU European Union

EUR euro

FAVAR Factor-Augmented Vector Autoregression

Fed Federal Reserve

FFR federal funds rate

FMIE Financial Market Inflation Expectations

FOMC Federal Open Market Committee

FRA Forward Interest Rate Agreement

FX Foreign Exchange

GDP Gross Domestic Product

GFC Global Financial Crisis

HFI High Frequency Identification

LP-IV Local Projections - Instrumental Variable

pp percentage points

SVAR Structural Vector Autoregression

U.S. United States

VAR Vector Autoregression

Master's Thesis Proposal

Author	Bc. Tereza Veselá
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Proposed topic	Disagreement about Expected Inflation and the Transmission of Monetary Policy in the Czech Republic

Motivation Inflation expectations serve as a crucial tool for monetary policy analysis. By understanding and managing these expectations, central banks can better achieve their price stability objectives, influence the transmission of monetary policy, and guide economic outcomes. Many central banks, including the Czech National Bank adopt inflation targeting frameworks, whereby they explicitly state their inflation objectives and commit to achieving them over a specific time horizon. Inflation expectations play a critical role in the success of inflation targeting regimes (eg. Svensson, 1997). They enter the modern New Keynesian DSGE forecasting models of central banks, such as the g3 or g3+ models of the Czech National Bank (Brázdik et al., 2020), through forward looking expectations augmented Phillips curve.

The majority of inflation expectations related global literature has focused on estimating the monetary policy reaction function and risks of uncertainty in inflation expectations to the transmission mechanisms (Clarida et al., 1998, Orphanides and Williams, 2002, 2004). Academic literature addressing inflation expectations in the Czech Republic include Fukač (2005), Holub and Hurník (2008) or Horváth (2008).

Variations over time in the level of disagreement regarding future inflation are commonly observed in survey data. However, limited knowledge exists regarding the interaction between disagreement and the effectiveness of monetary policy. The research paper of Falck et al. (2021) demonstrates that variations in individuals' inflation expectations have significant consequences for the transmission of monetary policy. Their results indicate that during periods of substantial disagreement about inflation expectations, tightening monetary policy leads to elevated inflation and inflation expectations. This situation poses a challenge to the central banks' ability to effectively manage and contain inflation. This thesis attempts to examine what is the effect of inconsistency in inflation expectations on inflation and on monetary policy transmission mechanism in the Czech environment. We will use similar methodology as Falck et al. (2021) to conclude if the strength of the signalling channel of monetary policy depends on the degree of disagreement.

Thus, this thesis will provide insight to the recent public debate on the monetary policy and inflation expectations effects to the great inflation episode in the Czech Republic which started in 2022. The results will also be relevant for monetary policy making, for example the Czech National Bank has prepared alternative scenario of increased inflation expectations (but without considering potential state-dependent effects of disagreement in inflation expectations on monetary policy) for the inflation forecast for its Board meeting in Autumn 2022 (Monetary Policy Report, Autumn 2022).

Hypotheses

Hypothesis #1: Disagreement in households' inflation expectations causes state-dependent effects of monetary policy shocks on inflation.

Hypothesis #2: In periods of high disagreement about inflation expectations the effects of monetary tightening are smaller than in the period of low disagreement.

Hypothesis #3: The financial market analysts' inflation expectations state-dependent effects of monetary policy shocks on inflation do not differ in a statistically significant way.

Methodology Empirical data driven analysis of monetary policy transmission dates back to the 1980s in the US when in reaction to rigid assumptions in theoretical macroeconomic models motivated Christopher A. Sims (1980) to introduce vector autoregressions (VARs) which since then became standard tool for macroeconomic empirical analysis.

Impulse responses (and variance decompositions) as one of the outputs of a VAR possess inherent significance as statistical measures. They offer empirical evidence that supports the theoretical frameworks of the economy, making them an essential empirical pursuit. The globally most prominent academic research using monetary VARs was conducted for example by Sims (1986), Uhlig (2005), Krippner (2013) or Wu and Xia (2016). For the Czech case research worth mentioning was done by Borys et al. (2009), Babecká et al. (2013), and Franta et al. (2014) who used Bayesian VAR with time varying parameters to access the transmission of monetary impulses in the Czech Republic.

However, there are several problems connected to VAR model type analysis. Shocks endogenously generated in the VARs do not necessarily represent exogenous monetary policy. To overcome this, researchers supply exogenous monetary policy shocks from outside of the model into the VAR. One option is to use narrative identification of the shocks (Romer and Romer, 1989, 2004). Alternative would be to use instrumental variables or high-frequency identification through proxy SVAR (Gertler and Karadi, 2015). Further issues are determination of the true data generating process (DGP) for macroeconomic time series and whether VAR is an appropriate method for capturing it (Cooley and Dwyer, 1998, Palm and Zellner, 1974, and Wallis, 1977). Combined solution to these problems could be to compute impulse responses for a vector time series based on local projections with externally supplied exogenous shocks proposed by Jordà (2005). This method can be estimated by simple least squares, is robust to misspecification of the DGP (Ramey 2016, Montiel Olea and Plagborg-Moller, 2021), and it easily accommodates experimentation with highly nonlinear specifications (Jordà, 2005).

In the thesis we will use smooth-transition local projections model to infer how impulse responses of inflation and other macroeconomic variables to monetary policy shocks differ in low and high disagreement regimes of inflation expectations.

A proxy variable for variability of households' inflation expectations from the European Comission dataset will be used as a treshold variable to identify the two regimes. The financial market analysts' inflation expectations will be taken from the Czech National Bank's Financial Market Inflation Expectations survey. The specification by Granger and Teräesvirta (1993) which uses a logistic probability function grants a smooth transition between the episodes of high and low disagreement rather than presuming distinct regimes.

Since Falck et al. (2021) use extended series of narrative monetary policy shocks from Romer and Romer (2004) and Wieland and Yaoung (2020), which are available only for the US, we will use a high-frequency identification through proxy SVAR as described in Gertler and Karadi (2015). Instead of changes in federal funds rate and eurodollar deposit futures, we will use changes in the exchange rate of the Czech crown with the euro and Czech forward rate agreements as two alternative instruments for purely unanticipated monetary policy shocks. Since intraday data is not available in the Refinitiv Eikon database, we will have to rely on daily data.

The aggregated macroeconomic data will be taken from the Czech Statistical Office and the Czech National Bank ARAD database in the main variant for the Czech Republic. The data on the forward rate agreements will be taken from Refinitiv Eikon database.

Expected Contribution The role of inflation expectations' in the monetary policy transmission mechanism has been quite well documented for the period up until the end of the first decade of 21st century (Fukač, 2005, Holub and Hurník, 2008, and Horváth, 2008). Since then, a lot has changed. The Global Financial Crisis was followed by a decade of low inflation, low inflation expectations, and low interest rates. Then after the COVID-19 pandemic, the breakout of the war in Ukraine, and series of other shocks, there was a rapid shift in the global macroeconomic environment. Interest rates and inflation sharply increased. By applying the novel approach of Falck et al. (2021) we will be able to capture both environments separately in our model and will infer about the differences between monetary policy transmission in the two periods. The results of the thesis may be useful mainly for the monetary policy makers, but also for the economic forecasters from the field.

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Chapter 1

Introduction

Inflation expectations play a pivotal role in the analysis of monetary policy, exerting influence on various macroeconomic outcomes such as household expenditures and firm pricing. In the pursuit of price stability objectives, central banks seek to comprehend and manage these expectations. The Czech National Bank adopted inflation targeting in 1998 and it is inflation expectations that play a critical role in the success of inflation targeting regimes (eg. Svensson 1997). These expectations are integrated into contemporary New Keynesian DSGE forecasting models like the g3 or g3+ models employed by the Czech National Bank (Brázdik, Hlédik, Humplová, Martonosi, Musil, Ryšánek, Šestořád, Tonner, Tvrz, & Žáček 2020) through a forward-looking expectations-augmented Phillips curve.

Fluctuations in the extent of disagreement about future inflation are commonly observed in survey data over different periods (Mankiw, Reis, & Wolfers 2003; Capistrán & Timmermann 2009; Dovern, Fritsche, & Slacalek 2012; Mokinski, Sheng, & Yang 2015; Andrade, Crump, Eusepi, & Moench 2016; Ballantyne, Gillitzer, Jacobs, Rankin *et al.* 2016; Brito, Carriere-Swallow, & Gruss 2018). Yet, it is much less understood how disagreement interacts with the efficacy of monetary policy. The pioneering study by Falck, Hoffmann, & Hürtgen (2021) illustrates that changes in individuals' inflation expectations have notable implications for the transmission of monetary policy. Their results indicate that during periods of substantial disagreement about inflation expectations, tightening monetary policy leads to elevated inflation and inflation expectations. Barbera, Zhu, & Xia (2023) further corroborate the adverse effect of significant disagreement about cyclical inflation expectations on monetary policy transmission. This situation poses a challenge to the central banks' ability to effectively manage and contain inflation.

This thesis attempts to examine what is the effect of disagreement about inflation expectations on inflation and on monetary policy transmission mechanism in the Czech Republic. Specifically, we attempt to confirm or refute the hypothesis that the interest rate instrument remains as effective to tame rising inflation and inflation expectations during periods of high disagreement as in normal periods. Furthermore, stemming from the stylized fact that disagreement among the general public is substantially higher than professional forecasters (Łyziak & Sheng 2023), we test whether the effect of the disagreement among consumers on the monetary policy transmission is more pronounced than that of disagreement among financial market analysts.

The methodological approach taken in this thesis is based on Falck *et al.* (2021) but we made several changes to address different nature and sometimes even paucity of the data for the Czech Republic. We use two different sources of inflation expectations: consumers and financial market analysts. The data are taken from the from the European Commission (EC) Consumer Survey for the former and from the CNB's Financial Market Inflation Expectations (FMIE) survey for the latter. It should be emphasized that no quantitative series of household inflation expectations exist for the Czech Republic that would span a sufficiently long period and include quantiles. Consequently, it is necessary to quantify both the expectations and the variance from the publicly available qualitative data. Disagreement about consumer inflation expectations is approximated as a standard deviation from the EC consumer survey qualitative data with the Carlson & Parkin (1975) probability method modified by Batchelor & Orr (1988), which was used for the same purpose in eg. Łyziak & Sheng (2023). Our contribution to the literature lies in the fact that, to date, this quantification method has not been applied so extensively in the Czech context, particularly in estimating both inflation expectations and their standard deviation. Detailed information about the estimation method can be found in Section 3.2. Disagreement about financial market analysts inflation expectations is taken directly as the standard deviation of the CNB's FMIE survey data.

Then, we utilise smooth-transition local projections model (Jordà 2005) to infer how impulse responses of inflation and other macroeconomic variables to monetary policy shocks differ in low and high disagreement regimes of inflation expectations. To avoid endogeneity issues, we resort to external identification of monetary policy shocks which are supplied into the local projections. Already established series of external shocks such as extended series of narrative monetary policy shocks from Romer & Romer (2004) and Wieland & Yang (2020) are available only for the US. The alternative option is to identify monetary policy shocks with high frequency financial data in the spirit of Gertler & Karadi (2015) with the Czech forward rate agreements used as instruments for purely unanticipated monetary policy shocks. So far, the high frequency identification (HFI) has not been used in the Czech setting, therefore, the inference on these high frequency shocks is our first contribution to the literature. The modified HFI method is discussed in more detail in Section 4.2.

This thesis uncovers several critical insights into the state-dependent effects of monetary policy in the Czech Republic, depending on the level of disagreement in inflation expectations. Most importantly, the effectiveness of monetary policy significantly varies between high and low disagreement regimes. In the low disagreement regime, the responses of GDP growth, inflation, inflation expectations, repo rate, and credit spread align well with standard economic theory. Conversely, the high disagreement regime exhibits subdued and often insignificant responses. Moreover, in the high disagreement regime of the financial market inflation expectations model, there is even a statistically significant and pronounced positive response of inflation to the contractionary monetary policy shock. The use of a non-linear regime-switching model proved essential in accurately capturing these dynamics. This model effectively eliminated the puzzling results observed with linear local projections, thereby providing a more accurate depiction of monetary policy transmission under different regimes of inflation expectations disagreement.

The findings suggest that monetary policy transmission is more effective in the low disagreement regime. One possible reason for inefficiency in the high disagreement regime is a muted response of the repo rate, indicating a tendency towards a more accommodative monetary policy stance during periods of high disagreement and uncertainty. This is supported by the baseline consumer model, which shows a muted repo rate response in the high disagreement regime followed by an inconclusive reaction of inflation and inflation expectations. Analyzing estimated unexpected monetary policy shocks alongside CNB repo rate changes reveals significant repo rate increases were coupled with smaller or even negative policy shocks, which may indicate the central bank's limited efforts to combat inflation in 2021 and 2022. However, models using FMIE and consumer expectations with alternative instrument in the HFI of the policy shocks indicate that inflation and inflation expectations rise despite a significant increase in the repo rate in the high disagreement regime. This supports the signaling channel hypothesis, suggesting that during times of high disagreement about inflation expectations, tightening monetary policy can lead to higher inflation and inflation expectations (Falck *et al.* 2021).

The remainder of this thesis is organized as follows. In Chapter 2 we provide a brief review of existing literature on monetary policy transmission. We focus on the role of inflation expectations and the impact of disagreement, shock identification strategies and monetary policy transmission in the Czech Republic. In Chapter 3 we present the data sources, sample period, and key properties of the times series used in the analysis. Furthermore, we provide details on the process of measuring inflation expectations and describe how consumer qualitative data is transformed into quantitative estimates of expected inflation and its cross-sectional variance. Chapter 4 describes the methodological approach, including the non-linear regime-switching model used to analyze the state-dependent effects of monetary policy. We also explain in detail the high frequency identification strategy and the selection of monetary policy shocks instruments. Chapter 5 discusses the empirical findings, highlighting the differences between high and low disagreement regimes and the implications for monetary policy effectiveness. We present results of the baseline model with consumer inflation expectations as well as results of a model including financial market inflation expectations and of other robustness checks. Chapter 6 interprets the results in the context of existing literature, discusses policy implications, and addresses potential limitations of the thesis. Chapter 7 summarizes the key findings, discusses their broader implications, and suggests directions for future research.

Chapter 2

Literature review

2.1 Inflation Expectations and Disagreement

In the most recent and extensive review of inflation expectations in the Czech Republic, Brázdik, Keseliová, Musil, Šnobl, Šolc, Tvrz, & Žáček (2024) emphasize their historically minimal impact on inflation until a recent spike in core inflation, where they contributed significantly to the overall dynamics, up to 40%, at their peak. The persistence of inflation has notably increased since late 2021, with core inflation being primarily driven by internal factors rather than expectations. Typically, in a stable economic environment with a credible central bank, long-term inflation expectations should align with the central bank's target within a 2-3 year range, irrespective of observed inflation levels. However, this alignment can be disrupted in high-inflation scenarios.

The effectiveness of central banks in anchoring inflation expectations has diminished significantly during the recent inflation surge, particularly for one-year expectations, though their influence on three-year expectations remains substantial. The importance of lagged inflation has markedly increased for one-year expectations over the past two years. During periods of elevated expectations, current inflation exerts a stronger influence on one-year expectations, a pattern not observed in long-term expectations. Core inflation began to climb sharply in mid-2021, reaching double digits by summer 2022, with the Czech National Bank's (CNB) forecasts showing consistently high positive errors. This indicates that factors beyond standard economic fundamentals were driving the increase in core inflation. (Brázdik *et al.* 2024)

Łyziak & Paloviita (2017) also provide evidence of reduced capacity of central banks to stabilize inflation expectations. They note that post global financial crisis, longer-term inflation expectations in the euro area have become more sensitive to short-term expectations and actual Harmonized Index of Consumer Prices inflation. The European Central Bank's (ECB) inflation target has become less influential on short- and medium-term expectations of professional forecasters. The risk of de-anchoring inflation expectations has increased, particularly when the target is perceived as being delayed. This suggests that more extensive forward guidance in monetary policy, such as conditional interest rate path announcements, could be beneficial. Petersen (2015) adds that while most participants' expectations align with the intended direction of monetary policy, they are often formed adaptively, heavily relying on past variables and forecasts.

Inflation expectations deviation indices also signaled episodes of weak short-term expectations anchoring over the past two years. This implies that short-term expectations may diverge from established targets. The results of Brázdik *et al.* (2024) emphasized the adaptive nature of short-term inflation expectations, with a more significant inflation pass-through during periods of high inflation. This adaptive behavior highlights the sensitivity of expectations to prevailing economic conditions (Brázdik *et al.* 2024). Especially consumers' medium- and long-term expectations often diverge significantly from central bank targets and tend to align more closely with short-term inflation news. This indicates a state-dependent nature of household attention to inflation, with their expectations being highly responsive to actual inflation and subjective experiences, reacting slowly to monetary policy changes. D'Acunto, Charalambakis, Georgarakos, Kenny, Meyer, & Weber (2024) emphasize the significance of consumer inflation expectations, which encompass a broader spectrum of societal beliefs compared to those of experts or financial market participants. Recent experiences in the euro area underscore the complexity, heterogeneity, and subjectivity of consumer expectations. Brázdik *et al.* (2024) also demonstrated that various groups (households, firms, and financial markets) have different perceptions of inflation, resulting in unique expectation formation. This variability adds to the uncertainties regarding expectations.

Inflation expectations disagreement among consumers stems from heterogeneity in individual fundamental inflation, divergent past expectations, differing expert views, and variations in consumers' propensities to learn from experts. Łyziak & Sheng (2023) found that 55 - 70% of U.S. households adjust their expectations towards expert forecasts, while the rest revise in the opposite direction. Central bank communication can reduce this disagreement, particularly if it targets professional analysts first, indirectly influencing household expectations. Whereby Ballantyne *et al.* (2016) warns that average and median measures of inflation expectations can conceal significant disagreement.

Disagreement among consumers is significantly larger than among professional forecasters and tends to co-move with the mean level of inflation expectations. Consumer expectations are sensitive to salient prices, such as petrol prices, indicating that pure sticky-information models may not fully capture the dynamics of expectations formation. (Ballantyne *et al.* 2016) Alternatively, Nakazono (2016) suggests that information rigidities are determinants of cross-sectional disagreement among both households and experts, with infrequent forecast revisions leading to disagreements. This behavior aligns with the noisy information model, where forecasters' behavior reflects a weighted average of signals for true states and previous forecasts based on outdated information.

Montes, Oliveira, Curi, & Nicolay (2016) analyze the impact of central bank transparency and communication on inflation expectations disagreement. Their findings indicate that transparency and clear communication significantly reduce disagreement among financial market experts in Brazil. Signaling future monetary policy with clarity also decreases disagreement about future inflation. Examining disagreement in inflation expectations in Colombia, Galvis Ciro & Anzoátegui Zapata (2019) further note that inflation volatility increases disagreements. Clear and credible central bank communication can reduce disagreement, again highlighting the importance of transparency in monetary policy.

In addition to expectations disagreement there is a large volume of published studies describing the role of uncertainty in monetary policy transmission. Glas & Hartmann (2022) differentiate between inflation uncertainty and disagreement, using data from the ECB's Survey of Professional Forecasters. They confirm that disagreement is an incomplete approximation of overall uncertainty. Both measures are influenced by macroeconomic conditions and monetary policy indicators but in different ways. Average individual inflation uncertainty is higher during expansionary monetary policy periods, while disagreement rises during contractionary periods.

Nain & Kamaiah (2014) investigate the influence of uncertainty on monetary policy effectiveness in India using a Bayesian Markov Switching-VAR model. Their results show that monetary policy shocks have weaker effects during high uncertainty periods compared to low uncertainty periods. This aligns with theoretical studies suggesting that uncertainty dampens the effectiveness of monetary policy shocks. Aastveit, Natvik, & Sola (2013) also find that high economic uncertainty reduces the impact of monetary policy on aggregate consumption and GDP.

A number of authors have considered the effects of policy uncertainty. Bauer, Lakdawala, & Mueller (2022) highlights the crucial role of uncertainty about future policy rates in the transmission of monetary policy to financial markets. Changes in policy uncertainty around Federal Open Market Committee (FOMC) announcements have significant effects on asset prices, distinct from conventional policy surprises. Beckmann, Belke, & Dubova (2022) demonstrate international spillovers of inflation expectations and policy uncertainty, noting that newspaper-based uncertainty contributes little to inflation expectations updates by professionals. Collectively, these studies outline a critical role of expectations disagreement and uncertainty in the efficacy of monetary policy.

2.2 The Price Puzzle in Monetary Policy Analysis

The "price puzzle" refers to the counterintuitive phenomenon where inflation rises following a contractionary monetary policy shock. This puzzle has been widely discussed and analyzed in economic literature. Stock & Watson (2001) argue that incorporating expectations into models helps simulate the forward-looking nature of monetary policy, as central banks typically adjust interest rates in response to anticipated rather than current inflation. Building on this view, Castelnuovo & Surico (2006) highlight additional factors that eradicate the price puzzle, such as the need to control for long-term inflation expectations and the importance of accurately identifying monetary policy shocks. They emphasize that proper identification is crucial for understanding the true effects of monetary policy actions.

Rusnák, Havranek, & Horváth (2013) conducted a meta-analysis to investigate the price puzzle, reviewing approximately 1,000 point estimates of impulse responses from 70 studies that used VARs to examine monetary transmission across various countries. They found that the price puzzle often arises from model misspecifications, particularly the omission of commodity prices, neglect of potential output, and reliance on recursive identification methods. Carlstrom, Fuerst, & Paustian (2009) argue that the usual recursive identification, which assumes that monetary policy impacts output and prices only with a lag, is inconsistent with New Keynesian theoretical models.

Ramey (2016) further discusses the persistence of the price puzzle present in different models, including the standard Structural Vector Autoregression (SVAR) by Christiano, Eichenbaum, & Evans (1999), HFI by Faust, Swanson,

& Wright (2004), and Uhlig's 2005 sign restrictions. Despite these issues, models developed by Romer & Romer (2004), Coibion (2012), Barakchian & Crowe (2013), and Gertler & Karadi (2015) demonstrate more significant impacts of monetary policy shocks on output, which helps mitigate the price puzzle to some extent (Ramey 2016).

Considering all of this evidence, it seems that the price puzzle can often be attributed to model misspecifications and the challenges associated with accurately identifying monetary policy shocks. We aim to address these issues by incorporating forward-looking inflation expectations and using high frequency identification method to provide a clearer understanding of the effects of monetary policy in the Czech Republic.

2.3 High-Frequency Identification of Monetary Policy Shocks

Much of the research on monetary policy shocks has focused on high frequency identification. Gertler & Karadi (2015) provide substantial evidence on the transmission mechanisms of monetary policy shocks within frameworks incorporating both economic and financial variables. By employing high-frequency data, such as the movements of Federal Funds futures around FOMC dates, they identify unexpected Federal Reserve (Fed) policy actions. This high-frequency identification, based on the timing of these events, offers more plausible assumptions compared to those using monthly or quarterly data. They combine HFI with proxy SVAR methods to assess the impact of monetary policy on macroeconomic variables, particularly those reflecting financial frictions like interest rate spreads. Their approach is motivated by the need to address two critical issues: the infeasibility of assuming no immediate response of financial market rates to federal funds rate (FFR) shocks under traditional Cholesky ordering, and the increasing reliance of the Fed on forward guidance to influence market expectations regarding future interest rates.

In their methodology, Gertler & Karadi (2015) use the 3-month ahead Fed Funds futures as an instrument for the shock variable and the 1-year government bond rate as the policy instrument. Their results show that monetary policy shocks lead to an increase in the 1-year rate, a significant reduction in industrial production, minimal impact on the Consumer Price Index (CPI) within the first year, and an increase in the Gilchrist & Zakrajšek (2012) excess bond premium.

Ramey (2016) explores the robustness of the previously described HFI shocks by employing a Jordà (2005) local projection framework. Using two lags of the shock itself, the interest rate on 1-year government bonds, industrial production, CPI, and the Gilchrist & Zakrajšek (2012) excess bond premium spread as control variables, she finds that interest rates rise slowly but remain elevated for an extended period. Output shows no response for a year but eventually subsequently increases, while prices exhibit little response for the first 30 months before eventually falling. Ramey's (2016) investigation reveals that the mean shock is not zero and is serially correlated, suggesting the need for caution when interpreting these shocks as purely unanticipated movements in interest rates.

Moreover, Bauer & Swanson (2023) question the exogeneity and relevance of monetary policy surprises identified using high-frequency data, as these surprises are often correlated with publicly available macroeconomic and financial information preceding FOMC announcements. To address this, Bauer & Swanson (2023) expand the set of monetary policy announcements to include speeches by the Fed Chair, effectively doubling the number of announcements. By orthogonalizing the surprises with respect to pre-announcement macroeconomic and financial data, Bauer & Swanson (2023) enhance the validity of the instruments. Their findings indicate that estimates of high-frequency effects on asset prices remain largely unchanged, but estimates of macroeconomic effects become significantly larger and more robust.

On the whole, the estimation of monetary policy shocks has evolved, with researchers placing greater emphasis on the identification and relevance of instruments. Innovative methods such as Factor-Augmented Vector Autoregressions (FAVARs) and the use of Greenbook forecasts have refined the conditioning set for these estimations. Alternatives to the Cholesky decomposition, including SVARs with sign restrictions, offer new perspectives. High-frequency data from financial markets and narrative data enhance the measurement of monetary shocks. However, caution is warranted in samples where anticipation effects might be significant, as HFI shocks may not always serve as appropriate external instruments for standard VARs. Notably, the systematic conduct of monetary policy in recent years has reduced the frequency of true monetary policy shocks (Ramey 2016) , although recent events like the COVID-19 pandemic and geopolitical instabilities may have reintroduced such shocks.

2.4 Regime-Switching Models in Monetary Policy Analysis

The integration of regime-switching models into monetary policy analysis has yielded significant insights into the state-dependent effects of monetary policy shocks. Falck *et al.* (2021) combine Jordá's (2005) local projection methodology with a smooth regime-switching model to examine the responses of macroeconomic variables to monetary policy shocks under different levels of disagreement about inflation expectations. They find that a 100 basis points contractionary U.S. monetary policy shock results in a statistically significant increase in inflation and inflation expectations by up to 0.7 percentage points during periods of high disagreement. Conversely, in periods of low disagreement, the same shock leads to a significant decline in these variables by approximately 0.8 percentage points. This indicates that the heterogeneity in individual inflation expectations critically influences the transmission of monetary policy.

Falck *et al.* (2021) measure disagreement using the cross-sectional standard deviation of individual forecasts about one-quarter-ahead inflation from the U.S. Survey of Professional Forecasters. Their model shows that in high-disagreement regimes, agents interpret central bank interest rate hikes as signals of increasing demand, prompting price increases and thereby temporarily raising inflation and inflation expectations. They call this the "signalling channel" of monetary policy. In contrast, when disagreement is low, the conventional monetary policy channel prevails, leading to reduced inflation and inflation expectations following a contractionary policy shock. These findings underscore the importance of accounting for the level of disagreement in inflation expectations when assessing the effects of monetary policy.

Argov, Epstein, Karam, Laxton, & Rose (2007) provide further evidence of regime-dependent behavior by examining inflation expectations in Israel. Their regime-switching model differentiates between low- and high-inflationary episodes, revealing that inflation expectations behave distinctly during high inflation periods. The consumer inflation expectations disagreement proxied by cross-sectional standard deviation of consumer inflation expectations, which is used in this thesis, is positively correlated with the inflation level. Thus, Argov et al.'s (2007) results indirectly offer valuable insights into non-linear effects of inflation expectations disagreement on monetary policy transmission in a small open economy such as Israel or the Czech Republic.

Ramey (2016) also highlights the use of regime-switching models to understand changes in monetary policy parameters. These models suggest that systematic changes in policy do not significantly explain fluctuations in inflation and output. However, they do indicate regime switches associated with changes in Fed chairmanship, although these switches do not substantially account for economic fluctuations. Similarly, Sims & Zha (2006) found evidence of regime switches that align with changes in Fed leadership but concluded that these do not significantly impact economic variability.

2.5 Monetary Policy Transmission in the Czech Republic

There is a relatively small body of literature that takes an empirical rather than structural approach to analyze the transmission of monetary policy in the Czech Republic. Early examples of such research include Borys, Horváth, & Franta (2009) who established a similarity of the monetary policy transmission in the Czech Republic to that of the euro area in terms of persistence and effectiveness. They employed a variety of VARs, including SVAR, Bayesian VAR with sign restrictions, and FAVAR, to assess the impact of monetary policy shocks on the Czech economy. Their analysis, which spans from January 1998 to May 2006 at a monthly frequency, incorporates GDP, a real-time output gap estimate, price indices, exchange rates, interbank interest rates, and commodity prices. Their findings indicated that a contractionary monetary policy shock results in a decreased economic activity and a lower price level, with the most significant effects occurring approximately one year after the shock. This aligns with the CNB's targeting horizon of 12 to 18 months, confirming the robustness of the monetary policy transmission mechanism.

Expanding on this, Babecká Kucharčuková, Franta, Hájková, Král, Kubicova, Pruteanu-Podpiera, & Saxa (2013) and Franta, Horváth, & Rusnák (2014) explored the the evolution of monetary policy transmission mechanism in the Czech Republic from mid-1990s to 2010 using a time-varying parameters Bayesian VAR. In addition, Franta *et al.* (2014) employed stochastic volatility into the model. Babecká Kucharčuková *et al.* (2013) discovered that the impact of monetary policy shocks is most pronounced at a horizon of approximately four quarters. Their findings indicated that the transmission of monetary impulses to the economy functions in a intuitive and expected manner, i.e. prices react negatively between four and eight quarters. Industrial production reacted negatively at impact, however, the response was mild and not significant even at 68.%. The research of Franta *et al.* (2014) revealed that the impact of monetary policy shocks on prices peaks between four and eight quarters post-shock, consistent with the CNB's policy horizon. Over time, the initial impact of these shocks on prices intensified, though their maximum impact became less pronounced and persistent. This suggests that economic agents have adapted to the monetary policy regime, effectively mitigating the long-term effects of monetary shocks. Additionally, their use of sign restrictions confirmed that an unexpected one percentage point increase in the interest rate leads to a decline in output and prices, with an initial appreciation of the nominal exchange rate.

Dvořáková (2022) employed a Bayesian SVAR with short-run zero and sign restrictions to disentangle the sources of inflation into seven distinct factors: domestic demand, domestic supply, monetary policy, exchange rate, fiscal policy, foreign demand, and foreign supply. Her study highlights the significant role of fiscal policy shocks in influencing inflation, whereas monetary conditions have a comparatively minor impact. The primary effects of these instruments are observed within the first ten quarters. Furthermore, a meta-analysis by Havránek & Rusnák (2012) indicated that transmission lags are generally longer in developed countries (25 to 50 months) compared to emerging economies (10 to 20 months). This discrepancy is attributed to the more advanced financial systems in developed economies, which offer a wider range of hedging instruments, thereby prolonging the transmission of monetary policy shocks. (Havránek & Rusnák 2012; Dvořáková 2022) Moreover, Brázdik, Grossmann, Hájková, Hromádková, Král, & Saxa (2021) suggested that the peak impact of monetary policy on prices in the Czech Republic occurs 20 to 24 months after the initial shock. This extended transmission lag underscores the complexity of the monetary policy transmission process in the Czech Republic and highlights the importance of understanding the various factors that influence its effectiveness (Brázdik *et al.* 2021).

Overall, these studies collectively insinuate that the Czech Republic has or at least had a well-functioning monetary policy transmission mechanism. Having said that, it is important to recognize that these studies investigate the impacts of the monetary policy on the Czech economy using a Bayesian VAR framework with sign restrictions. Applying sign restrictions presumes prior knowledge about the anticipated direction and timing of the shock's effects. Thus, conclusions from these studies regarding the impact of monetary policy shocks should be interpreted with caution.

Chapter 3

Data

Our baseline sample includes data from the Czech Republic on y-o-y inflation, consumer inflation expectations, financial market inflation expectations, real GDP growth, CNB repo rate, and credit spread for non-financial corporations. The monthly y-o-y inflation is available from the Czech Statistical Office (CSU) from January 1995.

The consumer inflation expectations data are available from the EC Consumer Survey database since January 1995. This information, accessible on a monthly basis, encompasses feedback from 1,000 participants concerning their perceptions and anticipations of economic trends. We use the freely available qualitative part of the survey with fixed answers. It is important to note that there are no quantitative datasets of household inflation expectations for the Czech Republic that cover an extended period and contain information about quantiles. Therefore, it is essential to derive both the expectations and the variance from the publicly accessible qualitative data. Further details about the estimation method are provided in Section 3.2. The monthly financial market inflation expectations are available from the CNB's FMIE survey since January 2001, however, individual forecasts have been published only since Janurary 2005. Typically comprising 16 to 18 respondents, the survey primarily involves macroeconomists affiliated with banks and other private financial institutions in the Czech Republic. Additionally, a handful of analysts from financial institutions abroad also contribute to the survey results.

Since both consumer and financial market expectations are for one year, we work with y-o-y inflation and GDP growth. The quarterly real GDP is available from CNB ARAD database since January 1997. The quarterly GDP data are interpolated to monthly data with monthly industrial production index available from January 2000. The Chow & Lin (1971) maximum likelihood estimation method was used for the disaggregation of the GDP data. The monthly GDP growth data was then obtained as the log difference of the disaggregated monthly GDP. Because of instances of large yearly differences in CPI, the log difference could produce inaccurate estimates of inflation. Hence, the monthly y-o-y inflation was obtained as the yearly difference in CPI divided by the base year CPI. And finally, the daily CNB repo rate is available from the Refinitiv Eikon database since January 1998. The monthly credit spread is calculated as the difference between long term cost of credit for non-financial corporations available since January 2004 from the CNB ARAD database and the monthly average CNB repo rate.

We further estimate exogenous monetary policy shocks with instrumental variables including 1X4, 3X6 and 6X9 CZK forward interest rate agreements (FRA). We also test EUR/CZK exchange rate and EUR/CZK 1 month FX forward swap, but these did not perform satisfactorily as instruments as described in Chapter 4. The instrument data are all acquired from the Refinitiv Eikon database and are available from January 2004 (FRAs), January 1999 (EUR/CZK), and June 2001 (EUR/CZK forward swap). Consequently, the longest sample available with appropriate instrument is from January 2004.

3.1 Time Series Properties

Plots of all time series used in the model can be found in Figures 3.1, 3.2, 3.4, and 3.5. We can identify three periods of notable recessions. Firstly, the period of Global Financial Crisis (GFC) between 2008 and 2010 when the real GDP growth plummeted to the lowest point of around negative 5% in 2009. Secondly, there was a slightly less pronounced recession around 2013 after the onset of the European sovereign debt crisis. Finally, the most prominent crisis in the sample occured during the COVID 19 pandemic when the real GDP growth nosedived into the territory around negative 15% in the second quarter of 2020. This had been succeeded by a rapid recovery already in the third quarter of the same year and then in 2021. After the vast increase in interest rates, Russian invasion in Ukraine, and the spike in energy prices, real GDP growth gradually declined and hovered around zero since then.

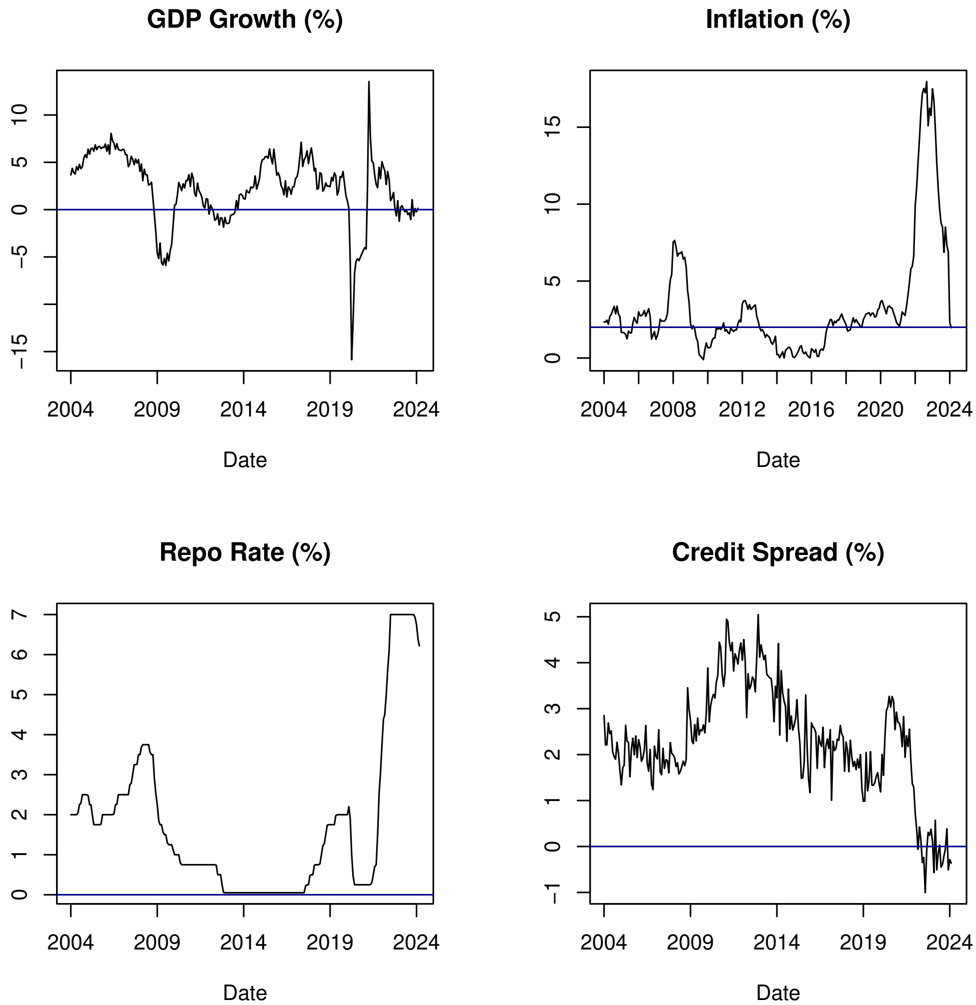
For inflation, it has moved slightly over or under the 2% target (marked by the red line in Figure 3.1) except for two instances of excessive inflation episodes and one instance of considerably subdued inflation. The first inflation spike occurred during the great recession in 2008 when inflation peaked at around 8%. This was followed by a deterioration to almost zero and subsequent rise above the target with the European sovereign debt crisis. Thereafter, the most pronounced episode of tepid inflation followed from c.a. 2014 to 2016. This period coincided with almost zero interest rates (CNB repo rate was 0.05%) and with CNB's unconventional monetary policy of exchange rate commitment to the floor of 27 EUR/CZK. Finally, the greatest inflation episode in the Czech Republic in the 21st century commenced in 2021. It was preceded by a slightly elevated inflation above the target for approximately two years. Inflation peaked at just under 18% in 2022. Since then, inflation sluggishly reverted back to the target at the beginning of 2024.

Speaking of interest rates, the development of CNB repo rate has roughly coincided with inflation. However, when the composition of the CNB Board was significantly changed in 2022, the rate stalled at seven percent while inflation continued to rise to just under 18%. We mentioned the period of almost zero repo rate (0.05% from November 2012 until August 2017) coinciding with the exchange rate commitment unconventional policy. Conversly, the development of the credit spread seems to be the reverse of the repo rate. There may be several reasons for this. Firstly, there seem to be some theoretical maximum for the credit costs for non-financial corporations, and thus, when the repo rate reaches higher levels and the credit costs stay at the maximum, the spread inevitably decreases. Another reason is the risk premium, which increased after the great recession and continued during the European sovereign debt crises and skyrocketed during the COVID 19 pandemic for non-financial corporations in the Czech Republic, which include a significant share of companies from industrial and manufacturing sectors. These periods coincide with extremely low CNB interest rates to combat the crises.

Checking for seasonality in time series data is essential for accurate forecasting, understanding underlying patterns, preventing bias, improving model performance, and enhancing the interpretability of the results. This is important not only for VAR and local projections but for any type of time series analysis. The only time series that was already seasonally adjusted was the quarterly real GDP. We inspected seasonal, trend and irregular components of the log interpolated monthly GDP, monthly CPI, monthly inflation expectations of consumers and financial market, and their standard deviations (see Section 3.2) and found remaining seasonality (see Figures A.1, A.2, A.3, A.4, A.5, and A.6 in Appendix A). We adjusted these time series for seasonality with X-13-ARIMA-SEATS method.

Testing for stationarity is a critical step in preparing time series data for VAR and local projection modeling, ensuring that the statistical properties of the

Figure 3.1: Evolution of Time Series



Source: Czech Statistical Office, CNB ARAD, Authors' calculations

Note: Blue line in the Inflation graph indicates the inflation target of 2%.

data remain stable over time, aligning with the assumptions of these models. By confirming stationarity, one can be more confident in the stability of the relationships between variables over time, leading to more reliable results from VAR and local projection models. We tested for stationarity of the final transformations of the series in percentages with one of the most common methods for testing stationarity, the Augmented Dickey-Fuller (ADF) test and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. The results from these test can be found in Table 3.1 below.

Table 3.1: Stationarity Tests Results

	ADF Test		KPSS Test	
Null	Unit Root		Level Stationary	
	Test Stat	p-value	Test Stat	p-value
GDP (%)	-3.520	0.041	0.000	0.1
Inflation	-3.979	0.010	0.620	0.021
Consumer Inf. Exp.	-3.955	0.012	0.834	0.01
Fin. Mar. Inf. Exp.	-3.100	0.114	0.514	0.039
Repo Rate	-4.158	0.01	1.553	0.01
Credit Spread	-1.381	0.836	1.516	0.01

Note: For KPSS test, p-value > 0.1 if 0.1 printed, and for both tests, p-value < 0.01 if 0.01 printed.

According to the ADF test we can reject the unit root at 5% significance for most of the time series except for Financial Market Inflation Expectations and Credit Spread. When we inspect the Financial Market Inflation Expectations visually (see Figure 3.5), the time series seems to always converge to c.a. 2%. Thus, at least based on the visual aspect, this series seems stationary. On the other hand, the Credit Spread series seems to potentially contain unit root based on the visual examination (see Figure 3.1).

In contrast, we can reject level stationarity at 5% significance for all of the time series except for real GDP growth. Due to the ADF based results of stationarity for most of the series, parsimony, and straightforward interpretation, we will not proceed with second differencing. There are several arguments against second differening a time series. It can lead to over-differencing, which removes not only trends but also much useful variation, potentially resulting in a loss of important features or dynamics in the data. It can also amplify short-term fluctuations or noise in the data, leading to increased volatility in the second differenced series. This may make it more challenging to identify true underlying patterns or trends. Furthermore, second differencing removes more long-term memory from the series compared to first differencing. This may lead to a loss of important information about the persistence of shocks or the autocorrelation structure of the data. Moreover, measurement errors that are entirely random could significantly affect the short-term element more than the long-term one (Cochrane 2018). Finally, it can introduce non-linearities or other undesirable properties into the differenced series, complicating the modeling process.

3.2 Measuring Inflation Expectations

Our aim here is to transform the consumer qualitative data into quantitative estimates of expected inflation and its cross-sectional variance, which will be used as a proxy for inflation expectations disagreement. We follow the methodology proposed by Łyziak & Mackiewicz-Łyziak (2014), Hałka & Łyziak (2015) and by Łyziak & Sheng (2023) which uses the Carlson & Parkin (1975) probability method modified by Batchelor & Orr (1988).

As we mentioned, for consumers' inflation expectations, we utilize survey information from the EC Consumer Survey, conducted monthly across EU economies. Data for the Czech Republic is available since January 1995. A comprehensive description of this survey can be found in European Commission (2006) and European Commission (2007). The qualitative inquiry about expected inflation included in this survey takes the following format:

"*By comparison with the past 12 months, how do you expect that consumer prices will develop in the next 12 months? They will ... (1) increase more rapidly, (2) increase at the same rate, (3) increase at a slower rate, (4) stay about the same, (5) fall, (6) don't know.*"

We denote the share of consumers who anticipate faster (1), constant (2) or slower increase (3) of prices $a^e_{1,t}$, $a^e_{2,t}$, and $a^e_{3,t}$ respectively. We indicate the share of consumers expect no change in prices (4) b^e_t and the share of those who predict price decrease (5) c^e_t.

Quantifying consumer inflation expectations through qualitative survey data can be seen as a method for converting subjective qualitative opinions into numerical values that align with official inflation metrics. The selected method for quantification requires several assumptions. First, we posit that the expected inflation follows a normal distribution within the population, characterized by an unknown mean and standard deviation. Secondly, we assume that the quantified expected inflation relies on the consumers' assessment of perceived inflation. This is in line with the construction of the survey query, where the consumer is asked to compare previous with expected price developments. To quantify consumers' perceived inflation rate π_t^p we utilize survey answers to the question regarding perceived price changes and employ a comparable probability method.

"*How do you think that consumer prices have developed over the last 12 months? They have ... (1) risen a lot; (2) risen moderately; (3) risen slightly; (4) stayed about the same; (5) fallen; (6) don't know.*"

Similarly as in the expected inflation case, we denote the respective shares of respondents with answers (1)-(5) about perceived inflation $a_{1,t}^p$, $a_{2,t}^p$, $a_{3,t}^p$, b_t^p, and c_t^p. Batchelor & Orr (1988) assume that respondents experiencing an increase in the price level compare their perceived price dynamics with the "natural"/"moderate" rate of inflation π_t^m. This represents the persistent or trend rate of inflation and can be estimated by smoothing the actual inflation using methods like the HP filter or moving averages. The estimate is then regarded as a scaling factor in quantifying perceived inflation.

Furthermore, we presume that respondents perceive or expect no price change are situated around zero within the sensitivity interval $(-l; l)$. In other words, we assume that among those stating "prices have stayed about the same", some perceive/expect the price dynamics as insignificantly different from zero. Following Hałka & Łyziak (2015) and Łyziak & Sheng (2023) we allow the sensitivity interval to vary over time (now denoted as l_t), and thus to respond to shifts in consumer disagreement. The assumption of a constant sensitivity interval over time introduces certain drawbacks to the quantification method. Alterations in the distribution of survey responses can disproportionately or even counter intuitively affect the estimate of the perceived/expected rate of inflation. This adjustment incorporates some of the effects of particular changes in the distribution of survey responses, preventing disproportionate flattening of the expected inflation distribution.

The second sensitivity interval $(\pi_t^m - s_t; \pi_t^m + s_t)$ encloses the scaling factor (π_t^m) and includes respondents who perceive price dynamics as "prices have increased moderately". Consequently, participants are expected to report "prices have risen a lot" if their assessments surpasses the upper limit of the sensitivity interval around the scaling factor $(\pi_t^m + s_t)$. Respondents selecting "prices have risen slightly" are those whose perceptions fall between the upper limit of the sensitivity interval around zero and the lower limit of the sensitivity interval around the scaling factor $(l_t; \pi_t^m - s_t)$. Individuals choosing "prices have fallen" are those whose perceptions are below the lower limit of the sensitivity interval around zero $(-l_t)$. Using the probability quantification method, we can express fractions of respondents $a^p_{1,t}$, $a^p_{2,t}$, $a^p_{3,t}$, b^p_t, and c^p_t in terms of cumulative normal distribution, $F(.)$ of the limits of sensitivity intervals surrounding zero $(-l_t; l_t)$ and moderate inflation rate $(\pi^m_t - s_t; \pi^m_t + s_t)$.

$$a^p_{1,t} = 1 - F^p_t(\pi^m_t + s_t) \tag{3.1}$$

$$a^p_{2,t} = F^p_t(\pi^m_t + s_t) - F^p_t(\pi^m_t - s_t) \tag{3.2}$$

$$a^p_{3,t} = F^p_t(\pi^m_t - s_t) - F^p_t(l_t) \tag{3.3}$$

$$b^p_t = F^p_t(l_t) - F^p_t(-l_t) \tag{3.4}$$

$$b^p_t = F^p_t(-l_t) \tag{3.5}$$

Where we standardise variables so that:

$$F^p_t(k) = \Phi_t(\frac{k - \bar{\pi_t}^p}{\sigma^p_t}) \tag{3.6}$$

By solving equations above we obtain formulas for the mean of the distribution $(\bar{\pi_t}^p)$, its standard deviation (σ^p_t), and both sensitivity intervals $(-l_t; l_t)$ and $(\pi^m_t - s_t; \pi^m_t + s_t)$.

$$\bar{\pi_t}^p = \pi^m_t \frac{g^p_t + h^p_t}{g^p_t + h^p_t - (e^p_t + f^p_t)} \tag{3.7}$$

$$\sigma^p_t = \pi^m_t \frac{-2}{g^p_t + h^p_t - (e^p_t + f^p_t)} \tag{3.8}$$

$$s^p_t = \pi^m_t \frac{f^p_t - e^p_t}{g^p_t + h^p_t - (e^p_t + f^p_t)} \tag{3.9}$$

$$l^p_t = \pi^m_t \frac{h^p_t - g^p_t}{g^p_t + h^p_t - (e^p_t + f^p_t)} \tag{3.10}$$

where:

$$e^p_t = \Phi^{-1}_t(1 - a^p_{1,t}); f^p_t = \Phi^{-1}_t(1 - a^p_{1,t} - a^p_{2,t});$$

$$g^p_t = \Phi^{-1}_t(1 - a^p_{1,t} - a^p_{2,t} - a^p_{3,t}); h^p_t = \Phi^{-1}_t(c^p_t)$$

Once we quantify the mean perceived inflation $(\bar{\pi_t}^p)$, we use it as a scaling factor in the analogous quantification of the mean expected inflation $(\bar{\pi_t}^e)$ and its standard deviation (σ^e_t). The utilization of perceived inflation as the scaling factor for expected inflation can be supported by a reasonably stable correlation in 2019 - 2023 of c.a. 0.7 between the two except for the abnormal year 2022 (Brázdik *et al.* 2024).

$$\bar{\pi_t}^e = \pi_t^p \frac{g_t^e + h_t^e}{g_t^e + h_t^e - (e_t^e + f_t^e)} \tag{3.11}$$

$$\sigma_t^e = \pi_t^p \frac{-2}{g_t^e + h_t^e - (e_t^e + f_t^e)} \tag{3.12}$$

$$s_t^e = \pi_t^p \frac{f_t^e - e_t^e}{g_t^e + h_t^e - (e_t^p + f_t^e)} \tag{3.13}$$

$$l_t^e = \pi_t^p \frac{h_t^e - g_t^e}{g_t^e + h_t^e - (e_t^e + f_t^e)} \tag{3.14}$$

Proceeding with the quantification approach described above, we have to start by selecting the appropriate proxy variable for the "natural"/"moderate" rate of inflation π_t^m. Following Łyziak & Mackiewicz-Łyziak (2014), we select moderate inflation from moving averages of current price dynamics with lags of 2-48 months based on their correlation with consumer perceived inflation data, specifically with the balance statistic defined as:

$$Balance_t = a_{1,t}^p + \frac{a_{2,t}^p}{2} - \frac{b_t^p}{2} - c_t^p \tag{3.15}$$

The current price dynamics (π_t) is represented by the year-on-year inflation rate, the same as in Lyziak (2010). We decide on our moderate inflation proxy based upon the highest Spearman rank correlation coefficient between the deviation of current price dynamics from the specific moving average and the balance statistic.

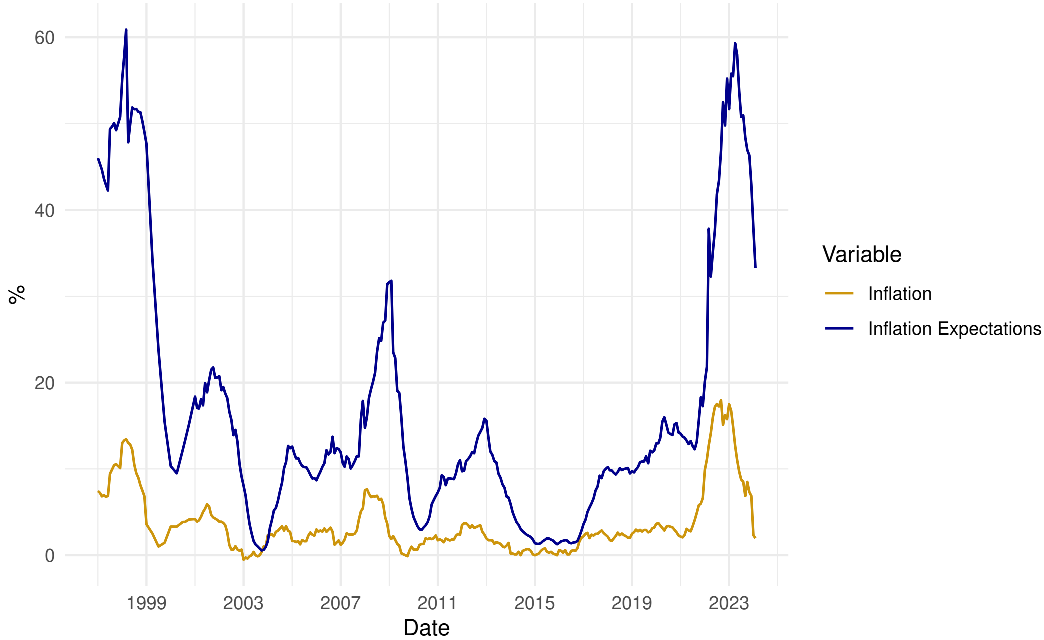
$$max\rho = 1 - \frac{6\sum_{t=1}^{T}((MA(\pi)_{it} - \pi_T) - Balance_t)^2}{T(T^2-1)} \tag{3.16}$$

Based on this methodology, we have selected the 13 month moving average of inflation as the proxy for moderate inflation, where the Spearman correlation of respected moving average with the Balance metric was c.a. 0.36. This result is quite different from Łyziak & Mackiewicz-Łyziak (2014), who selected the 29-th moving average for the Czech Republic using the same method. The reason for this discrepancy may be the rapidly changing dynamics of inflation in the past few years, which were not covered by Łyziak & Mackiewicz-Łyziak (2014), which resulted in less smooth inflation perceptions.

Figure 3.2 and Table 3.2 show the development and summary statistics of quantified consumer inflation expectations compared with y-o-y inflation.

The consumer inflation expectations are systematically and significantly higher than the actual yearly inflation rate, let alone the CNB inflation target. This is in line with the quantitative consumer inflation expectations shown in Brázdik

Figure 3.2: Quantified Consumer Inflation Expectations vs Actual Inflation



Source: CSU, EC Consumer Survey, Authors' calculations

Table 3.2: Expected and Actual Inflation Summary Statistics

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Quantified consumer inf. exp. (%)	0.554	7.655	11.444	16.552	18.771	60.895
Financial markets inf. exp. (%)	1.365	2.001	2.274	2.529	2.774	7.257
Yearly inflation (%)	-0.5161	1.3265	2.4731	3.5218	3.7155	17.9727

Source: CSU, CNB, EC Consumer Survey, Authors' calculations *et al.* (2024), who suggest short-term adaptive behavior among households as the reason, though, our estimates are even higher. However, for the 2016 - 2020 period, our estimate of around 10% expected inflation is close to that in Brázdik *et al.* (2024). A further possible explanation is that individuals display weak anchoring of inflation expectations (Kumar, Afrouzi, Coibion, & Gorodnichenko 2015). Furthermore, consumer inflation expectations are biased and do not contain relevant economic information. For example, Coibion, Gorodnichenko, & Weber (2022) found that on average, the FOMC statement has about the same effect on expectations as a mere announcement of the US Fed's inflation target.

The challenge of rational inattention is not the sole contributor to informational frictions; individuals, despite the readily available inflation statistics, assign a significant weight to less precise information sources, such as their memories of product prices in supermarkets (Cavallo, Cruces, & Perez-Truglia 2017). Much of the current literature on this topic actually reveals a tendency to rely on recent personal experiences, leading to distorted beliefs about inflation. Households base their inflation forecasts on specific goods, such as gasoline and food prices, when forming expectations about broader price movements. (Kumar, Afrouzi, Coibion, & Gorodnichenko 2015; Coibion, Gorodnichenko, Kumar, & Pedemonte 2020; Weber, D'Acunto, Gorodnichenko, & Coibion 2022) For example, Weber *et al.* (2022) pinpointed that in April 2020 after a surge in food prices and again in the summer of 2021 when used car prices rose sharply in the US, households reacted by increasing expectations for overall inflation in the next 12 months. Additionally, D'Acunto, Malmendier, & Weber (2021) observe that women tend to focus more on the prices of milk and bread, while men pay more attention to price changes in beer and gasoline when forming their inflation expectations. In addition, Cavallo *et al.* (2017) chose products from six broad categories of goods (infant formula, bread, pasta and noodle products, cereals, sodas, and shampoos and related products) and presented the respondents of their survey with price changes of these products to assess the extent to which individuals rely on information from their daily experiences when forming inflation expectations. Their results indicate that average inflation expectations react notably to the average price fluctuations listed in the table of supermarket products.

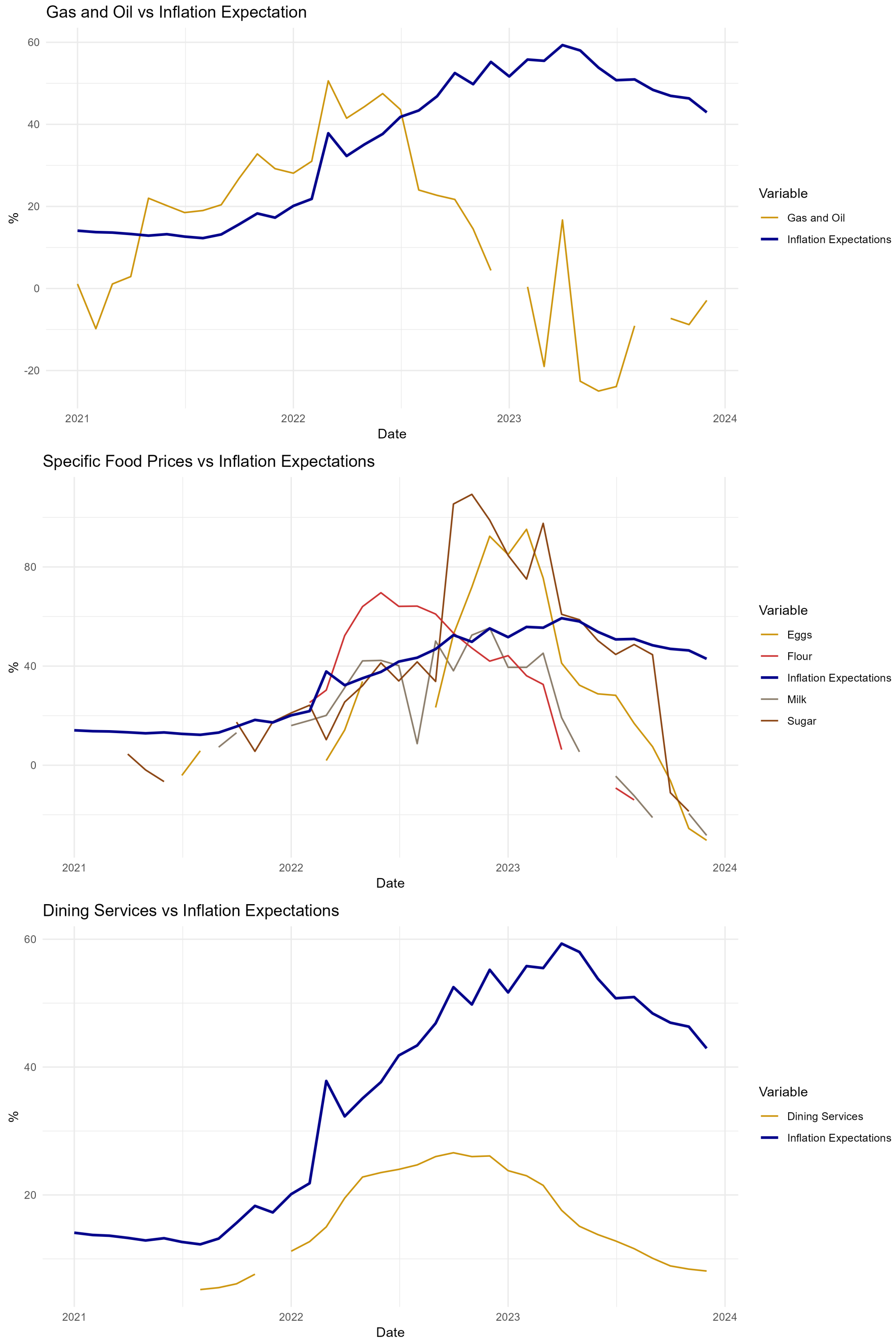
To analyze how these findings hold up in the context of the shaping of the Czech consumers' inflation expectations, we compare inflation in oil and gas, selected staple goods, and dining services prices with our estimates of consumer inflation expectations in Figure 3.3. We observe that although the quantified consumer inflation expectations appear remarkably high, they seem reason-able if these expectations are formed adaptively based on inflation in essential goods such as eggs, flour, milk, or sugar as is apparent from the second panel of Figure 3.3. Moreover, the upper panel of the figure illustrates that the substantial increase in consumer inflation expectations in 2022 was both preceded and accompanied by a surge in oil prices. Additionally, it is evident that the peak in inflation expectations, approximately in the first quarter of 2023, followed peaks in the inflation rates in prices of eggs and sugar. The overall trend in quantified consumer inflation expectations also closely mirrors the development of inflation in dining services, albeit with a slight temporal shift. These observations suggest that the hypotheses regarding the short-term adaptive nature and biases in the formation of inflation expectations also may hold true for Czech consumers.

Another reason for the inconsistency between actual inflation and the quantified inflation expectations might be the inaccuracy of the quantification method, which relies on some strong assumptions. These include normal distribution of expected inflation in the population, with unknown mean and standard deviation, location of expectations of the respondents stating that prices will not change around zero, or the strongest assumption that while selecting the response to the survey question, individuals compare currently observed price developments with the moderate rate of inflation, which can be proxied by a moving average of actual inflation (Łyziak & Sheng 2023). If any of these assumptions are violated, the results of the quantification may no longer be valid.

Furthermore, Brázdik *et al.* (2024) reports that perceived inflation was significantly higher than expected inflation in 2022 and 2023, with perceived inflation approaching 40%. This level aligns closely with our estimates of expected inflation during the same period. These findings suggest that the mechanisms underlying the formation of perceived and expected inflation are less interdependent than the quantification method assumes. This offers a potential explanation for the unusually high estimates of expected inflation produced by the method, that it essentially approximates expected perceived inflation rather than the expectation of the officially reported inflation communicated through media. During periods of high inflation, when certain prices escalate rapidly (see Figure 3.3), the disparity between the two can suddenly become substantial.

However, with the EC Consumer Survey being the only publicly available data on consumer inflation expectations in the Czech Republic and the methodology of Łyziak & Sheng (2023) being the only quantification method for this

Figure 3.3: Quantified Consumer Inflation Expectations Compared with Annual Inflation in Selected Goods



Source: CSU, EC Consumer Survey, Authors' calculations kind of data known to the authors, the utilization of this approach becomes indispensable, affirming its necessity in informing the research endeavors of this thesis.

In defense of the quantification approach, the inflation expectations seem to approximately follow the trend of actual inflation. This implies that although households' understandings generally align with economic trends, there is a significant difference in scale when compared to the real situation. The exception was the recent inflation episode (since 2021), when inflation expectations increased a few years before and remained elevated until the actual inflation spike. This observation is also in line with consumer inflation expectations development shown in Brázdik *et al.* (2024) and points to a possible forward looking nature of the consumer inflation expectations or to tight consumer demand expectations prior to and during the COVID 19 pandemic. The elevated inflation expectations in 2022 and 2023, and their gradual normalization in 2023 are also in line with the conclusions of Brázdik *et al.* (2024).

Figure 3.4 and Table 3.3 show the development and summary statistics of the quantified cross-sectional standard deviation of inflation expectations, which we will later use as a proxy for expectations disagreement. The quantified cross-sectional standard deviation seems to follow the level of inflation expectation themselves, which is an inherent property of the quantification method since both quantified inflation expectations and its standard deviation are scaled by the perceived inflation, which may be realistic in some cases, but does not have to always hold. Nonetheless, at least the latest spike in the standard deviation of inflation expectations (see Figure 3.4) can be justified, as Brázdik *et al.* (2024) also describe a gradual flattening of the probability density distribution of inflation expectations since 2016 until 2023.

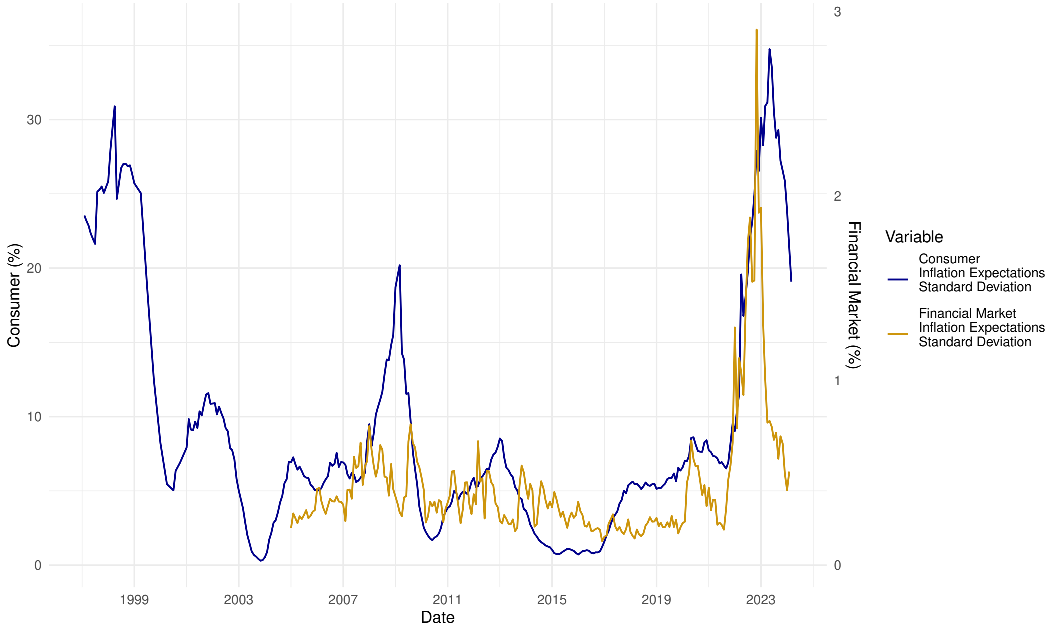
Table 3.3: Standard Deviation of Inflation Expectations Summary Statistics

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.
Quantified sd of consumer inf. exp. (%)	0.2995	4.2597	6.2269	8.9825	10.1339	34.7377
Sd of financial market inf. exp. (%)	0.1302	0.2384	0.3430	0.4305	0.4919	2.9006

Source: European Commission Consumer Survey, CNB, Authors' calculations

Table 3.2 and Figure 3.5 show summary statistics and the development of

Figure 3.4: Consumer and Financial Market Inflation Expectations Standard Deviations



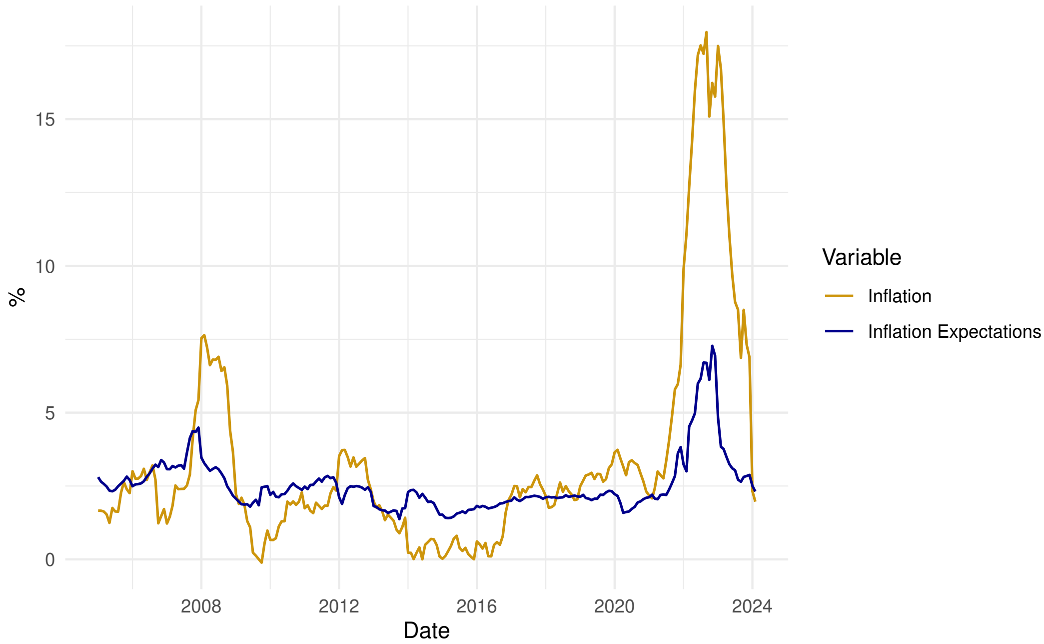
Source: CNB, European Commission Consumer Survey, Authors' calculations

average financial market inflation expectations compared with y-o-y inflation. Table 3.3 and Figure 3.4 show the summary statistics and development of the cross-sectional standard deviation of financial market inflation expectations which we will later also use as a proxy for expectations disagreement.

We can observe very similar patterns in the development of average financial market inflation expectations as in the quantified consumer inflation expectations except the level is on a much smaller scale. This is, however, not the case for the standard deviation which, except the latest inflation spike period, remained relatively transient during the previous periods of higher inflation. It is also important to highlight that while the standard deviation of consumer inflation expectations had increased several years prior and had remained elevated until the actual inflation surge in 2021, this was not the case for the standard deviation in financial market expectations. The latter briefly escalated at the onset of the COVID-19 pandemic and quickly returned to previous levels.

Moving back to the recent inflation surge, even after the initial spike in 2022, the standard deviation in financial market expectations returned much more quickly compared to the consumer case. Both observations suggest that financial market analysts demonstrate a significant level of consistency due to utilization of analytical tools and diverse forecasting methods to offer a reasonably uniform inflation forecast for the forthcoming year (Brázdik *et al.* 2024). To reiterate, from late 2022 onwards, financial market analysts have been shifting their inflation expectations back towards the inflation target and the cross sectional standard deviation has approached its long term mean.

Figure 3.5: Average Financial Market Inflation Expectations vs Actual Inflation



Source: CNB, Authors' calculations

Chapter 4

Methodology

4.1 Smooth transition local projections model

To measure state-dependent impacts of inflation expectations disagreement, we adopt the technique of Falck *et al.* (2021) that integrates the local projections methodology by Jordà (2005) with a smooth regime-switching model. The local projections model includes five endogenous variables: yearly inflation, inflation expectations, GDP growth, CNB repo rate, and credit spread (the difference between the long term cost of credit for non-financial corporations and the CNB repo rate). We chose them based on traditional monetary VAR literature and Falck *et al.* (2021). Moreover, we added the credit spread in regard to findings of Gertler & Karadi (2015) that inclusion of credit spread effects in the modeling of monetary policy transmission is necessary.

Contingent on the likelihood of either the high (H) or low-disagreement regime (L), we gauge the reactions of the endogenous variables, $y_{i,t}$, to a monetary policy shock ϵ_t. From the notation of Falck *et al.* (2021), the model with one lag can be expressed as:

$$\begin{gathered} y_{i,t} = (\alpha_i^H + \beta_i^H \epsilon_t + \gamma_i^H y_{t-1}) F(z_{t-1}) + \\ (\alpha_i^L + \beta_i^L \epsilon_t + \gamma_i^L y_{t-1})(1 - F(z_{t-1})) + u_{i,t}; \end{gathered} \tag{4.1}$$

where $i \in \{0, ..., I\}$ denotes the number of periods after the shock, $\{\alpha_i^\lambda, \beta_i^\lambda, \gamma_i^\lambda\}$, $\lambda = H, L$, are regime-specific parameters, and $u_{i,t}$ is the regression residual.

The likelihood of being in a high-disagreement regime at time $t-1$ is represented by the function $F(z_{t-1})$ within the range $[0, 1]$. The interaction between $F(z_{t-1})$ and $(\alpha_i^\lambda + \beta_i^\lambda \epsilon_t + \gamma_i^\lambda x_{t-1})$ allows for the impact of monetary policy shocks to be contingent on the probability of being in either a high or low-disagreement regime. These regimes are identified using the variable z_{t-1}, which should reflect the disagreement level about inflation expectations. To prevent potential endogeneity bias, the regime-indicating variable is lagged by one period. The continuous function $F(z_{t-1})$ follows a logistic shape:

$$F(z_{t-1}) = \frac{exp(\theta \frac{z_{t-1}-c}{\sigma_z})}{1 + exp(\theta \frac{z_{t-1}-c}{\sigma_z})}; \tag{4.2}$$

where c denotes the median and σ_z the standard deviation of z_{t-1}. The specification that Falck *et al.* (2021) use was derived from Granger & Teräsvirta (1993) and facilitates a gradual shift between high and low disagreement states. This characteristic acknowledges that certain periods may not be definitively assigned to a specific regime. The parameter θ governs the curvature of $F(z_{t-1})$ and thus influences how responsive the probability function is to changes in disagreement. Like prior studies that specify rather than estimate the degree of regime-switching (Auerbach & Gorodnichenko 2013; Tenreyro & Thwaites 2016; Falck *et al.* 2021), we set θ to 5 (Falck *et al.* 2021). It shall be mentioned the state-dependent model includes the linear version, where $F(z_{t-1})$ can be equal to 1 or 0.

We employ local projections for estimating impulse responses, which directly estimate the dependent variable's reaction i periods after the shock ϵ_t. This response depends on whether the economy is in a high- or low-disagreement regime before the shock occurs. The estimation is iterated for each horizon i, and the sequence $\{\beta_i\}_0^I$ represents the impulse response function for y_t within the initial I periods. In our analysis, we made the decision not to include a time trend, as our sample begins in 2004. This contrasts with the approach of Falck *et al.* (2021), whose study covers the period from 1998 to 2007. During the years from 1998 to 2008, there was a noticeable downward trend in inflation in the Czech Republic, however, inflation appears to have stabilized since then. Despite this stabilization, we continue to observe significant autocorrelation in inflation. Consequently, to address correlation across time and horizons, we adjust standard errors for both autocorrelation and heteroscedasticity using the method proposed by Newey & West (1986).

The local projections estimation is a combined solution for issues of correct identification of the true data generating process to which they are more robust (Montiel Olea & Plagborg-Møller 2021) and issues with potential endogeneity of VAR generated shocks, whereby they incorporate exogenously supplied shocks. Whatsmore, local projections easily accommodate experimentation with highly nonlinear specifications (Jordà 2005) as they allow potential regime switches after the shock. (Falck *et al.* 2021)

The model considers the probability of high-disagreement regime before the shock but does not presume anything about the regime the economy is in the subsequent periods. Any reaction of disagreement to the shock is accounted for in the estimated coefficients. A state-dependent VAR model, on the other hand, would necessitate modelling the transformation process for z_{t-1}.

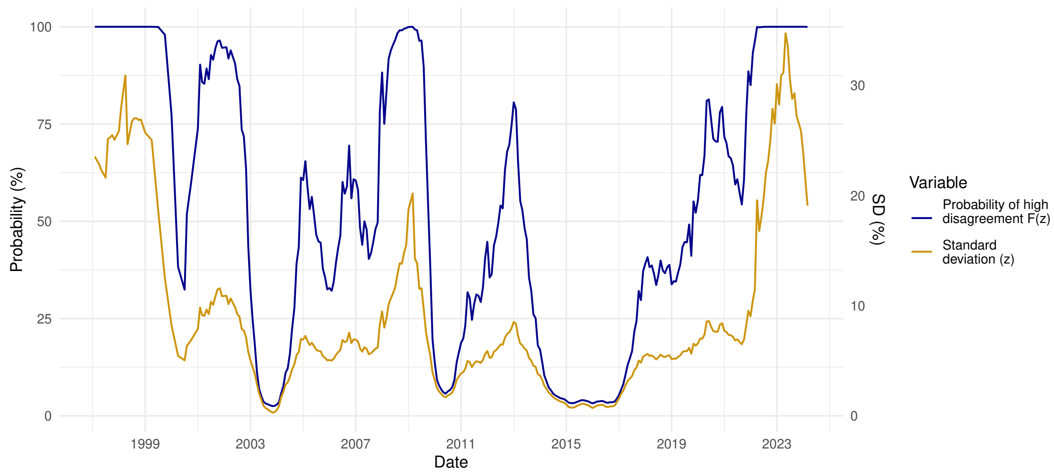
As for the regime-indicating variable z_{t-1}, we choose the cross sectional standard deviation of inflation expectations. We use two alternative specifications, the previously quantified consumer inflation expectations standard deviation and standard deviation of the FMIE Survey of the CNB.

Figure 4.1 shows the standard deviation of inflation expectations of consumers along with the probability of high disagreement regime. We can identify four periods of high disagreement in THE consumer inflation expectations. The first period was roughly from the beginning of the sample period in 1996 until 2004 with a slight dip around the year 2000. The Czech economy was going through economic transformation at that time and we can assume that consumer inflation expectations were not yet anchored. Second period of high disagreement was centred around the GFC. In this period, there was a high uncertainty not just about inflation but also about other economic indicators such as GDP and unemployment. The third episode of disagreement occurred around the year 2013 throughout the peak of European debt crisis and at the start of CNB's exchange rate commitment. As Coibion *et al.* (2020) point out, changes in inflation expectations can be associated with changes in other economic expectations: pessimism about the overall economy, business conditions, ability to obtain credit, and greater uncertainty about the future. The announcement of the CNB's exchange rate commitment aimed to increase inflation also likely contributed to expectations uncertainty as the central bank had not used unconventional instruments before and its effect was unpredictable.

The beginning of the fourth period of elevated disagreement about inflation expectations, which persisted to the beginning of 2024, roughly coincides with the beginning of the COVID-19 pandemic. Similar like the GFC, this period was characterized by high uncertainty, and not just about economic indicators, but also about health, social security etc. The high uncertainty persisted even after the effects of the pandemic abated. The Russian invasion of Ukraine, coupled with a spike in energy prices and high inflation, seamlessly followed and took over as the main source of uncertainty. These could be the reasons for the elevated disagreement in inflation expectations in the recent period.

Figure 4.2 shows the standard deviation of the inflation expectations of the financial market along with the probability of high disagreement regime. From the first look, similar four periods of disagreement can be identified, yet, there is a much larger volatility of the disagreement probability. Additionally, in contrast with consumer expectations, there was a sharp drop in disagreement probability in 2021. The larger variability in disagreement may be attributed to several factors. First, market analysts should be more informed about economic development, and thus, their inflation expectations are more sensitive to economic news and changes in trends. Second, because it is calculated in a standard manner, contrary to the quantified consumer standard deviation, the cross sectional standard deviation of market analysts is more nuanced.

Figure 4.1: Probability of being in the high-disagreement regime: Consumer inflation expectations

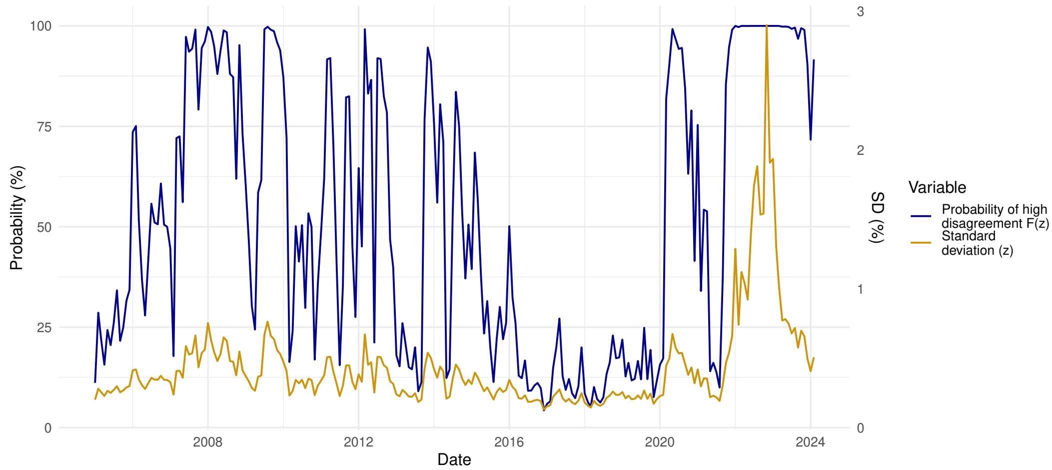


Source: Czech Statistical Office, European Commission Consumer Survey, Authors' calculations

4.1.1 Selecting Lag Length for the Baseline Models

To select the lag length for the baseline models we set the maximum leg length to twice the data frequency, or 24, and observed what the Akaike (AIC), Hannan-Quinn (HQ), Schwarz (SC), and Final Prediction Error (FPE) Criteria recommended. For both models including financial market and consumer inflation expectations, the AIC recommended 24 lags, HQ and SC recommended 2 lags and FPE recommended 19 and 20 lags respectively (see Table 4.1). When maximum number of lags is set to the frequency, or 12, both AIC and FPE recommend 12 lags (see Table 4.1). In view of the fact that selecting an appropriate number of lags requires balancing the trade-off between capturing

Figure 4.2: Probability of being in the high-disagreement regime: Financial Market inflation expectations



Source: Czech Statistical Office, European Commission Consumer Survey, Authors' calculations

sufficient autocorrelation in the data and avoiding overfitting or underfitting the model, we chose to include 12 lags for each baseline model. Monthly data often exhibits seasonal patterns, and selecting 12 lags corresponds to capturing a full year's worth of seasonal variation. This ensures that the model accounts for seasonal effects adequately. Furthermore, in economic and financial contexts, a yearly cycle is often relevant for analyzing various phenomena. To further support the selection of lag length, we note that Bauer & Swanson (2023) who model similar local projections using high frequency identification, also advocate for 12 lags for this setting.

Table 4.1: Information Criteria for Lag Selection

model	Cons. Inf. Exp.		Fin. Mar. Inf. Exp.	
lag length	24	12	24	12
AIC	24	12	24	12
HQ	2	2	2	2
SC	2	2	2	2
FPE	19	12	20	12

Note: Akaike (AIC), Hannan-Quinn (HQ), Schwarz (SC), and Final Prediction Error (FPE) Criteria.

4.2 Estimating Exogenous Monetary Policy Shocks

As already indicated, we utilize Jordà (2005) smooth-transition local projections model to infer the differences in impulse responses of inflation and other macroeconomic variables to monetary policy shocks in high and low disagreement environments. Impulse responses serve as integral outputs from a VAR, carrying inherent importance for our research. These responses provide empirical validation for the theoretical frameworks presented by this thesis, establishing them as a crucial aspect of our empirical investigation.

However, there are various issues associated with VAR model analysis. Shocks internally generated within VARs may not necessarily reflect exogenous monetary policy. To overcome this, we shall supply exogenous monetary policy shocks from outside of the model into the local projections. One option is to use narrative identification of the shocks (Romer & Romer 1989; 2004; Wieland & Yang 2020), used also by Falck *et al.* (2021), whose paper primarily inspired our theoretical foundation. Nevertheless, this is not an option for us since the narrative shocks are only available for the U.S. For this reason, we are using instrumental variables or high-frequency identification. We trail the hybrid approach developed by Gertler & Karadi (2015), which was in turn inspired by Gürkaynak, Sack, & Swanson's (2005) approach.

Utilizing unexpected shifts in the FFR and Eurodollar futures during FOMC dates, Gürkaynak *et al.* (2005) focus on gauging policy surprises. The examination of the effects of policy surprises on interest rates has also been undertaken by researchers such as Kuttner (2001); Hamilton (2008); and Campbell *et al.* (2012). For the purpose of addressing potential simultaneity issues, Gertler & Karadi's (2015) hybrid HFI approach incorporates intraday data to measure policy shocks. Specifically, policy surprises are identified as unexpected movements in the Fed Funds futures within a narrow timeframe (e.g., thirty minutes) of the FOMC decision. Due to the unavailability of intraday data for the Czech Republic, this thesis exclusively relies on daily data.

The fundamental presumption revolves around the idea that policy decisions remain unaffected by economic news during the FOMC days, with relevance attributed solely to the information from the day prior. This implies that surprises in the Fed Funds futures on the FOMC dates are orthogonal to concurrent movements in economic and financial variables. An additional advantage of this approach is its capability to integrate shocks to forward guidance due to surprises in the Fed Funds futures. These surprises capture amendments in beliefs about the future path of short-term rates that happen on FOMC dates.

While standard HFI methods can measure the immediate impact of a policy surprise on market interest rates, the identification of the persistence of this impact or the examination of the response of variables like output and inflation poses challenges. In contrast, Gertler & Karadi's (2015) approach blends elements of VAR and HFI methodologies, utilizing the HFI approach to identify exogenous policy surprises and subsequently employing a VAR to document the dynamic responses of real and financial variables. The combination of VAR and HFI methodologies to identify monetary policy shocks has been also used in eg. Bagliano & Favero (1999); Cochrane & Piazzesi (2002); Faust, Swanson, & Wright (2004); and Barakchian & Crowe (2013).

In particular, Gertler & Karadi's (2015) methodology to identify monetary surprises with external instruments was built upon Mertens & Ravn (2013) and Stock & Watson (2012). In this thesis, we will employ their strategy with slight modifications such as altering the instrumental variables or frequency of the monetary policy surprises data. We also do not differentiate between policy instrument and policy indicator like Gertler & Karadi (2015) do. Instead of fed funds target rate, they choose the longer term 1 year government bond yield as the policy indicator because it more reacts to forward guidance. We are not using a government bond yield as the policy indicator since the Czech government bond yields significantly respond to interest rate differentials and the CNB monetary policy meetings are sometimes days within FOMC or ECB monetary policy meeting dates.

4.2.1 Explanation of the external instruments methodology

Z_t is a vector of instrumental variables, ϵ_t^p a structural monetary policy shock, and ϵ_t^q a vector structural shock other than the policy shock. To be a valid set of instruments for the policy shock, Z_t has to be correlated with ϵ_t^p but orthogonal to ϵ_t^q, i.e.

$$E[Z_t(\epsilon_t^p)^T] = \phi > 0 \tag{4.3}$$

$$E[Z_t(\epsilon_t^q)^T] = 0 \tag{4.4}$$

We first acquire estimates of the reduced form residuals vector u_t from the ordinary least squares regression of the reduced form VAR. We further divide u_t into u_t^p, the reduced form residual from the equation for the policy indicator, and u_t^q, the remaining reduced form residuals. We are primarily interested in the variation in the reduced form residual for the policy indicator that is due to the structural policy shock. That is obtained in the first stage with regression of u_t^p on Z_t. The variation of the resulting fitted value $\hat{u_t^p}$ can be attributed solely to ϵ_t^p.

Unlike Gertler & Karadi (2015), who use surprises in Fed Funds futures and Eurodollar futures on FOMC dates, we use the differences between the value of the 1X4, 3X6, and 6X9 forward interest rate agreements on the end of the day before and the end of the day of the Czech National Banks's monetary policy Bank Board meetings, following the same logic that these instruments should be forward looking. We wanted to also include the EUR/CZK exchange rate and its 1 month forward, since the unexpected monetary authority's actions also tend to be priced in the same day, and over the other instruments it has the advantage that the market for it is more liquid. However, these did not perform satisfactorily as instruments as described in Subsection 4.2.2.

If we define the settlement price of the forward instrument on the monetary policy meeting date in month t expiring in month j as f_{t+j} (for the EUR/CZK exchange rate instrument $j = 0$) and the price of the same asset the day before the monetary policy meeting date f_{t+j-1}, then

$$(E_t\{i_{t+j}\})^u = f_{t+j} - f_{t+j-1} \tag{4.5}$$

is the unanticipated change in the monetary policy interest rate that is believed to hold in month $t + j$ and

$$(E_t\{i_t\})^u = i_t^u \tag{4.6}$$

is the surprise in the current monetary policy interest rate. For $j \geq 1$, the unexpected change in the anticipated rate can be viewed as quantifying a forward guidance shock. As outlined by Gürkaynak *et al.* (2005), the $t+j$ (for $j \geq 1$) surprise in the expected target rate may be thought of as measuring a shock to forward guidance.

4.2.2 Selecting Monetary Policy Shock Instruments

In this subsection, we address the matter of selecting instruments for the monthly local projections. We first need to recalculate the daily surprises in instruments into monthly averages. In reality, the day of the CNB Bank board meetings varies throughout the month, making our task more complex. If all the meetings were consistently on the first day of each month, we could easily use the surprises on those days as our measure of monthly average surprise. However, we want to avoid disregarding valuable information due to the varying meeting dates. Additionally, since we use monthly average rates (rather than end-of-month rates) for our monetary policy indicators, a surprise occurring at the end of a month has less influence on the monthly average rate than a surprise at the beginning of the month. To address this, we reproduce the approach of Gertler & Karadi (2015) and do a two-step calculation: first, we accumulate the surprises on any CNB Bank board meeting days during the last 31 days (e.g., on February 15, we cumulate all the CNB Bank board day surprises since January 15); second, we average these monthly surprises across each day of the month.

To test for a week instrument problem we regress CNB repo rate residuals from a simple VAR containing the same variables as our baseline local projections model (inflation, inflation expectations, GDP growth, average repo rate, and credit spread) on the monthly average instrument surpriseS. Stock, Wright, & Yogo (2002) suggest using an F-statistic threshold of ten in the first stage regression in two stage least squares to ensure the absence of a weak instrument issue with confidence. (Gertler & Karadi 2015) Table 4.2 reports the R^2 and the robust F-statistic for each regression of the simple VAR residuals on each of the instrument candidates (1X4, 3X6, and 6X9 FRA, EUR/CZK, and EUR/CZK 1 month forward).

The most effective instrument is the 1X4 FRA, which accounts for almost 22 percent of the monthly variation in the reduced monetary residual and is accompanied by a robust F-statistic of 60.7 which exceeds the proposed threshold of 10 by a significant margin. The second best instrument is 3X6 FRA with a robust F-statistic close to the threshold of 8.7. Furthermore, its non robust F-statistic is 23.85, more then twice the proposed threshold. Conversely, both the EUR/CZK and its one month forward reach dismally low R^2 and F-statistics, and therefore we exclude them as instruments. We select the 1X4 FRA as our baseline instrument and perform robust checks with both 3X6 and 6X9 FRAs as instruments. The mean of the 1X4 FRA shock series is 8.254785e-18. From that we include that our shock is zero mean. However, there is evidence of serial correlation based on Durbin & Watson (1950) and Ljung & Box (1978) tests.

The time series of estimated monthly monetary policy shocks using the FRA 1X4 instrument, compared with monthly changes in the repo rate, is displayed in Figure 4.3. Estimated monetary policy shocks using the alternative FRA 3X6 and 9X6 instruments are similar but smaller in scale, and can be found in

Table 4.2: Effects of High-Frequency Instruments on the First Stage Residuals of the Simple VAR (January 2004 - February 2024)

	1x4 FRA	3x6 FRA	6x9 FRA	EUR/CZK	EUR/CZK 1MF
Coefficient	1.040***	0.5111***	0.351***	0.030	0.006*
	(0.131)	(0.104)	(0.092)	(0.067)	(0.003)
N	230	230	230	230	230
R^2	0.216	0.094	0.06	0.001	0.023
Robust F-statistic	60.749	8.662	3.5384	0.746	0.046

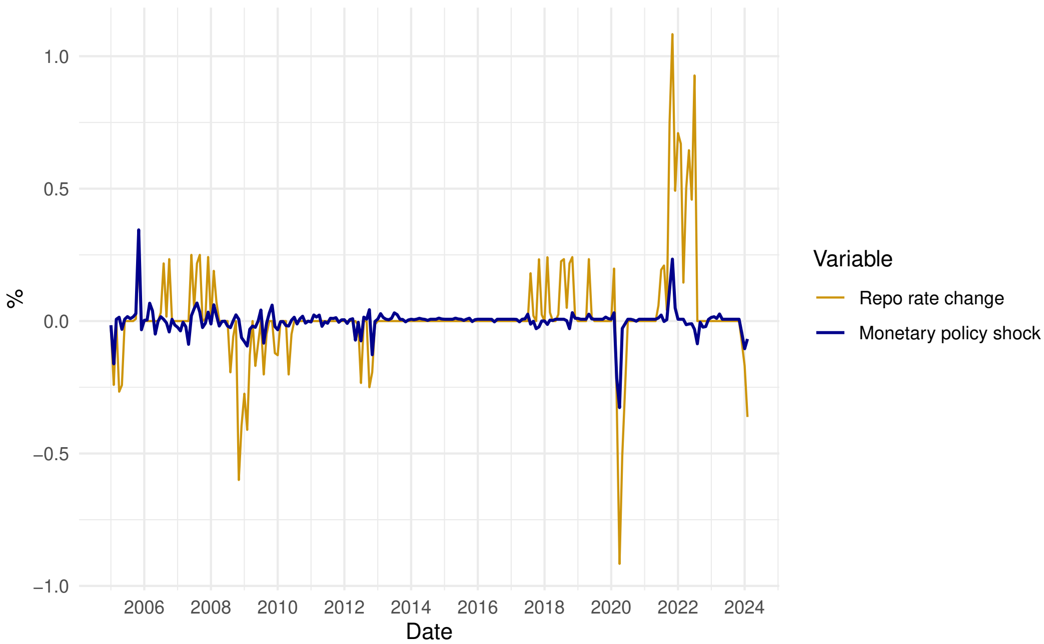
Note: Standard errors in parentheses, *** significant at the 1 percent level, ** significant at the 5 percent level, * significant at the 10 percent level

Appendix A (see Figures A.7 and A.8). The monetary policy shocks estimated with the FRA 1X4 instrument also produce larger shocks during the great recession.

The largest positive unexpected monetary policy shock in the sample occurred at the end of October 2005. There were apparently expectations of a downward correction in the repo rate, indicated by the upward shock at the beginning of 2006. The first repo rate hike of 2006 had been expected sooner, indicated by the negative shock in the first half of 2006. On the other hand, the second rate hike in September 2006 had been expected to be higher, as indicated by the negative policy shock. In 2007, the market expected a rate hike to come sooner, as evident from the negative shock right before the first repo rate hike in June 2007. The subsequent series of monetary policy tightenings in 2007 and at the beginning of 2008 seemed to have been at least partially expected since the shocks were visibly smaller in scale than the increases in the repo rate. The monetary easing in the second half of 2008 and around the beginning of 2009 also seemed to have been partially expected, as indicated by the smaller negative monetary policy shocks than the actual decreases in the repo rate and later even positive shocks. Further monetary easing in 2009 and 2010 was expected to be higher because of positive shocks.

The repo rate cuts in 2012 were evidently partially expected, but not to the same extent as indicated by the negative shocks at the given time. There were expectations of further rate cuts in 2013, as indicated by the positive shocks. The repo rate hikes from 2017 to 2019 appear to have been to a lesser or greater extent expected. The repo rate hike at the beginning of 2020 was expected to a larger degree. The series of massive repo rate cuts in the spring of 2020 seem to have been unexpected by the market, or at least to that extent. This is also the instance of the greatest negative unexpected monetary policy shock in the sample. The initial rate hikes in the summer of 2021 were to a large extent expected; however, the second round in the last quarter of 2021 was not, as indicated by the extensive positive shocks toward the end of 2021. All of the rate hikes in 2022 were expected to be of larger magnitude, as indicated by the negative shocks. Finally, the first instance of a repo rate cut after a 1.5-year period of stable rates in December 2023 was partially expected, but not to the full extent.

Figure 4.3: Monthly Monetary Policy Shocks estimated with FRA 1X4 Instrument



Source: Refinitive Eikon, Authors' calculations

Chapter 5

Results

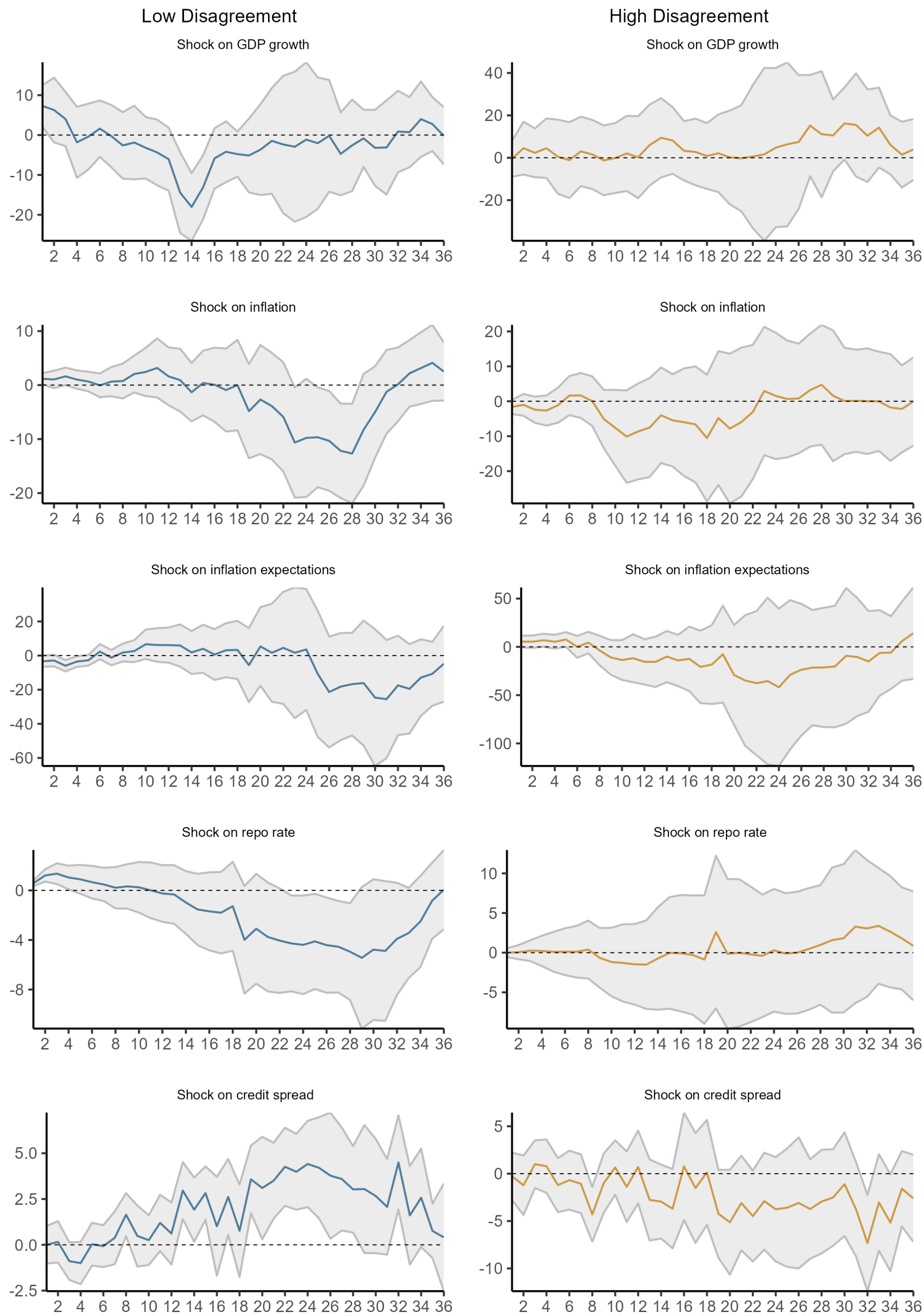
5.1 State-dependent Monetary Policy Effects

5.1.1 Consumer Inflation Expectations

In this section, we explore the predicted state dependent impacts of Czech monetary policy under the specified conditions. Figure 5.1 depicts the impulse responses of GDP growth, inflation, consumer inflation expectations, repo rate, and credit spread to an unexpected contractionary 25 basis points (bps) monetary policy surprise under high and low disagreement regimes. The maximum horizon of the impulse response functions is set to three years (h = 36). The left column illustrates the impact of the shock within a low-disagreement regime (${\beta_i}^L$), while the right column illustrates the outcomes within a high-disagreement regime (${\beta_i}^H$). The figure shows confidence bands on the 95% level. It should be noted that 25 bps unexpected monetary policy shock does not equal 25 bps change in the repo rate. As demonstrated by Figure 4.3, unexpected monetary policy shocks exhibit considerably smaller magnitudes compared to fluctuations in the repo rate, with a deviation of 25 basis points occurring within the 997th promile of the shock distribution. Notably, a shock of a similar magnitude was observed only once in the sample, back in November 2005. Consequently, due to the substantial magnitude of the shock, the impulse responses are characterized by their significant scale. The 25 bps shock was chosen for illustration as it aligns with the most common CNB singular rate hike or rate cut.

In the low disagreement regime (Figure 5.1, left column), GDP growth and inflation respond in accordance with standard economic theory. GDP growth experiences a significant increase immediately following the shock (approx-

Figure 5.1: State-dependent Effects of a 25 bps Unexpected Monetary Policy Shock: Consumer Inflation Expectations



Note: Estimation results of Equation 4.1 with yearly GDP growth, yearly inflation, one year quantified consumer inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2004 - Feb 2024 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

imately 7.3 percentage poits), followed by a notable and significant negative response of approximately -18 percentage poits (pp) after 14 months. Similarly, inflation effect peaks around 28 months post-shock with a significant negative impact of approximately -12.7 pp on average. In contrast, within the high disagreement regime, the impulse responses of both GDP growth and inflation are generally insignificant and on average smaller in magnitude. GDP growth responses in different regimes are statistically different in the 14th month after the shock. Notably, despite the differences in inflation impulse responses within regimes, we do not observe a price puzzle in the high disagreement regime, as inflation demonstrates a negative, though not significant, response between 8 and 22 months after the shock.

In terms of inflation expectations, we find a statistically significant response in the low disagreement regime three months post-impact, with a negative impact of approximately 6 pp on average. Yet, the most pronounced effect occurs much later after around 31 months, with a negative impact of -25 pp. Although it is fairly consistent with the inflation response, it is slightly shifted further in time. Initially, in the high disagreement regime, the response of inflation expectations is positive. The inflation expectations responses in low and high disagreement regime are statistically different at 95% in the third month after the shock, when the response in the high disagreement regime is significantly positive. Apart from this initial difference, the response remains fairly similar to that of the low disagreement regime, albeit insignificant. The average impact is faster than in the low disagreement regime being the most negative on average after 24 months. On the whole, however, the response of inflation expectations is either relatively small in scale or insignificant in both regimes.

The repo rate initially exhibits a significantly positive response in the low disagreement regime, peaking around three months post-shock at 1.4 pp. However, it transitions into negative territory after one year, reaching a low of approximately -5.4 pp on average after 29 months, where it again becomes statistically significant at the 95% confidence level. This coincides in time with the inflation response being the most negative 28 months post shock. In contrast, the repo rate response in the high disagreement regime is generally less pronounced and insignificant. It maintains a negative trend from 8 to 15 months post-impact before turning positive. The outcome can be linked to the dependence of inflation on the state. More specifically, because the response of repo rate after the contractionary shock is subdued in the high disagreement regime, inflation is not curbed as in the low disagreement regime.

The responses of credit spreads are the most volatile, although a general trend can be discerned. In the low disagreement regime, the credit spread response is predominantly positive and significant from 13 to 29 months post-shock, peaking at approximately 4.4 pp on average after 24 months. Conversely, in the high disagreement regime, the credit spread response is generally negative and not statistically significant, except at the 8th and 32nd month post-shock. Credit responses in different regimes are statistically different in the 32nd and 34th month after the shock.

To conclude, the impulse responses observed in the two regimes exhibit distinct patterns, with responses in the low disagreement regime being significant and aligning with expectations from standard New Keynesian theory. Overall, evidence suggests a more effective transmission of monetary policy in the low disagreement regime, although its impact on inflation expectations remains weak. A possible source of the inefficiency in the high disagreement regime is the subdued reaction of repo rate. This suggests that in times of high disagreement and uncertainty monetary policy adopts more accommodative approach.

Regarding consumer inflation expectations, we did not observe a pronounced “price puzzle”, as identified, for example, by Falck *et al.* (2021) in the US Michigan and Livingston consumer surveys (refer to Online Appendix). However, we did identify slight differences within the first four months after the shock. In the low disagreement regime, consumer inflation expectations respond significantly negatively to an unexpected contractionary monetary policy shock, whereas in the high disagreement regime, they respond significantly positively in the third month.

In summary, these findings indicate that monetary policy has a significant impact on consumer inflation expectations approximately one quarter after the shock, while the most pronounced effect occurs after approximately 2.5 years.

The slightly negative credit spread response in the high disagreement regime may be influenced by the post COVID-19 period, during which inflation expectations disagreement was elevated, yet both repo rates and credit spreads remained low. This is supported by the robustness check with a pre COVID subsample in Subsection 5.2.2, where the negative trend in the credit spread response in the high disagreement regime disappears.

5.1.2 Inflation Expectations of the Financial Market

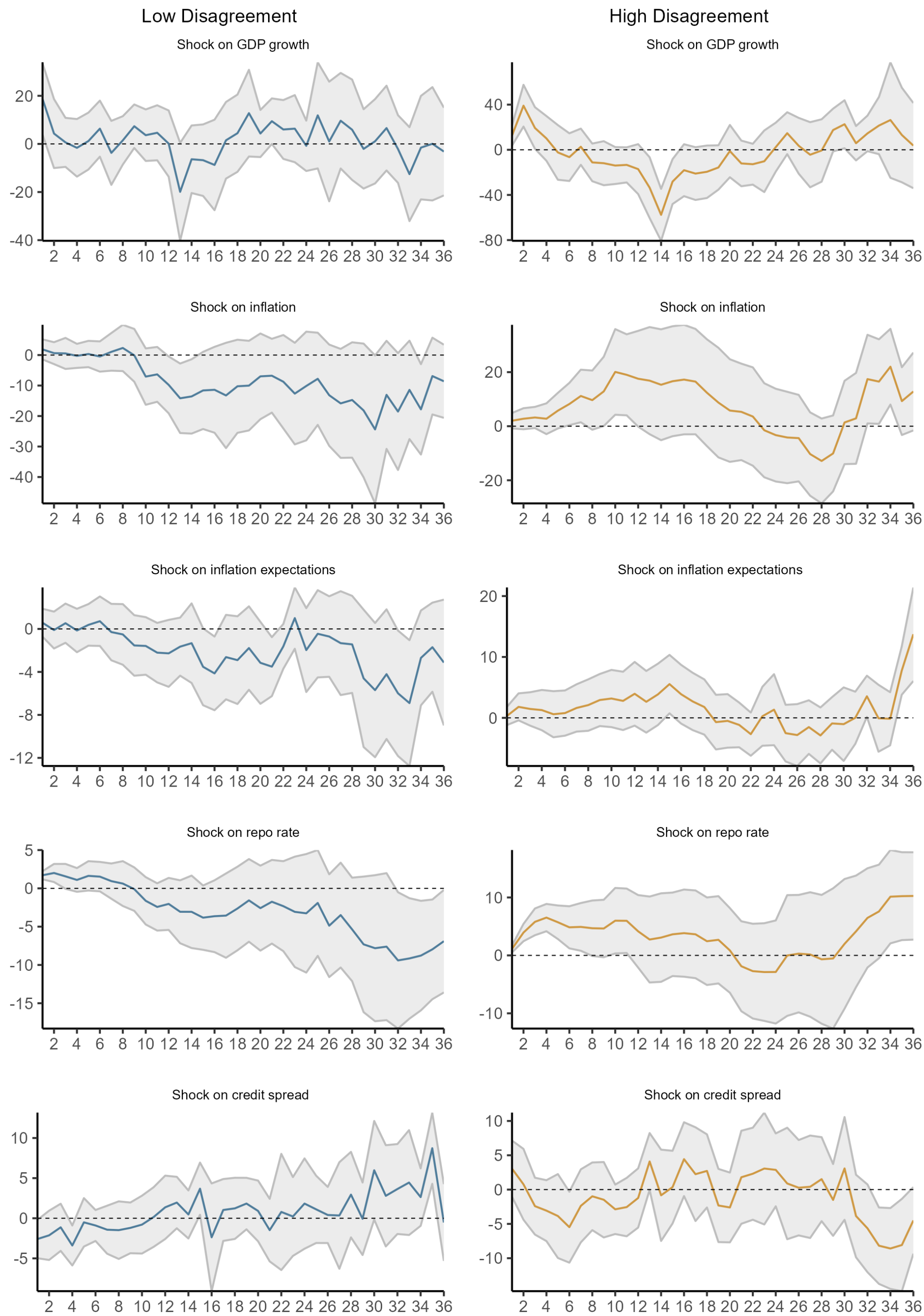
In this subsection, we explore the predicted state dependent impacts of Czech monetary policy under the same specified conditions as in Subsection 5.1.1, only this time with inflation expectations of macroeconomic analysts (Inflation Expectations of the Financial Market). Figure 5.2 depicts the impulse responses of GDP growth, inflation, financial market inflation expectations, repo rate, and credit spread to an unexpected contractionary 25 bps monetary policy surprise under high and low disagreement regimes. The same disclaimer about the monetary policy shocks as in the introduction to Subsection 5.1.1 applies here.

The GDP growth impulse responses are quite similar across both regimes and to the GDP growth response in the low disagreement regime in the consumer expectations model. Notably, only the high disagreement response is significant. Initially, it is positive (approximately 9.8 pp in the second month), then it turns negative after 14 months (approximately -14.4 pp on average). This response is almost identical to the low disagreement response in the consumer model.

In contrast to the consumer expectations model, there is a statistically significant positive response of inflation in the high disagreement regime, approximately 5 pp on average, 10 months after an unexpected contractionary monetary policy shock. Furthermore, in the high disagreement regime, the response is significantly more positive than in the low disagreement regime 10 - 13 months after the shock, as indicated by the 95% confidence intervals. This result aligns with Falck *et al.* (2021), who also record a price puzzle in the high disagreement regime. The inflation response remains positive on average until 23 months after the shock, at which point it turns negative, though not significantly. Conversely, the inflation response in the low disagreement regime is negative and statistically significant after 13 months, at approximately -3.5% on average. Compared to the consumer inflation expectations model, the response in the low disagreement regime is faster, although both responses reach their most negative points much later, on average at 28 and 30 months after the shock, respectively.

The inference on inflation expectations is similar to that on actual inflation. In the high disagreement regime, we observe a statistically significant positive response in the 15th month after the shock, at approximately 4.2 pp on average. This is in contrast to the insignificant but mostly negative response of consumer inflation expectations in the previous model. Moreover, this positive response is significantly higher than the low disagreement response, as

Figure 5.2: State-dependent Effects of a 25 bps Unexpected Monetary Policy Shock: Financial Market Inflation Expectations



Note: Estimation results of Equation 4.1 with yearly GDP growth, yearly inflation, one year macroeconomic analysts' inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2005 - Feb 2024 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

per the 95% confidence intervals, similar as in the actual inflation case. These results are consistent with Falck *et al.* (2021), who also presented a positive expectations response of professional forecasters to an unexpected monetary policy shock. Now, within the low disagreement regime, the response of inflation expectations is predominantly negative and even significant at 95% in four instances (16th, 21st, 32nd and 33rd month). We also highlight the generally faster response of financial market inflation expectations.

The response of the repo rate in the low disagreement regime is quite similar in shape and scale to that in the consumer inflation expectations model, being significantly positive on impact and significantly negative after 32 months. However, the repo rate response in the high disagreement regime is notably more pronounced than in the consumer expectations model. Here, the repo rate responds positively on impact, peaking at approximately 1.6 pp on average after four months, then turning negative at approximately -0.7 pp on average from the 21st to the 25th month after the shock, though not significantly, and finally turning significantly positive after 33 months. The repo rate response in the high disagreement regime is more contractionary than in the consumer model and even than in the low disagreement regime. This pattern is more in accordance with the monetary policy rate response in Falck *et al.* (2021).

Lastly, the response of the credit spread in the low disagreement regime is far subtler, initially negative but eventually turning positive. In contrast, the response in the consumer expectations model is more consistently positive across almost the entire horizon. The credit spread response in the high disagreement regime is statistically insignificant and does not follow a consistent trend for most of the horizon, except after the 32nd month when it turns significantly negative.

In summary, the most notable and apparent distinction between the consumer and financial market expectations models lies in the responses of inflation and inflation expectations within the high disagreement regime. In the consumer model, the responses are largely insignificant, whereas in the financial market model, they exhibit significant price puzzles for both variables. All of that in spite of the more contractionary response of the repo rate in the high disagreement regime. This finding supports hypothesis of Falck *et al.* (2021) that in a high disagreement regime with pronounced signaling effects, economic actors rely on the central bank's interest rate decisions to gain better insights into supply and demand conditions. This evidence only applies to professional macroeconomic analysts' inflation expectations in the Czech Republic. However, this mechanism should also more or less involve price makers as indicated by the observed increase in actual inflation under the high disagreement regime in both models. For instance, firms may perceive an unexpected hike in interest rates as a sign of rising demand, prompting them to increase their prices, which temporarily boosts inflation.

5.2 Further Robustness Checks

5.2.1 Linear Local Projections with Shock Instruments

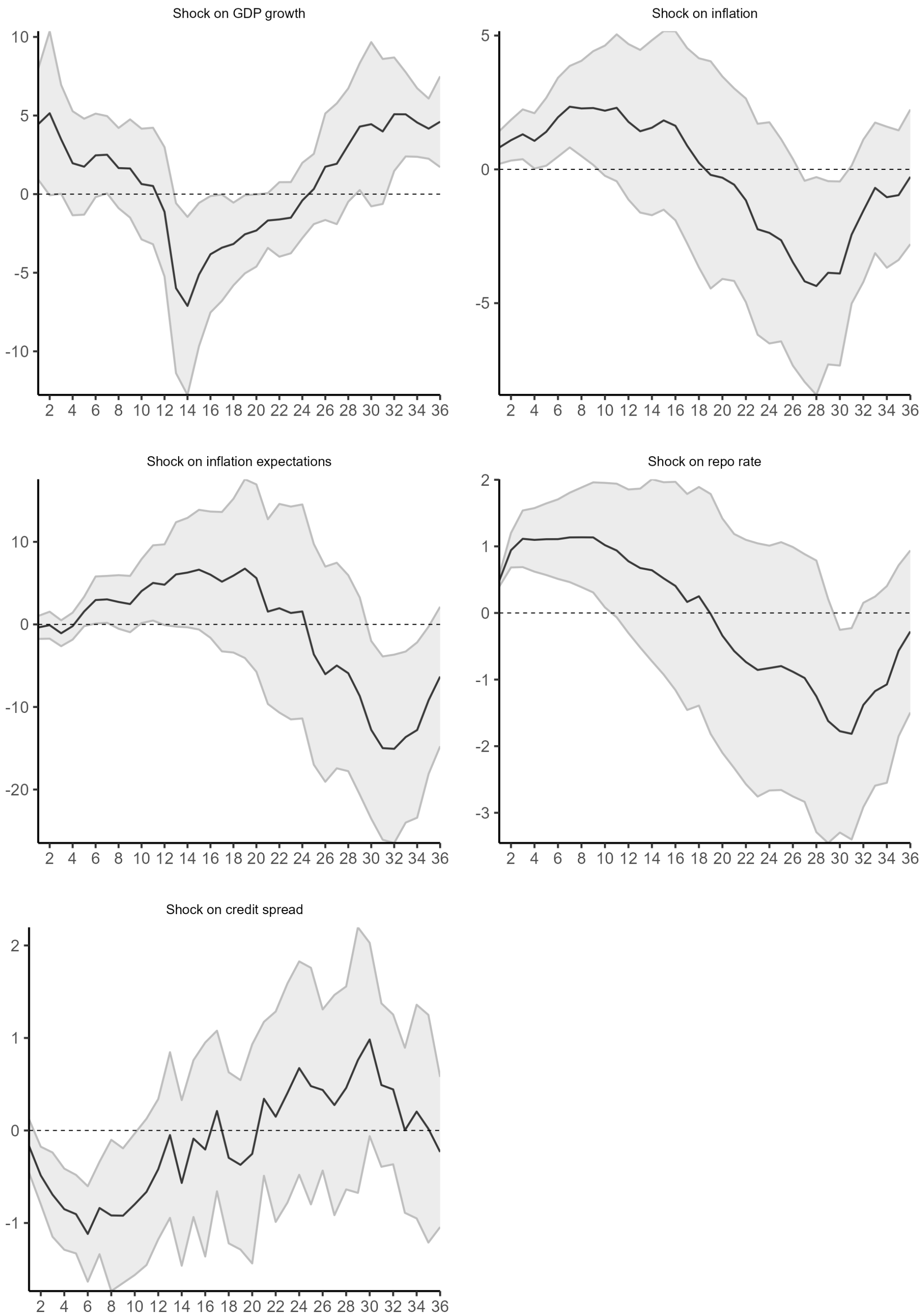
To demonstrate the added value of employing a non-linear regime-switching model, we compare the main results with those obtained from linear local projections using the same estimated unexpected monetary policy shocks. The results are presented in Figure 5.3. In the low disagreement regime of the baseline model, we observe a standard monetary policy transmission: initially, there is no or slightly negative effect on inflation and inflation expectations, followed by a negative effect after approximately 2.5 years. However, a pronounced price puzzle is evident in the responses of both inflation and inflation expectations in the linear model. Specifically, inflation significantly increases by 3.3 pp on average 8 months after the 25 bps unexpected monetary policy shock. The response of inflation expectations is both positive and significant, reaching approximately 4-5 pp rise on average 10 - 11 months after the shock. These results suggest that failing to account for the distinct regimes of inflation expectations disagreement leads to premature conclusions of dysfunctional monetary policy transmission.

Another bias in the linear model results is evident in the response of the credit spread, which appears significantly negative at impact, reaching approximately -1.1 pp on average after 6 months. In contrast, the credit spread response in the low disagreement regime of the baseline consumer model is significantly positive. Overall, the substantial differences between the impulse responses of the linear and regime-switching models underscore the added benefit of using the non-linear model for interpreting monetary policy transmission.

5.2.2 State-dependent Effects in a Pre-Covid 19 Sub Sample

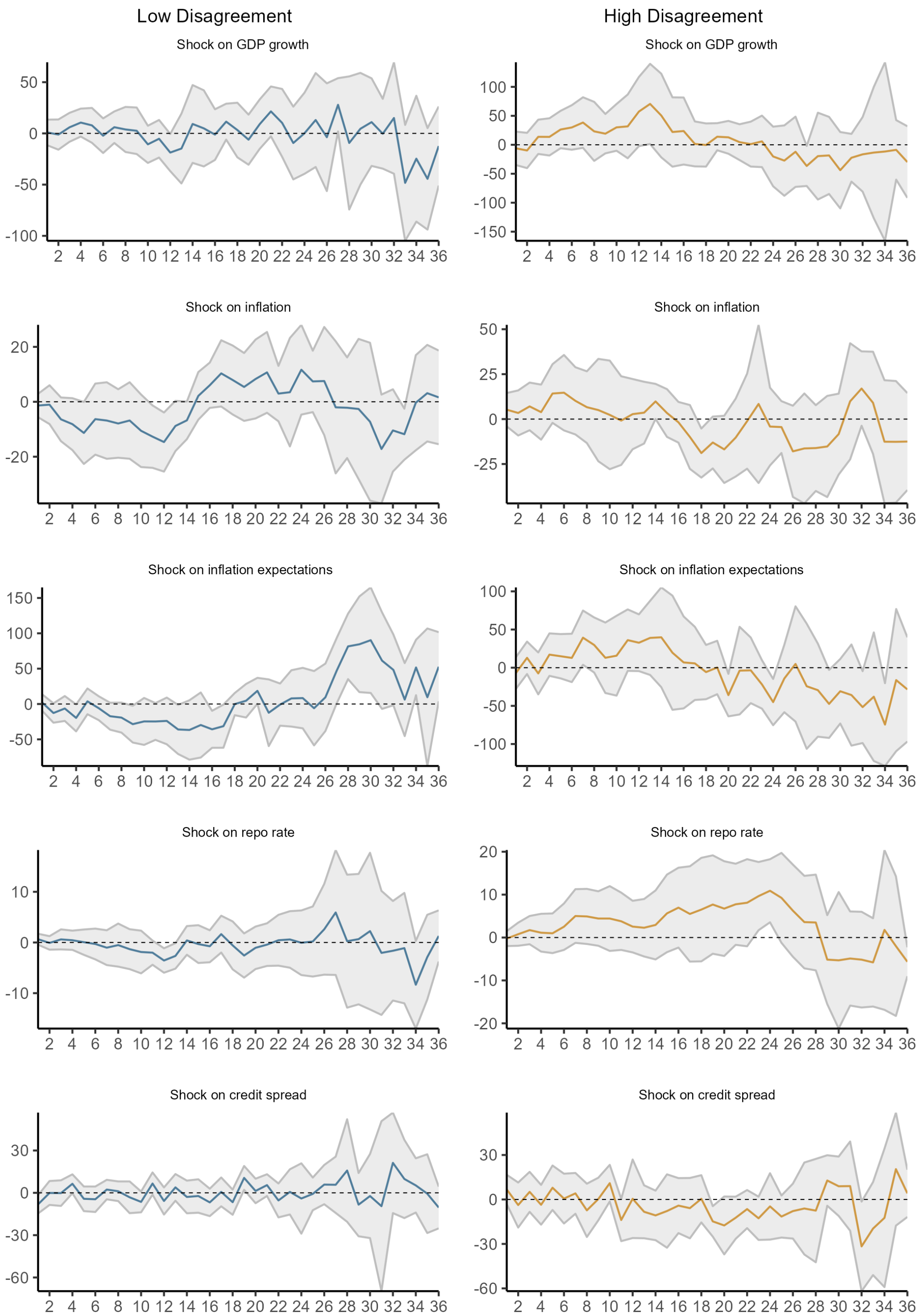
Figure 5.4 illustrates the state-dependent effects of a 25 bps unexpected monetary policy shock in a pre-COVID-19 sub-sample. First, examining the impulse

Figure 5.3: Linear Effects of a 25 bps Unexpected Monetary Policy Shock



Note: Estimation results of a linear variant to the baseline model with yearly GDP growth, yearly inflation, one year consumer inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2004 - Feb 2024 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

Figure 5.4: State-dependent Effects of a 25 bps Unexpected Monetary Policy Shock in a Pre-Covid 19 Subsample



Note: Estimation results of Equation 4.1 with yearly GDP growth, yearly inflation, one year quantified consumer inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2004 - Feb 2020 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

responses visually, we can conclude that there are no substantial differences between them. The GDP growth response becomes insignificant in both regimes. This finding contrasts with previous studies that used different identification methods on pre-COVID samples. For instance, Castelnuovo & Surico (2010), Franta *et al.* (2014), and Aldasoro & Unger (2017), who employed sign restrictions, identified a significant negative output response to a monetary policy shock. Similarly, Falck *et al.* (2021) used the Romer & Romer (2004) narrative identification series and found a negative real GDP response in both high and low disagreement regimes. Conversely, Babecká Kucharčuková *et al.* (2013) and Dvořáková (2022), who also used sign restrictions, found almost no response of real GDP to a monetary policy shock in a pre-COVID sample, aligning with our results, albeit in a different type of model. The reason might be that in the pre-COVID sample, the high-frequency shock data identify a limited number of monetary policy shocks. This scarcity might explain the absence of a significant GDP response. It is possible that, when the disinflation period from 1998 to 2004 is excluded, there are insufficient monetary policy shocks to elicit a substantial GDP reaction.

Second, the initial average responses of inflation in the low and high disagreement regimes are negative and positive, respectively, though neither is statistically significant. Interestingly, despite this, inflation responses in both regimes become significantly negative after 12 months in the low disagreement regime and 18 months in the high disagreement regime. Thus, we cannot assert with certainty that the responses differ in any meaningful way. A similar observation applies to the inflation expectations responses, which are significantly negative after 16 months in the low disagreement regime and after 20 and 24 months in the high disagreement regime. Furthermore, the response of inflation in the low disagreement regime turns substantially and significantly positive after approximately twenty-eight months, which does not occur in the high disagreement regime.

In summary, the transmission of monetary policy into inflation expectations and inflation in the high disagreement regime is at least as efficient, if not more so, than in the low disagreement regime. This contrasts with the results from the baseline model, which includes the COVID-19 and post-COVID-19 periods. From this, we can speculate that the period of high uncertainty and disagreement about inflation expectations over the past four years has caused the previously linear system of monetary policy transmission to become nonlinear. It would be interesting to observe whether this stabilizes over time and returns to its previous state or remains as it is.

5.2.3 State-dependent Effects Using Alternative Instruments

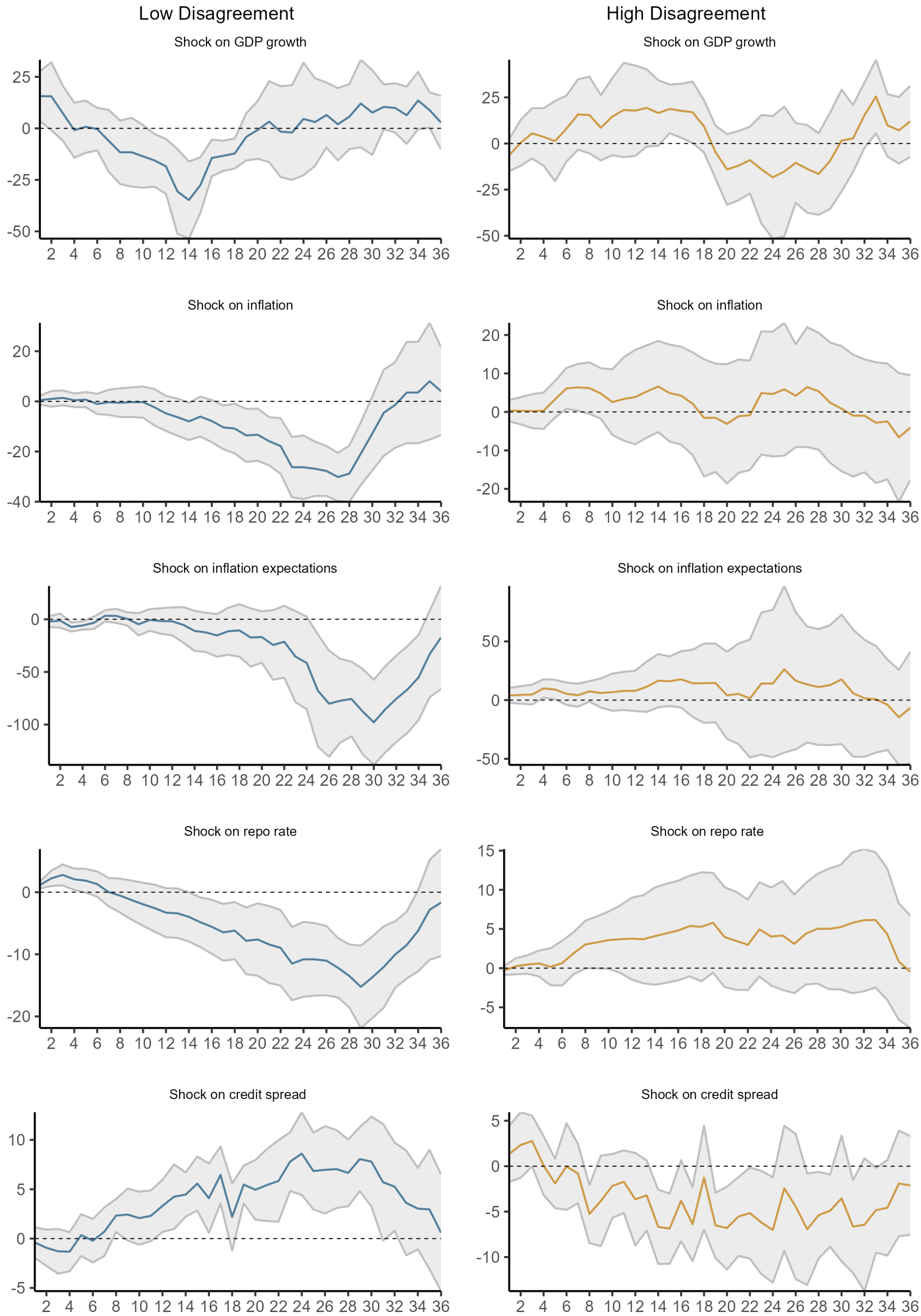
In this subsection, we present the results of a regime-switching model with consumer inflation expectations, using FRA 3X6 and FRA 6X9 as alternative instruments for monetary policy instead of FRA 1X4. The impulse responses are shown in Figures 5.5 and 5.6. With later settlement date of the forward rate agreement, these instruments become less sensitive to contemporaneous changes in the repo rate and more responsive to forward guidance from policymakers at meeting dates. Consequently, although these shocks are similar to the baseline shocks using FRA 1X4 as an instrument, they are smaller in scale, resulting in seemingly exaggerated impulse responses.

However, considering the general shape and significance, our baseline results are robust to the horizon of the forward rate agreement chosen as an instrument. Moreover, the effects of different regimes are even more pronounced than in the baseline model. Specifically, this is evident in the significantly negative response of inflation expectations in the low disagreement regimes of both alternative models. Furthermore, in the model using the FRA 6X9 instrument, we observe price puzzles in both inflation and inflation expectations within the high disagreement regime, aligning with the patterns observed in the financial market inflation expectations model.

The responses of the repo rate in the low disagreement regime are similar to those in the baseline model. However, the repo rate response in the high disagreement regime in the model using the FRA 6X9 instrument reveals a delayed but significant positive reaction after approximately two years, resembling the repo response in the high disagreement regime in the financial market expectations model. The credit spread responses are consistent with the baseline model, being positive in the low disagreement regime and negative in the high disagreement regime.

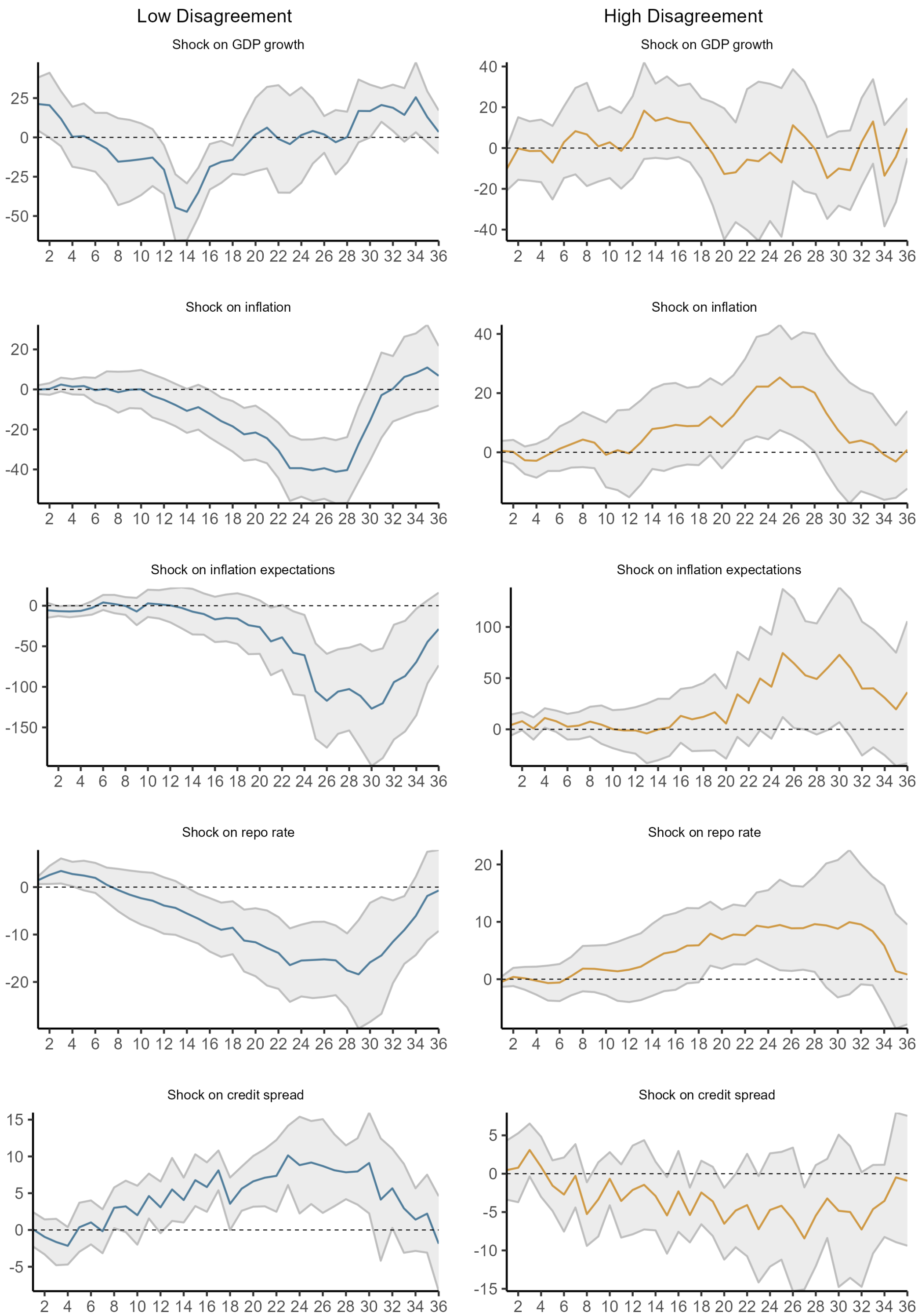
To sum up, our findings indicate that the choice of forward rate agreement horizon does not compromise the robustness of our findings, thereby reinforcing the reliability of our model. Moreover, the heightened effects in different regimes indicate that regime-specific dynamics play a crucial role in the transmission of monetary policy.

Figure 5.5: State-dependent Effects of a 25 bps Unexpected Monetary Policy Shock: FRA 3X6 instrument



Note: Estimation results of Equation 4.1 with yearly GDP growth, yearly inflation, one year quantified consumer inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2004 - Feb 2024 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

Figure 5.6: State-dependent Effects of a 25 bps Unexpected Monetary Policy Shock: FRA 6X9 instrument



Note: Estimation results of Equation 4.1 with yearly GDP growth, yearly inflation, one year quantified consumer inflation expectations, CNB repo rate, and credit spread as the dependent variables (all in percentages).
Grey regions mark 95% confidence intervals. Jan 2004 - Feb 2024 sample.
Newey & West (1986) standard errors and covariance matrix estimators adjusted for finite sample.

Chapter 6

Discussion

This study reveals the significant state-dependent effects of Czech monetary policy, highlighting pronounced differences between high and low disagreement regimes. In the low disagreement regime, the responses of GDP growth, inflation, inflation expectations, repo rate, and credit spread are significant and align with standard economic theory. Conversely, the high disagreement regime exhibits subdued and often insignificant responses. These findings underscore the effectiveness of monetary policy transmission in low disagreement regime and emphasize the necessity of accounting for regime-specific dynamics in monetary policy analysis.

The results corroborate previous studies suggesting that uncertainty influences monetary policy effectiveness (Dixit & Pindyck 1994; Bloom 2009; 2014; Aastveit, Natvik, & Sola 2013; Vavra 2014). Additionally, Bauer, Lakdawala, & Mueller (2022) reported that uncertainty about future policy rates plays a crucial role in the transmission of monetary policy to financial markets. It is important to acknowledge that disagreement is an incomplete approximation of overall uncertainty (Glas & Hartmann 2022). Nonetheless, comparing the effects of uncertainty with those of disagreement remains plausible, as both measures are associated with macroeconomic conditions and indicators of monetary policy.

For instance, Nain & Kamaiah (2014) examined the influence of uncertainty on monetary policy effectiveness in India using a Bayesian Markov Switching-VAR model. Their results indicated weaker effects of monetary policy shocks during high uncertainty regimes compared to low uncertainty regimes. Last, and most importantly, our findings of pronounced differences between high and low disagreement regimes are consistent with those of Falck *et al.* (2021), who identified state-dependent effects of inflation expectations disagreement and decreased monetary policy effectiveness in high inflation expectations disagreement regimes.

Overall, this study contributes to the literature by demonstrating the necessity of considering state-dependent dynamics in monetary policy analysis, thereby providing insights into the varying effectiveness of policy measures under different disagreement regimes.

This thesis specifically examines the impact of an unexpected contractionary 25 bps shock on various economic indicators under high and low disagreement regimes. Recent studies have emphasized the importance of assessing consumers' inflation expectations. Therefore, the baseline model incorporates consumer inflation expectations and their standard deviation. Unlike other indicators of expected inflation, such as those derived from experts or financial market participants, consumers' inflation expectations encompass a broader spectrum of societal beliefs about inflation (D'Acunto *et al.* 2024).

In the low disagreement regime, inflation significantly decreases around 28 months post-shock. These findings align with Gertler & Karadi (2015), who employed a similar high-frequency identification strategy for monetary policy shocks and observed an inflation response consistent with standard monetary VAR results. The significant negative effect on prices after 28 months also corroborates the findings of Ramey (2016), who utilized Gertler and Karadi's 2015 HFI shocks in local projections and identified a significant negative effect after 30 months. Additionally, similar to Gertler & Karadi (2015), the credit spread reacts positively and significantly to the shock in the low disagreement regime. Regarding inflation expectations, we observe a statistically significant response in the low disagreement regime three months post-impact, with the most pronounced negative effect occurring around 31 months. Although this aligns fairly well with the peak inflation response, it is even more delayed.

The maximum impact on inflation observed in our results after 28 months is notably slower than that found by Babecká Kucharčuková *et al.* (2013) and Franta *et al.* (2014), who estimated the maximum impact of a monetary policy shock on prices in the Czech Republic to occur approximately 12 to 24 months post-shock, which aligns with the monetary policy horizon of the Czech National Bank. Brázdik, Grossmann, Hájková, Hromádková, Král, & Saxa (2021) estimated the peak impact on prices to occur slightly later, between 20 to 24 months. Our observed sluggish impact of a monetary policy shock on prices is consistent with the results of a meta-analysis on the transmission of monetary policy by Havránek & Rusnák (2012), which found that transmission lags are more prominent in developed countries (25 to 50 months) compared to emerging economies (10 to 20 months). This phenomenon can be attributed to the fact that economies with more advanced financial systems provide financial institutions with a broader range of hedging instruments to mitigate unexpected fluctuations in monetary policy, leading to a more prolonged transmission of monetary policy shocks (Dvořáková 2022).

In the high disagreement regime, the inflation response is generally insignificant and smaller in contrast to the low disagreement regime. Although impulse responses in the two regimes exhibit distinct patterns, with significant responses in the low disagreement regime aligning with standard New Keynesian theory, we do not observe a price puzzle in the high disagreement regime. Specifically, inflation demonstrates an average negative response between 8 and 22 months after the shock. This outcome can be attributed to the state-dependent nature of inflation. In the high disagreement regime, the subdued response of the repo rate following a contractionary shock means that inflation is not curbed as effectively as in the low disagreement regime. This mechanism of transmission is substantially different from that described by Falck *et al.* (2021), where the FFR increases in the high disagreement regime and declines in the low disagreement regime. In their study, the FFR rises temporarily to counteract the increase in inflation and inflation expectations in the high disagreement regime, while a decline in inflation allows for a reduction in the FFR in the low disagreement regime. On the other hand, we observe some evidence of a price puzzle in consumer inflation expectations, which initially respond positively, showing a significant increase after three months.

The overall results are partially consistent with Falck *et al.* (2021), who also report effective monetary policy transmission in the low disagreement regime, evidenced by significant negative responses in inflation and inflation expectations. However, unlike Falck *et al.* (2021), we do not observe substantial evidence of a price puzzle in inflation and inflation expectations in the high disagreement regime within our baseline model.

Although, when we shift our focus to the model incorporating financial market inflation expectations, the inflation response becomes significantly positive 10 months post-shock in the high disagreement regime, contrasting with a negative response in the low disagreement regime. Additionally, inflation expectations also respond positively and significantly in the high disagreement regime after 15 months. Furthermore, in the model utilizing the FRA 6X9 instrument, we observe price puzzles in both inflation and consumer inflation expectations within the high disagreement regime, aligning with the patterns observed in the financial market inflation expectations model. These outcomes are closely related to those in Falck *et al.* (2021), who also observed a positive response from professional forecasters in the high disagreement regime from the initial impact up to 30 months. This finding supports the hypothesis of Falck *et al.* (2021) that in a high disagreement regime with pronounced signaling effects, economic actors rely on the central bank's interest rate decisions to gain better insights into supply and demand conditions.

While we have emphasized some valuable results here, their applicability is constrained by certain limitations. For instance, relative to the inflation responses, the inflation expectations responses in both consumer and financial market models were rather weak. Furthermore, while they correlate reasonably well with the peak of inflation responses, their timing is notably more delayed. These findings are consistent with those of Falck *et al.* (2021) and D'Acunto *et al.* (2024), who suggest that household inflation expectations respond sluggishly to monetary policy shocks. Specifically, given consumers' relative inattention to policy rates, household inflation expectations typically react in a muted manner and with a significant lag to both conventional and unconventional monetary policy shocks. These lags reflect the fact that expectations are highly sensitive to actual inflation and subjective inflation experiences. Consequently, a stronger transmission to expectations is likely to occur only after a delay if at all, following the lagged transmission of monetary policy to actual prices as eventually observed by consumers. D'Acunto *et al.* (2024) attributes this phenomenon to the highly subjective nature of consumers' inflation expectations, citing evidence that indicates a notable lack of interest in and attention to news about inflation, particularly from official sources.

What follows is an account of several relevant studies on the Czech Republic that we can compare with our baseline results, though the literature on the empirical rather than structural approach to monetary policy transmission in the Czech Republic is rather sparse. Borys *et al.* (2009), Babecká Kucharčuková *et al.* (2013), Franta *et al.* (2014), and Dvořáková (2022) all found that a contractionary monetary policy shock negatively affects the price level, which is consistent with the inflation response observed in the low disagreement regime. However, it is crucial to note that these studies examine the effects of Czech monetary policy on the economy within a Bayesian VAR framework with sign and zero restrictions. Imposing sign and zero restrictions assumes a priori knowledge about the expected direction and timing of the shock's effects. Therefore, conclusions about the effects of monetary policy shocks should be drawn cautiously when using this methodology.

6.1 Contribution

To demonstrate the added value of employing a non-linear regime-switching model, we compare the main results with those obtained from linear local projections using the same estimated unexpected monetary policy shocks. A pronounced price puzzle is evident in the responses of both inflation and inflation expectations in the linear model. Specifically, inflation significantly increases 8 months after the shock, and the response of inflation expectations is both positive and significant. These results suggest that failing to account for the distinct regimes of inflation expectations disagreement leads to premature conclusions regarding dysfunctional monetary policy transmission.

This puzzling effect was not found in Ramey's 2016 local projections with high-frequency identification shocks. However, she used only three monthly lags for her LP-IV specification, while this thesis employs 12 lags. There is an interesting parallel with the results of Bauer & Swanson (2023), who also found puzzling results for price responses to a high-frequency monetary policy surprise in similar linear local projections with 12 monthly lags. The impairment in their results was eliminated after adding additional monetary policy surprise data in the form of speeches, press conferences, and Congressional testimony by the Federal Reserve Chair, and orthogonalizing the surprises with respect to macroeconomic and financial data that pre-date the announcement. In our case, using regime switching in inflation disagreement also eliminated the puzzling results, specifically the positive responses of inflation, inflation expectations, and the credit spread.

Another parallel can be drawn to Argov *et al.* (2007), who differentiate between low- and high-inflationary episodes in a small macro model of Israel. They ensure that model inflation expectations behave differently during periods of high inflation than during standard times. This regime-switching variable is to a degree similar to our measure of inflation expectations disagreement, as our cross-sectional standard deviation of consumer inflation expectations is scaled by inflation, making it positively related to the inflation level. They observe that dynamic responses of the non-linear model to shocks more closely resemble the properties observed in the Israeli data.

Ultimately, this thesis demonstrates the significant value of using a non-linear regime-switching model to analyze Czech monetary policy transmission. By comparing results with linear local projections, it highlights how failing to account for distinct regimes of inflation expectations disagreement can lead to misleading conclusions, such as the observed price puzzle. The regime-switching approach effectively eliminates these puzzling results, aligning theoretical expectations and empirical findings. This methodology provides a more accurate depiction of monetary policy transmission, particularly in differing disagreement regimes, thus offering a crucial contribution to the existing literature on monetary policy analysis.

6.2 Policy Implications

Overall, the evidence indicates a more effective transmission of monetary policy in the low disagreement regime. A potential factor contributing to the inefficiency in the high disagreement regime is the subdued reaction of the repo rate. This suggests that during periods of high disagreement and uncertainty, monetary policy tends to lean towards a more accommodative stance. This interpretation would be supported by the results of the baseline consumer model with a muted repo rate response in the high disagreement regime and a following increase in inflation. This narrative can also be discerned from the series of estimated monetary policy shocks compared with CNB repo rate changes shown in Figure 4.3. The disproportionatelly smaller or even negative shocks compared to substantial repo rate increases combined with the results mentioned above possibly show how little vigorous the central bank's crackdown on inflation in 2021 and 2022 actually was. If this observation holds true, policymakers may benefit from closely monitoring inflation expectations disagreement. In instances of high disagreement, a more restrictive monetary policy approach could be warranted.

However, if the signaling channel hypothesis of monetary policy during high disagreement (Falck *et al.* 2021) proves to be accurate, implementing a more restrictive monetary policy could inadvertently lead to undesirable outcomes such as heightened inflation expectations and inflation itself. This explanation is corroborated by the results of the financial market expectations model and the consumer expectations model with FRA 6X9 as instrument. In these models, similarly as in (Falck *et al.* 2021), inflation and inflation expectations rise despite a significant increase in the repo rate.

If monetary policy exhibits reduced effectiveness during periods characterized by high disagreement regarding inflation expectations, policymakers may need to address the issue of disagreement itself. Łyziak & Sheng (2023) argue that disagreement among households regarding forecasts diminishes as the weight placed on new information increases. This suggests that central bank communication should aim to overcome public inattention to lessen disagreement. They specifically recommend that central bank communications target professional analysts to mitigate their disagreement, as such discrepancies can influence public opinion indirectly through household expectations.

Regarding the clarity of central bank communication, Montes *et al.* (2016) find that signaling future monetary policy actions helps reduce disagreement. Transparency in central bank operations is also crucial, as noted by Montes *et al.* (2016), to mitigate discrepancies in inflation expectations. These insights underscore the importance of effective communication strategies and transparency in central bank operations in managing inflation expectations and enhancing the effectiveness of monetary policy.

The analysis underscores a critical insight into monetary policy effectiveness: the degree of inflation expectations disagreement significantly influences policy outcomes. In high disagreement environments, where policy transmission mechanisms may be subdued, policymakers face the challenge of implementing effective measures to anchor expectations and specifically, disagreement in expectations.

6.3 Limitations

The accuracy of our methodology and results critically depends on the assumption that high-frequency monetary policy surprises constitute exogenous shocks. However, recent studies have raised concerns about both the exogeneity and the relevance of using high-frequency changes in interest rates around central bank board announcements as instruments, particularly in estimating the macroeconomic effects of monetary policy shocks. It has been observed, for instance, that monetary policy surprises exhibit correlations with publicly available macroeconomic and financial data prior to the announcements, thereby violating the standard exogeneity condition necessary for the instrument's validity. Consequently, the use of high-frequency monetary policy surprise instruments appears to introduce biases in certain cases (Ramey 2016; Bauer & Swanson 2023).

A potential solution could involve adjustments to the estimation of monetary policy surprises. Bauer & Swanson (2023) suggest expanding the scope of monetary policy announcements to include speeches by the central bank chair or governor, although such additional qualitative analyses are beyond the current thesis's scope. Furthermore, Bauer & Swanson (2023) proposes orthogonalizing the surprises with respect to macroeconomic and financial data preceding the announcement, noting that these adjustments substantially mitigate biases.

There is a another limitation concerning the interpretability of the causal relationship between monetary policy shocks and inflation expectations or inflation. This arises due to the subdued response of the repo rate in the high disagreement regime, which, based on our sample, tends to coincide with heightened inflation. Consequently, it becomes challenging to discern whether the observed increases in inflation and inflation expectations stem from the signaling effect of monetary policy contraction or from an inadequate increase in the repo rate to initially restrain the elevated inflation and expectations thereof. This issue contrasts with the findings of Falck *et al.* (2021), where the policy rate response in the high disagreement regime was stronger, thereby circumventing this ambiguity. Notwithstanding, the current outcome seem to reflect a more accommodative stance by the Czech National Bank during periods of high disagreement.

During the pre-COVID-19 subsample period, where the central bank's policy response in the high disagreement regime resembled that of Falck *et al.* (2021), we observed a positive but nonsignificant response in inflation expectations during the first year and a half. Conversely, in the low disagreement regime, despite a negative repo rate response, inflation expectations remained negative during the corresponding period post-shock. This empirical evidence lends credence to Falck et al.'s 2021 signaling hypothesis, suggesting that economic agents interpret central bank interest rate hikes in high disagreement periods as indicative of demand pressures in the economy.

To address this issue, several approaches could be considered. One possibility is to include an interaction term between high disagreement and the policy rate in local projections. Another approach involves identifying an instrument for the domestic repo rate, such as an international interest rate, which influences domestic monetary policy without directly affecting domestic inflation. However, finding such instrument for a small open economy like the Czech Republic is challenging, as potential candidates such as the ECB refinancing rate or the FFR indirectly impact domestic prices and demand through import prices and foreign demand for exports. Alternatively, simulating a counterfactual scenario with a stronger repo rate response could provide additional insights into the dynamics of monetary policy transmission under conditions of high disagreement.

Mentioned considerations highlight the ongoing methodological challenges in accurately measuring and interpreting the effects of monetary policy shocks, underscoring the need for rigorous approaches in future research to address the complexities associated with exogenous monetary shocks.

Chapter 7

Conclusion

This thesis was undertaken to evaluate how disagreement about inflation expectations affects the transmission of monetary policy in the Czech Republic. By leveraging a regime switching local projections model, the thesis provides a nuanced analysis of how the effectiveness of monetary policy shifts between periods of high and low disagreement, indicated by cross sectional standard deviation in inflation expectations. Particularly, we aim to verify or disprove the hypothesis that the interest rate tool is just as effective in controlling rising inflation and inflation expectations during periods of high disagreement as it is in normal periods. Additionally, we compare the impact of disagreement on the transmission of monetary policy between consumers' and financial market analysts' inflation expectations. The main findings indicate that during periods of high disagreement, the transmission of monetary policy shocks is less effective, suggesting that when consumers and financial markets have divergent expectations about inflation, the intended effects of policy measures are often diluted.

One of the pivotal contributions of this thesis is the identification of regime-dependent responses of inflation and inflation expectations to unexpected monetary policy shocks. The utilization of a non-linear regime-switching model was crucial in precisely capturing these dynamics. In the low disagreement regime, this model successfully resolved the puzzling outcomes observed with linear local projections, thus offering a more precise depiction of monetary policy transmission across varying states of inflation expectations disagreement. The results reveal that in the high disagreement regime, the response of inflation expectations and actual inflation to contractionary monetary policy shocks is less pronounced than under normal circumstances or even positive. This finding suggests that during such periods, the signals sent by the central bank through policy changes are either overshadowed by other factors influencing expectations or not correctly comprehended.

Moreover, the study finds that during high disagreement periods, the central bank's policy rate responses tend to be weaker, which could be interpreted as a more accommodative stance. This weaker response complicates the ability to curb initially elevated inflation and inflation expectations. This raises the question of whether the observed inflation dynamics are a result of insufficiently aggressive policy stance or signaling effects, whereby economic actors perceive central bank interest rate hikes as indicators of rising demand, leading them to raise prices and consequently causing a temporary increase in inflation and inflation expectations (Falck *et al.* 2021). This theory was further supported by the results of financial market expectations and an alternative consumer expectations model. In these scenarios, both inflation and inflation expectations escalated despite a significant surge in the repo rate within the high disagreement regime.

To address this question, several future approaches could be considered. One option is to include an interaction term between high disagreement and the policy rate in local projections. Another method involves identifying an instrument for the domestic repo rate, such as an international interest rate that influences domestic monetary policy without directly affecting domestic inflation. However, finding such instrument for a small open economy like the Czech Republic is challenging, as potential candidates like the ECB refinancing rate or the FFR indirectly impact domestic prices and demand through import prices and foreign demand for exports. Alternatively, simulating a counterfactual scenario with a stronger repo rate response could provide further insights into the dynamics of monetary policy transmission under conditions of high disagreement.

The implications of these findings are significant for monetary policy formulation and implementation. Central banks, particularly in small open economies like the Czech Republic, need to account for the heterogeneity in inflation expectations when designing their policy measures. The results point to the necessity for central banks to adopt more robust policy rules that can adapt to different regimes of disagreement. By doing so, policymakers can better manage the transmission mechanism and mitigate the adverse effects of high disagreement periods. Future policy strategies could benefit from incorporating more sophisticated tools for monitoring and addressing expectation heterogeneity. Previous academic literature has suggested that enhancing the transparency and clarity of communication helps mitigate disagreement about expected inflation (Montes *et al.* 2016; Łyziak & Sheng 2023). This approach can enhance the effectiveness of monetary policies, particularly during periods of high uncertainty and disagreement. The findings of this thesis further underscore this need.

A limitation of this thesis is that our ability to accurately measure and interpret results relies heavily on assuming that sudden changes in interest rates, such as those around central bank announcements, are independent external influences. Recent research, however, has cast doubt on this assumption. There are concerns about whether these policy surprises truly represent external shocks, as they have been found to correlate with publicly accessible macroeconomic and financial information before the announcements. This correlation violates the standard requirement that instruments be exogenous, thereby potentially biasing our estimation of the macroeconomic impact of monetary policy shocks. Future research could address the challenges by modifying how monetary policy surprises are calculated. One approach could be broadening the events considered to include speeches by the central bank chair or governor, in addition to formal announcements. Moreover, Bauer & Swanson (2023) suggest a technique called orthogonalization, which adjusts the surprises to ensure they are independent of macroeconomic and financial data before the announcement. They argue that these adjustments significantly reduce any potential biases in the estimation process.

Moreover, the study is constrained by the specific time frame and economic context of the Czech Republic, which may limit the applicability of the results to other periods or economies. Future research could expand on this work by incorporating other small open economies with similar inflation targeting frameworks which could provide a more comprehensive understanding of the phenomenon. A comparable method of adapted high-frequency identification, as explored in this thesis, could also be implemented in other Central European economies like Poland or Hungary, with their own monetary policies and relevant data on instruments similarly accessible.

In conclusion, this thesis advances our understanding of how disagreement in inflation expectations influences the effectiveness of monetary policy. Building upon the seminal findings of Falck *et al.* (2021) in the context of a large economy like the US, this study provides alternative insights relevant to a small open economy such as the Czech Republic. It underscores that the diversity in individuals' inflation expectations significantly impacts the transmission mechanisms of monetary policy.

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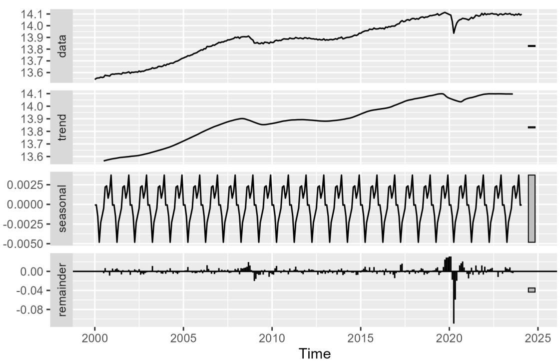
Appendix A

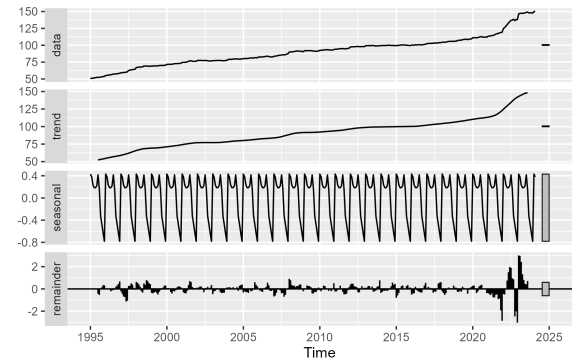
Supplement Figures

Figure A.1: Seasonal, Trend and Irregular Components Decomposition of Log of Real GDP



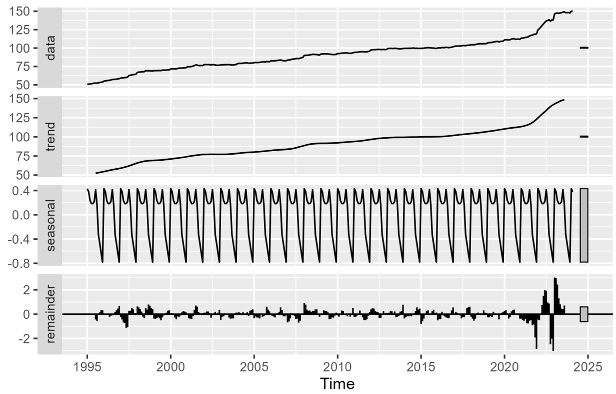
Source: Czech Statistical Office, Authors' calculations

Figure A.2: Seasonal, Trend and Irregular Components Decomposition of CPI



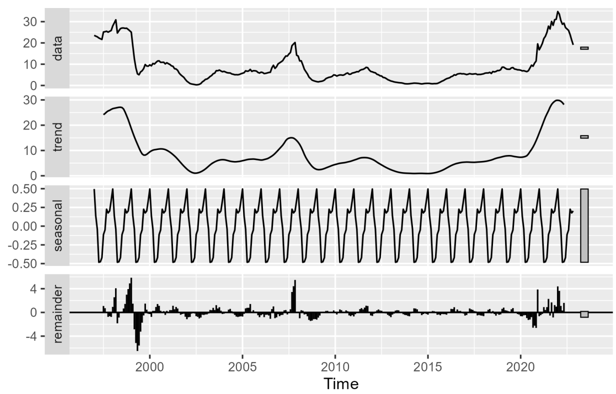
Source: Czech Statistical Office, Authors' calculations

Figure A.3: Seasonal, Trend and Irregular Components Decomposition of Quantified Consumer Inflation Expectations



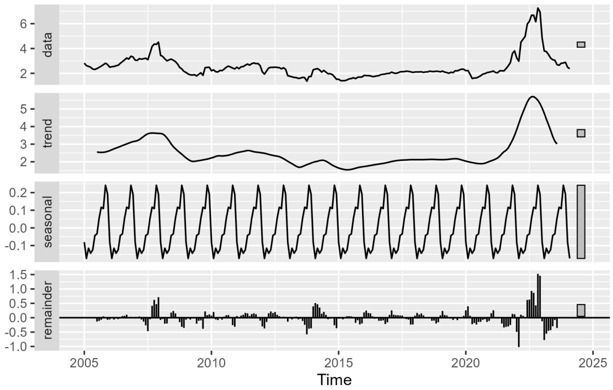
Source: Czech Statistical Office, European Commission Consumer Survey, Authors' calculations

Figure A.4: Seasonal, Trend and Irregular Components Decomposition of Quantified Standard Deviation of Consumer Inflation Expectations



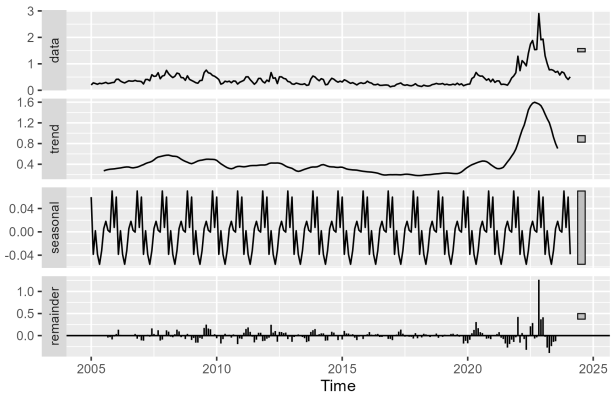
Source: Czech Statistical Office, European Commission Consumer Survey, Authors' calculations

Figure A.5: Seasonal, Trend and Irregular Components Decomposition of Financial Market Inflation Expectations



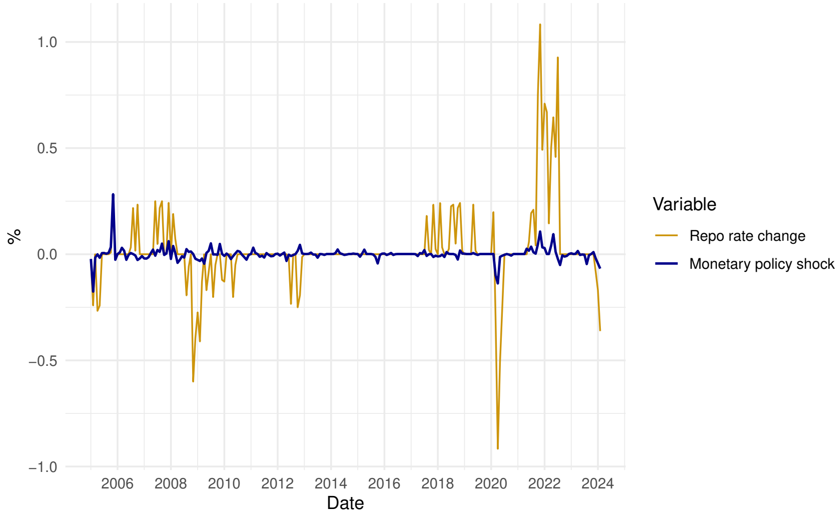
Source: CNB, Authors' calculations

Figure A.6: Seasonal, Trend and Irregular Components Decomposition of Standard Deviation of Financial Market Inflation Expectations



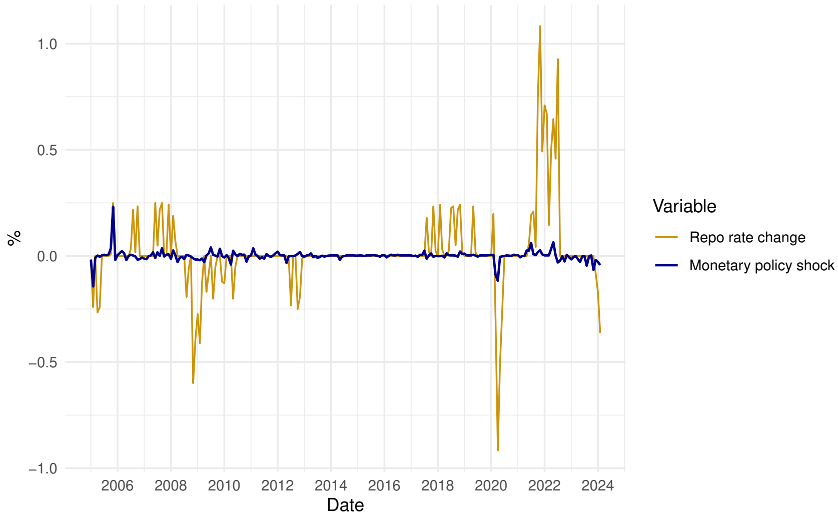
Source: CNB, Authors' calculations

Figure A.7: Monthly Monetary Policy Shocks estimated with FRA 3X6 Instrument



Source: Refinitive Eikon, Authors' calculations

Figure A.8: Monthly Monetary Policy Shocks estimated with FRA 6X9 Instrument



Source: Refinitive Eikon, Authors' calculations